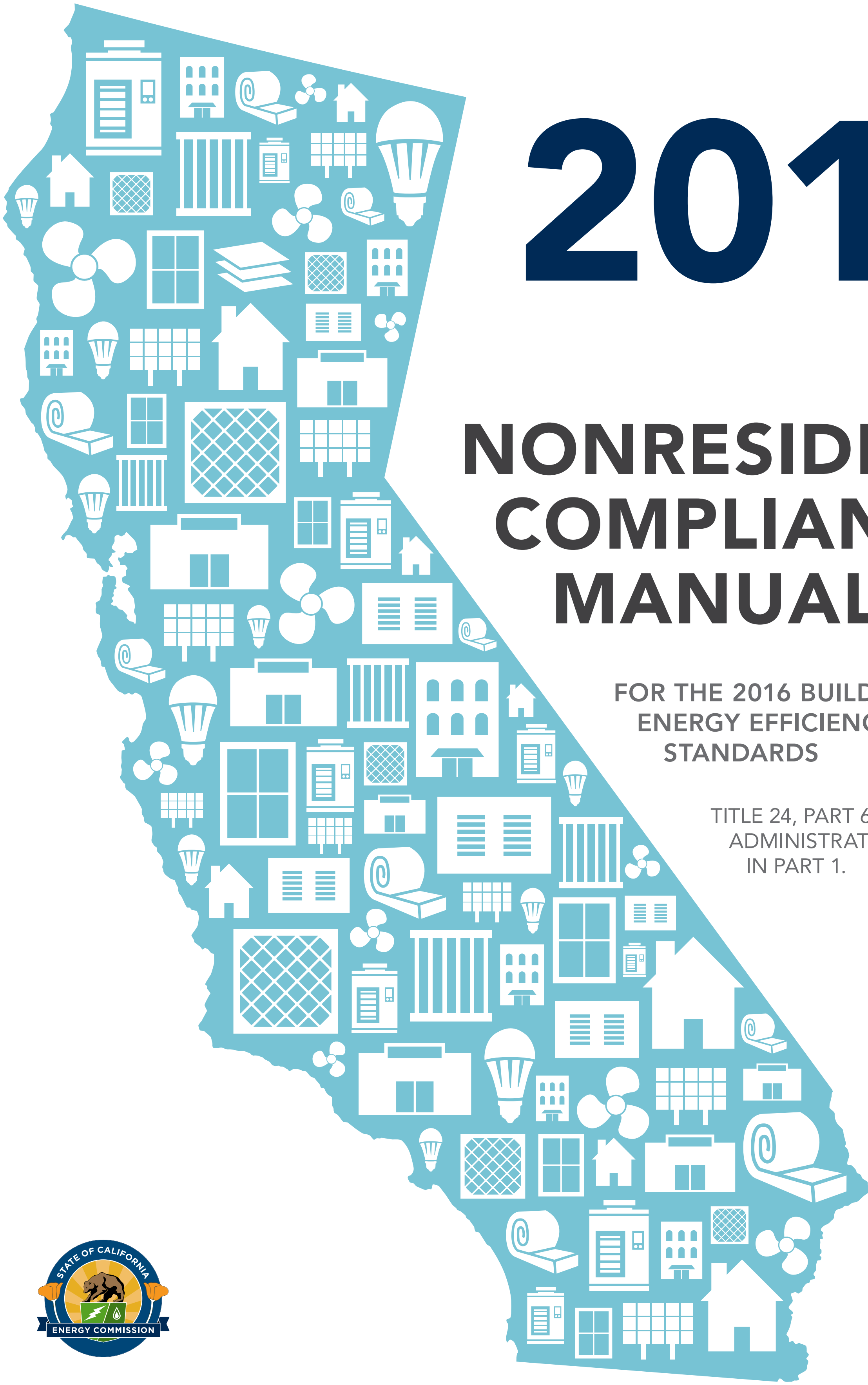

2016

NONRESIDENTIAL COMPLIANCE MANUAL

FOR THE 2016 BUILDING ENERGY EFFICIENCY STANDARDS

TITLE 24, PART 6, AND ASSOCIATED ADMINISTRATIVE REGULATIONS IN PART 1.

STATE OF CALIFORNIA
ENERGY COMMISSION

NOVEMBER 2015
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Edmund G. Brown Jr., Governor

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Acknowledgments

The Building Energy Efficiency Standards (Energy Standards) were first adopted and put into effect in 1978 and have been updated periodically in the intervening years. The Energy Standards are a unique California asset that have placed the State on the forefront of energy efficiency, sustainability, energy independence, and climate change issues, and have provided a template for national standards within the United States as well as for other countries around the globe. They have benefitted from the conscientious involvement and enduring commitment to the public good of many persons and organizations along the way. The 2016 Energy Standards development and adoption process continues a long-standing practice of maintaining the Standards with technical rigor, challenging but achievable design and construction practices, public engagement, and full consideration of the views of stakeholders.

2016 is a major step towards meeting the Zero Net Energy (ZNE) goal by the year 2020 and is the second of three updates to move California toward achieving that goal, building on the 2013 Energy Standards and setting the stage for the upcoming 2019 update.

The 2016 Energy Standards revision and the supporting documents were conceptualized, evaluated and justified through the excellent work of Energy Commission staff and consultants working under contract to the Energy Commission, supported by the utility-organized Codes and Standards Enhancement (CASE) Initiative, and shaped by the participation of over 150 stakeholders and the contribution of over 1000 formal public comments. We would like to acknowledge Commissioner Andrew McAllister and his adviser, Patrick Saxton, P.E. for their unwavering leadership throughout the standards development. Maziar Shirakh, P.E., who served as the project manager and senior engineer; Bill Pennington, Special Advisor to the Efficiency Division, who provided overall guidance and contributed to the technical content of the Standards documents; Eurlyne Geiszler, who served as the Manager for the Buildings Standards Office; Peter Strait, who served as the supervisor for the Standards Development Unit; Pippin Brehler and Galen Lemei, who provided legal counsel; and technical staff contributors of the Building Standards office including Mark Alatorre, P.E.; Payam Bozorgchami, P.E.; Todd Ferris; Hilary Fiese; Larry Froess, P.E.; Simon Lee P.E; Jeff Miller, P.E; Farakh Nasim; Adrian Ownby; Dee Anne Ross; Michael Shewmaker; Alexis Smith; Danny Tam; Gabriel Taylor, P.E.;. RJ Wichert. The Standards Implementation office which includes Andrea Bailey; Randy Brumley; Suzie Chan; Tav Commins; Paula David; Gary Fabian; James Haile; Joe Loyer; Rashid Mir, P.E; Javier Perez; Alex Pineda; Heriberto Rosales; Alex Wan; Courtney Ward; Daniel Wong; Nelson Peña; Energy Commission editors including Carol Robinson and Gaylene Cooper, and the Energy Commission Hotline staff and Web Team. Key Energy Commission and CASE consultants included NORESCO, Bruce Wilcox, Taylor Engineering, Proctor Engineering, Benya Lighting Design, Chitwood Energy Management, Davis Energy Group, EnerComp, McHugh Energy, Energy Solutions, E3, RASENT Solutions LLC, L’Monte Information Services, and TRC Solutions. The CASE Initiative is supported by a consortium of California utility providers which includes the Pacific Gas and Electric Company, Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, the Sacramento Metropolitan Utility District, and the Los Angeles Department of Water and Power.

Abstract

The Building Energy Efficiency Standards were first adopted in 1976 and have been updated periodically since then as directed by statute. In 1975 the Department of Housing and Community Development adopted rudimentary energy conservation standards under their State Housing Law authority that were a precursor to the first generation of the Standards. However, the Warren-Alquist Act was passed one year earlier with explicit direction to the Energy Commission (formally titled the State Energy Resources Conservation and Development Commission) to adopt and implement the Standards. The Energy Commission's statute created separate authority and specific direction regarding what the Standards are to address, what criteria are to be met in developing the Standards, and what implementation tools, aids, and technical assistance are to be provided.

The Standards contain energy and water efficiency requirements (and indoor air quality requirements) for newly constructed buildings, additions to existing buildings, and alterations to existing buildings. Public Resources Code Sections 25402 subdivisions (a)-(b) and 25402.1 emphasize the importance of building design and construction flexibility by requiring the Energy Commission to establish performance standards, in the form of an "energy budget" in terms of the energy consumption per square foot of floor space. For this reason, the Standards include both a prescriptive option, allowing builders to comply by using methods known to be efficient, and a performance option, allowing builders complete freedom in their designs provided the building achieves the same overall efficiency as an equivalent building using the prescriptive option. Reference Appendices are adopted along with the Standards that contain data and other information that helps builders comply with the Standards.

The 2016 update to the Building Energy Efficiency Standards focuses on several key areas to improve the energy efficiency of newly constructed buildings and additions and alterations to existing buildings. The most significant efficiency improvements to the residential Standards include improvements for attics, walls, water heating, and lighting. The most significant efficiency improvements to the nonresidential Standards include alignment with the ASHRAE 90.1 2013 national standards. New efficiency requirements for elevators and direct digital controls are included in the nonresidential Standards. The 2016 Standards also include changes made throughout all of its sections to improve the clarity, consistency, and readability of the regulatory language.

Public Resources Code Section 25402.1 also requires the Energy Commission to support the performance standards with compliance tools for builders and building designers. The Alternative Calculation Method (ACM) Approval Manual adopted by regulation as an appendix of the Standards establishes requirements for input, output and calculational uniformity in the computer programs used to demonstrate compliance with the Standards. From this, the Energy Commission develops and makes publicly available free, public domain building modeling software in order to enable compliance based on modeling of building efficiency and performance. The ACM Approval Manual also includes provisions for private firms seeking to develop compliance software for approval by the Energy Commission, which further encourages flexibility and innovation.

The Standards are divided into three basic sets. First, there is a basic set of mandatory requirements that apply to all buildings. Second, there is a set of performance standards – the energy budgets – that vary by climate zone (of which there are 16 in California) and building type; thus the Standards are tailored to local conditions. Finally, the third set constitutes an alternative to the performance standards, which is a set of prescriptive packages that are basically a recipe or a checklist compliance approach.

Keywords:

California Energy Commission
California Building Code
California Building Energy Efficiency Standards
Title 24, Part 6
2016 Building Energy Efficiency Standards
Residential
Nonresidential
Newly Constructed
Additions and Alterations to Existing Buildings
Mandatory
Prescriptive
Performance
Time Dependent
Valuation
TDV
Ducts in Conditioned Spaces
High Performance Attics
High Performance Walls
High Efficacy Lighting
Water Heating
Windows
Envelope Insulation
HVAC
Building Commissioning
Process Load
Refrigeration
Data Center
Exhaust
Compressed Air
Acceptance Testing
Data Collection
Cool Roof
On-site Renewable

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1. Introduction

1.1 Organization and Content

This manual is designed to help building owners, architects, engineers, designers, energy consultants, builders, enforcement agencies, contractors and installers, and manufacturers comply with and enforce the California Building Energy Efficiency Standards (Energy Standards) for nonresidential buildings. The manual is written as both a reference and an instructional guide and can be helpful for anyone that is involved in the design and construction of energy efficient nonresidential buildings.

Thirteen chapters make up the manual:

Chapter 1 introduces the Energy Standards and discusses the application and scope.

Chapter 2 reviews the compliance and enforcement process, including design and the preparation of compliance documentation through acceptance testing.

Chapter 3 addresses the requirements for the building envelope.

Chapter 4 covers the requirements for HVAC systems and water heating systems.

Chapter 5 addresses the requirements for indoor lighting.

Chapter 6 addresses the requirements for outdoor lighting.

Chapter 7 addresses the requirements for sign lighting (for both indoor and outdoor applications).

Chapter 8 addresses the requirements for electrical power distribution.

Chapter 9 covers the solar ready requirements.

Chapter 10 addresses covered processes energy requirements.

Chapter 11 covers the performance approach.

Chapter 12 covers the commissioning requirements.

Chapter 13 covers the acceptance test requirements.

Cross-references within the manual use the word 'Section' while references to sections in the Energy Standards are represented by "§."

The first chapter is organized as follows:

1.1 Organization and Content

1.2 Related Documents

1.3 The Technical Chapters

1.4 Why California Needs Energy Standards

1.5 What's New for 2016?

1.6 Mandatory Measures and Compliance Approaches

1.7 Scope and Application

1.8 About the Energy Standards

1.2 Related Documents

This compliance manual is intended to supplement several other documents that are available from the California Energy Commission (Energy Commission). These documents include:

A. *The 2016 Building Energy Efficiency Standards, Title 24, Part 6 (Energy Standards)* - This manual supplements and explains the California's energy efficiency standards, which is the main document that describes the requirements that all covered buildings, must comply with; this manual explains those requirements in simpler terms, but it does not replace or supersede them. Readers should have a copy of the Energy Standards to refer to while reading this manual.

B. The Reference Appendices:

- Reference Joint Appendices contain information that is common to both residential and nonresidential buildings.
- Reference Residential Appendices contain information that is for residential buildings only.
- Reference Nonresidential Appendices contain information that is for nonresidential buildings only.
- The Nonresidential Approval and Reference ACM Manuals are primarily a specification for compliance software that is used for compliance purposes.

Note: *High-rise residential and hotel/motel occupancies – For these occupancies' location and design data, opaque assembly properties are located in the Reference Joint Appendices; while mechanical and lighting information is located in the Reference Nonresidential Appendices. Residential water heating information is located in the Reference Residential Appendices.*

Material from these documents is not always repeated in this manual. However, if you are using the electronic version of the manual, there may be hyperlinks that will take you directly to the document that is referenced.

1.3 The Technical Chapters

Each of the eleven technical chapters (3 through 13) begins with an overview, which is followed by a presentation of each subsystem. For the building envelope, subsections include fenestration, insulation, infiltration, etc. For HVAC, the subsections include heating equipment, cooling equipment, and ducts. Mandatory measures and prescriptive requirements are described within each subsection or component. These determine the stringency of the Energy Standards and are the basis of the energy budget when the performance method is used.

1.4 Why California Needs Energy Standards

Energy efficiency reduces energy costs for owners, increases reliability and availability of electricity for the State, improves building occupant comfort, and reduces environmental impact.

1.4.1 Energy Savings

Reducing energy use is a benefit to all. Building owners save money, Californians have a more secure and healthy economy, the environment is less negatively impacted, and our electrical grid can operate in a more stable state. The 2016 Energy Standards (for residential and nonresidential buildings) are expected to reduce the growth in electricity use and reduce the growth in gas use.

1.4.2 Electricity Reliability and Demand

Buildings are one of the major contributors to electricity demand. We learned during the 2000/2001 California energy crisis, and the East Coast blackout in the summer of 2003, that our electric distribution network is fragile and system overloads caused by excessive demand from buildings can create unstable conditions. Resulting blackouts can disrupt business and cost the economy billions of dollars.

Since the California electricity crisis, the Energy Commission has placed more emphasis on demand reduction.

1.4.3 Comfort

Comfort is an important benefit of energy efficient buildings. Energy efficient buildings include high performance windows to reduce solar gains and heat loss, and properly designed HVAC systems, which provide improved air circulation. Poorly designed building envelopes result in buildings that are less comfortable. Oversized heating and cooling systems do not assure comfort in older, poorly insulated, or leaky buildings.

1.4.4 Economics

For the building owner, energy efficiency helps create a more profitable operation. From a broader perspective, the less California depends on depletable resources such as natural gas, coal, and oil, the stronger and more stable the economy will remain in the face of energy cost increases. A cost-effective investment in energy efficiency benefits everyone. In many ways, it is far more cost effective for Californians to invest in saving energy than it is to invest in building new power plants.

1.4.5 Environment

The use of depletable energy has led to oil spills, acid rain, smog, and other forms of environmental pollution that threaten the natural beauty of our planet. California is not immune to these problems, but the Appliance Efficiency Regulations, the Energy Standards, and utility programs that promote efficiency and conservation help to maintain environmental quality. Other benefits include increased preservation of natural habitats which protect animals, plants, and ecosystems.

1.4.6 Greenhouse Gas Emissions and Global Warming

Burning fossil fuel adds carbon dioxide (CO_2) to the atmosphere and is a major contributor to global warming; the atmosphere already contains 25 percent more CO_2 than it did two centuries ago. Carbon dioxide and other greenhouse gasses create an insulating layer around the earth that leads to global climate change. The Energy Commission's research shows that most sectors of the State economy face significant risk from climate change, including water resources (from reduced snow pack), agriculture, forests, and the natural habitats of indigenous plants and animals.

Energy efficiency is a far-reaching strategy that is making an important contribution to the reduction of greenhouse gasses. The National Academy of Sciences has urged the country to follow California's lead on such efforts, saying that conservation and efficiency should be the chief elements in energy and global warming policy. Their first efficiency recommendation was simple: Adopt nationwide energy efficiency building codes.

The Energy Standards are expected to have a significant impact on reducing greenhouse gas and other air emissions.

1.5 What's New for 2016

1.5.1 Envelope

1. Revisions to the mandatory requirements for metal framed and demising walls (§120.7(b)).
2. Changes to the prescriptive envelope requirements (§140.3(a)).
3. Revisions to the roof/ceiling insulation tradeoff for aged solar reflectance (Table 140.3 of the Energy Standards).
4. Significant changes to the total skylight area requirement (§140.3(c)4).
5. Revisions to the requirements for all fenestration alterations (§141.0(b)2A).

1.5.2 Lighting

1. Clarification and simplification of existing language; removing exceptions no longer relevant (§130.0 through §130.5 and §140.6 through §140.8).
2. Reductions to Lighting Power Density (LPD) values in Tables 140.6-B, 140.6-C, and 140.6-G.
3. Removal/addition of Power Adjustment Factors (PAFs) (§140.6(a)2).
4. Significant reductions in outdoor lighting power allowances (Table 140.7-A).
5. Clarification and streamlining of alteration requirements, including addition of a new compliance path that allows compliance by reducing the existing lighting power. For indoor lighting, this path foregoes bi-level control requirements but is otherwise identical to the 85 percent or less of lighting power allowance path.

1.5.3 Mechanical

1. Revision of the mandatory requirements for equipment efficiency in Tables 110.2-A through 110.2-K of the Energy Standards.
2. Interlock controls requirements when operable wall or roof openings are present (§140.4(n)).
3. Revisions to fan control system requirements in Table 140.4-D of the Energy Standards.
4. Energy Management Control System (EMCS) to comply with the thermostatic control requirements (§120.2(a)).
5. Changes to the requirements for dampers installed on outdoor air supply and exhaust equipment (§120.2(f)).
6. New section specifying direct digital controls (DDC) applications and qualifications (§120.2(j)).

7. Revisions to the requirements for space conditioning systems with DDC to the zone level (§120.2(k)).
8. New general requirements for pipe insulation (§120.3(a)).

1.5.4 Electrical

1. New definitions of electrical metering, service equipment, plug load, and low voltage dry-type distribution transformer are added to §100.1.
2. Revisions and clarifications of service electrical metering §130.5(a), separation of electrical circuits in §130.5(b), voltage drop in §130.5(c), and circuit controls in §130.5(d).

1.5.5 Covered Processes

1. New mandatory requirements for elevators, escalators and moving walkways (§120.6(f) and §120.6(g)).

1.5.6 Commissioning

1. Revisions to language and content to make §120.8 more clear.

1.6 Mandatory Measures and Compliance Approaches

In addition to the mandatory measures, the Energy Standards provide two basic methods for complying with nonresidential energy budgets: the prescriptive approach and the performance approach. The mandatory measures must be installed with either method, but note that mandatory measures may be superseded by more stringent measures under the prescriptive or performance approach.

1.6.1 Mandatory Measures

With either the prescriptive or performance compliance paths, there are mandatory measures that must always be met. Mandatory measures include infiltration control, lighting systems, minimum insulation levels, and equipment efficiency. The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance requirements.

1.6.2 Prescriptive Approach

The prescriptive approach (composed of prescriptive requirements described in Chapters 3, 4, 5, 6, 7, and 10) is the most direct approach of the two. Each individual energy component of the proposed building must meet a prescribed minimum efficiency. The prescriptive approach offers relatively little design flexibility, but is easy to use. There is some flexibility for building envelope components, such as walls, where portions of the wall that do not meet the prescriptive insulation requirement may still comply as long as the area-weighted average wall performance complies. If the design fails to meet even one of the requirements, then the system does not comply with the prescriptive approach. In this case, the performance approach provides the most flexibility to the building designer for choosing alternative energy efficiency features.

A. **Building Envelope**. The prescriptive envelope requirements are the required thermal performance levels for each building component (walls, roofs, and floors). These requirements are described in detail in Chapter 3. The stringency of the envelope requirements vary according to climate zone and occupancy type.

B. **Mechanical.** The prescriptive mechanical requirements are described in detail in Chapter 4. The prescriptive approach specifies equipment, features, and design procedures that must be followed, but does not mandate that a particular type of HVAC system be installed.

C. **Indoor Lighting.** The prescriptive lighting power requirements are determined by one of three methods: the complete building method, the area category method, or the tailored method. These three approaches are described in detail in Chapter 5. The allowed lighting under the Energy Standards varies according to the requirements of the particular building occupancy or task requirements

D. **Outdoor Lighting**. The Outdoor Lighting Standards are described in Chapter 6. They set power limits for various applications such as parking lots, pedestrian areas, sales canopies, building entrances, building facades, and signs. The Energy Standards also set minimum requirements for cutoff luminaires and controls. Outdoor lighting compliance is prescriptive in nature and is determined by the lighting application type (general and specific) and the lighting zone for each application. Detailed information on the outdoor lighting power allowance calculations is found beginning in Section 6.4.

1.6.3 Performance Approach

The performance approach (Chapter 11) allows compliance through a wide variety of design strategies and provides greater flexibility than the prescriptive approach. It is based on an energy simulation model of the building. The Energy Standards specify the method for determining an energy budget for the building.

The performance approach requires an approved computer software program that models a proposed building, determines its allowed energy budget, calculates its energy use, and determines when it complies with the budget. Design options such as window orientation, shading, thermal mass, zonal control, and building configuration are all considered in the performance approach. This approach is used because of its flexibility and because it provides a way to find the most cost-effective solution for compliance.

The performance approach requires that the annual Time Dependent Valuation (TDV) energy be calculated for the proposed building or space, and be compared to the TDV energy budget. The performance approach may be used for:

- envelope or mechanical compliance;
- envelope and mechanical compliance;
- envelope and indoor lighting compliance; or
- envelope, mechanical, and indoor lighting compliance.

It is not applicable to outdoor lighting, or to indoor lighting in the absence of envelope compliance. The performance path is not available for sign lighting, exempt process load, some covered process loads (e.g. refrigerated warehouses), or solar ready applications.

TDV energy is the “currency” for the performance approach. TDV energy not only considers the type of energy that is used (electricity, gas, or propane), but also when it is used. Energy saved during periods when California is likely to have a statewide system peak is worth more than energy saved at times when supply exceeds demand. Appendix JA3 of the Reference Appendices has more information on TDV energy.

Four basic steps are involved:

1. Design the building with energy efficiency measures that are expected to be sufficient to meet the energy budget. (The prescriptive approach requirements in §140.0 through §140.8 provide a good starting point for the development of the design.)
2. Demonstrate that the building complies with the mandatory measures (see Chapters 3 through 10).
3. Using an approved calculation method, model the energy consumption of the building using the proposed features to create the proposed energy budget. The model will automatically calculate the allowed energy budget for the proposed building.
4. If the proposed energy budget is no greater than the allowed energy budget, the building complies.

1.6.3.1 **Compliance Options**

The Energy Standards have mandatory requirements, and prescriptive or performance methods for compliance. They establish a minimum level of performance which can be exceeded by advanced design and construction practices.

The Energy Commission has established a formal process for certification of compliance options of new products, materials, designs or procedures that can improve building efficiency levels established by the Energy Standards. §10-109 allows for the introduction of new calculation methods and measures which cannot be properly accounted for in the current approved compliance approaches.

The Energy Commission encourages the use of energy-saving techniques and designs for showing compliance with the Energy Standards. The compliance options process allows the Energy Commission to review and gather public input regarding the merits of new compliance techniques, products, materials, designs or procedures to demonstrate compliance for newly constructed buildings and additions and alterations to existing buildings.

Approved compliance options encourage market innovation and allow the Energy Commission to respond to changes in building design, construction, installation, and enforcement.

If the performance approach will be used for additions and alterations, see Chapter 11 for details.

1.7 Scope and Application

The Energy Standards apply to both nonresidential and residential buildings. This manual addresses the requirements for nonresidential buildings, including hotels, motels, and high-rise residential buildings (those over three stories above grade in height). The Residential Manual addresses the requirements for low-rise residential buildings, which include single family and duplex residential buildings.

1.7.1 Building Types Covered

The Nonresidential Standards apply to all buildings of the California Building Code (CBC) occupancies of Group A, B, E, F, H, M, R, S, and U. If these buildings are directly or indirectly conditioned, they must meet all mechanical, envelope, indoor, and outdoor lighting requirements of the Standards. Those buildings that are not directly or indirectly conditioned must only meet the indoor and outdoor lighting requirements of the Energy Standards.

The Energy Standards do not apply to CBC Group I or L. This group includes such buildings as hospitals, daycare, nursing homes, and prisons. The Standards also do not apply to buildings that fall outside the jurisdiction of CBC, such as mobile structures. If outdoor lighting is associated with a Group I or L occupancy, it is exempt from the Energy Standards requirement; however, if the outdoor lighting is part of any of occupancy groups listed above, it must comply with the Standards requirements.

1.7.2 Historic Buildings

Exception 1 to §100.0(a) states that qualified historic buildings, as regulated by the California Historical Building Code Title 24, Part 8, or California Building Code, Title 24, Part 2, Volume I, Chapter 34, Division II, are not covered by the Energy Standards. §140.6(a)3Q and Exception 13 to §140.7(a) clarify that indoor and outdoor lighting systems in qualified historic buildings are exempt from the lighting power allowances only if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems in qualified historic buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other lighting systems in qualified historic buildings must comply with the Standards.

The California Historical Building Code (CHBC) Section 102.1.1 specifies that all non-historical additions must comply with the regular code for new construction, including the Energy Standards. CHBC Section 901.5 specifies that when new or replacement mechanical, plumbing, and/or electrical (including lighting) equipment or appliances are added to historic buildings; they *should* comply with the Energy Standards, including the Appliance Efficiency Regulations.

The California State Historical Building Safety Board has final authority in interpreting the requirements of the CHBC and determining to what extent the requirements of the Standards apply to new and replacement equipment and other alterations to qualified historic buildings. It should be noted that in enacting the CHBC legislation, one of the intents of the Legislature was to encourage energy conservation in alterations to historic buildings (Health and Safety Code Section 18951).

Additional information about the CHBC can be found at:

http://www.dgs.ca.gov/dsa/AboutUs/shbsb.aspx.

Contact the State Historical Building Safety Board at (916) 445-7627.

1.7.3 Low-Rise Residential Buildings

The Residential Energy Standards cover single-family and low-rise residential buildings (occupancy groups R1, R2, and R3) and CBC Group U buildings including:

1. All single-family dwellings of any number of stories.
2. All duplex (two-dwelling) buildings of any number of stories.
3. All multifamily buildings with three or fewer habitable stories above grade (Groups R 1 and R-2).
4. Additions and alterations to all of the above buildings.
5. Private garages, carports, sheds, and agricultural buildings.

Table 1-1: Nonresidential vs. Residential Energy Standards

Nonresidential Standards	Residential Standards
These Standards cover all nonresidential occupancies (Group A, B, E, F, H, M, R, S or U), as well as high-rise residential (Groups R-1 and R-2 with four or more habitable stories), and all hotel and motel occupancies.	These Standards cover all low-rise residential occupancies including:
Offices Retail and wholesale stores Grocery stores Restaurants Assembly and conference areas Industrial work buildings Commercial or industrial storage Schools and churches Theaters Hotels and motels Apartment and multi-family buildings, and long-term care facilities (Group R-2), with four or more habitable stories	All single family dwellings of any number of stories (Group R-3) All duplex (two-dwelling) buildings of any number of stories (Group R-3) All multi-family buildings with three or fewer habitable stories above grade (Groups R-1 and R-2) Additions and alterations to all of the above buildings
Note: The Energy Standards define a habitable story as one that contains space in which humans may live or work in reasonable comfort, and that has at least 50% of its volume above grade.	

1.7.4 Scope of Improvements Covered

The Energy Standards apply to any new construction that requires a building permit, whether for an entire building, for outdoor lighting systems, for signs, or for a modernization. The primary enforcement mechanism is through the building permitting process. Until the enforcement agency is satisfied that the building, outdoor lighting, or sign complies with all applicable code requirements, including the Standards, it may withhold the building permit (or, after construction, the occupancy permit).

The Energy Standards apply only to the construction that is the subject of the building permit application (with the exception of existing spaces that are "conditioned" for the first time, in which case existing envelope components, and existing lighting systems, whether altered or not, must also show compliance with the Standards).

Other than for lighting, the Energy Standards apply only to buildings that are directly or indirectly conditioned by mechanical heating or mechanical cooling.

1.7.5 Speculative Buildings

1.7.5.1 Known Occupancy

Speculative buildings of known occupancy are commonly built by developers. For example, if a big box retail center or an office building were built on speculation, the owner would usually know the ultimate occupancy of the space, but might not know the actual tenants. For this type of building, the owner has two compliance choices:

1. Declare the building to be unconditioned space, forcing tenants to be responsible for envelope, interior lighting, possibly some exterior lighting, and mechanical compliance. This option may be very costly as most envelope and mechanical measures are far more expensive when they are installed in the building after the shell is completed (see discussion below).
2. Include envelope compliance as well as mechanical and/or lighting compliance, when those systems are to be installed prior to leasing.

There are several potential pitfalls with delaying envelope compliance. For example, tenants may have a difficult time showing compliance, depending on fenestration areas and glass efficiency. An energy code update between the time of shell construction and energy compliance for a tenant improvement could make compliance even more difficult. Constructing a “big box” style building without skylights, where skylights are required under the prescriptive approach, will also create a compliance challenge (and possibly impose large costs to retrofit skylights). In most instances, upgrading the envelope later increases total construction costs, as it is easier to install envelope features at time of construction than afterwards. And for buildings that are certain to be conditioned, some enforcement agencies require envelope compliance at the time of shell construction.

For information about energy compliance for tenant improvements in existing buildings, see Section 1.7.12.

An obvious example is declaring the shell to be unconditioned, not insulating the shell and having to insulate the shell as part of the tenant improvement that adds air conditioning. This increases the final cost of the building and should render the shell less valuable for spaces that are ultimately going to be conditioned.

A less obvious example is the shell of a building that will ultimately become a big box retail store or a warehouse with lighting power densities greater than 0.5 W/ft², ceiling heights greater than 15 feet, and an enclosed area greater than 5,000 ft². Such occupancies are prescriptively required to have skylights and daylighting controls. Installing skylights in the roof of the speculative building shell is less expensive than retrofitting them later. This should be considered when designing speculative shell buildings for big box retail or warehouse markets, as they will be more saleable than those requiring skylight retrofits.

Because compliance may be demonstrated for each component separately, the owner can simply demonstrate that the systems being built meet the Energy Standards. The remaining construction and Standards compliance work can be dealt with as each tenant obtains building permits for work in their individual spaces.

1.7.5.2 **Unknown Occupancy**

Speculative buildings are often built for which the ultimate occupancy is determined at the time of leasing and not during construction of the building shell. The structure, for example, could be used as an office, a warehouse, a restaurant, or retail space. Because the Energy Standards treat these occupancies in a similar fashion, the fact that the ultimate occupancy is unknown is not significant. The major items affected by the ultimate occupancy have to do with lighting and ventilation requirements. If, at the time of permitting, a tenant is not identified for a multi-tenant space, the “All other areas” lighting power density allowances from Energy Standards Table 140.6-C shall be used.

The major problem that can occur with this type of building comes when the owner elects to declare it an unconditioned building and defer Standards compliance until such time as a tenant installs mechanical space conditioning equipment.

1.7.6 Mixed and Multiple Use Buildings

Because the Energy Standards are different for residential, high-rise residential, and nonresidential buildings, and because mixed-use buildings occasionally include more than one type of nonresidential occupancy, there is potential for confusion in application. The Energy Standards address these circumstances regarding mixed-use buildings:

1.7.6.1 Mixed Low-Rise Residential and Nonresidential Occupancies.

When a building includes both low-rise residential and nonresidential occupancies, the requirements are different depending upon the percentages of the conditioned floor that is occupied by each occupancy type:

A. Minor Occupancy (Exception 1 to §100.0(f).) When a residential occupancy occurs in the same building as a nonresidential occupancy, and if one of the occupancies is less than 20 percent of the total conditioned floor area, the smaller occupancy is considered a “minor” occupancy. Under this scenario, the entire building may be treated as if it is the major occupancy for the purpose of envelope, HVAC, and water heating. Lighting requirements in §140.6 through §140.8 or §150.0(k) must be met for each occupancy separately. The mandatory measures applicable to the minor occupancy, if different from the major occupancy, would still apply.

B. Mixed Occupancy. When residential occupancy is mixed with a nonresidential occupancy, and if neither occupancy is less than 20 percent of the total conditioned floor area, these occupancies fall under different sets of Standards and must be considered separately. Two compliance submittals must be prepared, each using the calculations and documents of its respective Standards. Separate compliance for each occupancy, to their respective Standards, is an option when one of the occupancies is a minor occupancy, as discussed in the paragraph above.

1.7.6.2 Different Nonresidential Occupancies.

When multiple occupancies, such as office, restaurant, and retail fall under the Nonresidential Standards, they would be treated under the same compliance approach as separate occupancies. In general, all nonresidential occupancies have the same envelope requirements and can be treated the same across all nonresidential occupancies. High-rise residential and hotel-motel guest rooms have different envelope requirements from the nonresidential envelope requirements and should be treated differently. Lighting and mechanical requirements vary among the various types of space usage categories and should also be treated differently according to each occupancy type.

A. Hotel/Motel and Nonresidential Occupancies. A hotel/motel with guest rooms, restaurants, sports facilities, and/or other nonresidential occupancies is defined as hotel/motel occupancy. The only variance is that the guestroom envelope and lighting and HVAC control requirements are different from the nonresidential occupancy energy requirements that would apply to the “common” areas of the building.

Example 1-1

Question

A 250,000 ft² high-rise office building includes a small 900 ft² apartment on the first floor for use by visiting executives. This is clearly a residential occupancy, so is the apartment required to meet the residential requirements of the Energy Standards, and if so which ones – high rise residential or low rise residential?

Answer

No. First of all, the apartment occupies less than 20 percent of the total conditioned floor area, so it is a minor occupancy and may be treated as part of the office occupancy. Second, since it is located on the first floor of the building it is technically a low rise residential building. As a result, all of the residential mandatory measures apply.

1.7.7 High-rise Residential

High-rise residential buildings (four habitable stories or more) are covered by this manual and the Nonresidential Energy Standards.

The Energy Standards apply separately to the living quarters and to other areas within the building. Living quarters are those non-public portions of the building in which a resident lives. High-rise residential dwelling units must incorporate the envelope and mechanical elements of the Nonresidential Energy Standards, with the lighting and service hot water needs of residential buildings. Outdoor lighting, including parking lots and garages for eight or more vehicles, and for indoor or outdoor signs (other than exit signs), must comply with the Nonresidential Energy Standards. Exit signs must comply with the Appliance Efficiency Regulations.

The following subsections discuss the special compliance requirements that apply to high-rise residential occupancies.

1.7.7.1 **Mandatory Measures**

The mandatory measures for nonresidential envelope, mechanical, indoor lighting, outdoor lighting, and signs apply to high-rise residential buildings. Special requirements for high-rise residential buildings are summarized below:

1. Living quarters must meet the applicable indoor lighting requirements for residential buildings.
2. Outdoor lighting must meet the applicable outdoor lighting requirements of the Nonresidential Energy Standards.
3. Indoor and outdoor signs (other than exit signs) must comply with the Nonresidential Energy Standards. Exit signs must comply with the Appliance Efficiency Regulations.
4. High-rise residential occupancies must meet setback requirements applicable to residential occupancies.
5. Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.

6 Automatic lighting shut-off controls are not required for living quarters.

1.7.7.2 **Prescriptive Compliance**

The prescriptive requirements for envelope, mechanical, and lighting apply to high-rise residences. The following summarizes the special prescriptive requirements for high-rise residential buildings:

1. The envelope must meet the prescriptive envelope criteria for high-rise residential buildings (Energy Standards Table 140.3-C).
2. High-rise residential living quarters are not required to have economizer controls.
3. High-rise residential living quarters are exempt from the nonresidential lighting power density requirements. However, lighting within the dwelling units must meet the lighting requirements of §150.0(k) that governs lighting in all spaces (including kitchen lighting requirements) except closets less than 70 ft^2 floor area. See Chapter 6 of the Residential Compliance Manual.
4. Each occupancy (other than living quarters) in the high-rise residence must comply with the Nonresidential Lighting Standards.

5. For compliance with water heating requirements, use the Residential Energy Standards.

1.7.7.3 Performance Compliance

The rules for high-rise residential performance compliance are identical to the performance compliance rules for all nonresidential buildings. The area of each function of a high-rise residence is input into approved compliance software along with its corresponding envelope, mechanical, and lighting features. The compliance software will automatically calculate an energy budget for the standard design, and the proposed design's energy use.

1.7.8 Hotels and Motels

This section discusses both the similarities and differences between the requirements for a hotel/motel and other nonresidential or high-rise residential buildings.

The design of a hotel or motel is unique in that the design must incorporate a wide variety of occupancies and functions into one structure. The occupancies range from nonresidential occupancies to hotel/motel guest rooms. Design functions that affect guests range from the "experience of arrival" created through the main lobby's architectural features to the thermal comfort of the guest rooms. Other functions that hotel/motel designs must address include restaurants, kitchens, laundry, storage, light assembly, outdoor lighting, sign lighting, and other items that are necessary to the hotel/motel function. In short, these structures can range from simple guest rooms with a small office, to a structure encompassing a small city.

Like other occupancies, compliance is submitted for the features covered in the permit application only. The nonresidential areas must meet the envelope, mechanical, indoor lighting, outdoor lighting, and sign lighting portions of the Nonresidential Standards. The guest room portions of hotels/motels must meet the envelope, mechanical, and lighting provisions applicable only to hotels/motel guest rooms. In essence, each portion of the building individually complies with the provisions applicable to that occupancy.

Since hotel/motels are treated as a mixture of occupancies covered by the Energy Standards, the concepts presented at the beginning of each chapter apply to hotels/motels as they would any other nonresidential occupancy.

1.7.8.1 Mandatory Measures

The mandatory measures for envelope, mechanical, indoor lighting, outdoor lighting, and sign lighting apply to hotels/motels. The following bullets describe special requirements or exceptions for hotel/motel buildings:

1. Hotel/motel guest rooms must meet the applicable Residential Lighting Standards.
2. Outdoor lighting must meet the applicable Outdoor Lighting Standards.
3. Indoor and outdoor signs (other than exit signs) must comply with the Nonresidential Standards. Exit signs must comply with the Appliance Efficiency Regulations.
4. Hotel and motel guest room thermostats shall have numeric temperature settings.
5. Readily accessible area switching controls are not required in public areas provided switches that control the lights in public areas are accessible to authorized personnel.
6. Automatic lighting shut-off controls are not required for hotel/motel guest rooms.

1.7.8.2 **Prescriptive Compliance**

The prescriptive requirements for envelope, mechanical, and lighting apply to hotel/motels. The following prescriptive requirements are specific to hotel/motels:

1. Hotel/motel guest rooms must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings.
2. Hotel and motel guest rooms are not required to have economizer controls.
3. Guest rooms in hotel/motels are exempt from the lighting power density requirements. However, lighting must meet the residential requirements of §150.0(k).
4. Each occupancy (other than guest rooms) in the hotel/motel must comply with the Nonresidential Lighting Standards.
5. For compliance with water heating requirements, use the residential compliance.

1.7.8.3 **Performance Compliance**

The rules for performance compliance are identical to the rules for complying for all other nonresidential and high-rise residential buildings. The area of each function of a hotel/motel is input into the approved compliance software along with its corresponding envelope, mechanical, and indoor lighting features. The computer software program will automatically calculate an energy budget for the standard design, and the proposed design's energy use. The proposed design must be less than or equal to the standard design for the building to comply.

1.7.9 Live-Work Spaces

Live-work buildings are a special case of mixed occupancy buildings, as they combine residential and nonresidential uses within individual units. In general, the low-rise or high-rise residential requirements (depending on the number of habitable stories) apply since these buildings operate (and are conditioned) 24 hours per day. Lighting in designated workspaces is required to show compliance with the Nonresidential Lighting Standards (§140.6).

1.7.10 Unconditioned Space

An unconditioned space is neither directly nor indirectly conditioned. Both the requirements for lighting and minimum skylight area apply to unconditioned space. Some typical examples of spaces that may be unconditioned:

- Enclosed parking structures
- Automotive workshops
- Enclosed entry courts or walkways
- Enclosed outdoor dining areas
- Greenhouses
- Loading docks
- Warehouses
- Mechanical/electrical equipment rooms

Keep in mind that these kinds of spaces are not always unconditioned. The specifics of each case must be determined.

1.7.11 Newly Conditioned Space

When previously unconditioned space becomes conditioned, the space is then considered an “addition” and all the building’s components must then comply as if it were a new building.

This situation has potentially significant construction and cost implications. For example, if an unconditioned warehouse is upgraded with a heating system, thus becoming conditioned space, the building envelope must comply with the current envelope requirements and the lighting system must be brought into conformance with the current lighting requirements, including mandatory wiring and switching. If the envelope has large windows, it is conceivable that some would have to be eliminated or replaced with more efficient windows. If the lighting system is inefficient, fixtures might have to be removed and new, more efficient fixtures installed.

This requirement can cause difficulty when the owner of a building seeks exemption from complying with the Energy Standards by erecting a shell with no plans to condition it.

For example, the owner of an office building obtains a permit for the structure and envelope, but wishes to leave the space conditioning and lighting improvements to the tenants. If that owner claims unconditioned status for that building, the owner does not have to demonstrate compliance with the envelope requirements of the Standards, but does have to demonstrate compliance with the lighting requirements. If at the time of permitting a tenant is not identified for a multi-tenant space, the “All other areas” lighting power density allowances from Energy Standards Table 140.6-C shall be used. However, as soon as the tenant applies for a permit to install the HVAC equipment, the envelope and any existing lighting to remain must then be brought into full compliance with the requirements for the occupancy designated.

This is the only circumstance when systems, other than those subject to the current permit application, fall under the Standards. If the building was initially designed in a way that makes this envelope compliance difficult, the building envelope may require expensive alterations to bring it into compliance.

Many enforcement agencies require the owner to sign an affidavit at the time of the initial building permit for the shell, acknowledging the potential difficulties of future envelope or lighting compliance.

To minimize Energy Standards compliance difficulties, the recommended practice is to demonstrate energy compliance at the time the envelope is built, and to demonstrate compliance for the lighting systems when lighting systems are installed.

1.7.12 New Construction in Existing Buildings

Tenant improvements, including alterations and repairs, may be considered new construction in an existing building. For example, the base building has been constructed, but the individual tenant spaces have not been completed. Tenant improvements can include work on the envelope, mechanical, or lighting systems. Whatever the case, the system or systems being installed are considered to be new construction, and must comply with some or all of the current Standards, depending on the extent of the changes (see following sections).

The only circumstance when systems other than those subject to the current permit application come under scrutiny is when the tenant improvement results in the conditioning of previously unconditioned space.

1.7.13 Alterations to Existing Conditioned Spaces

§141.0(b)

An alteration is any change to a building's water heating system, space conditioning system, indoor lighting system, outdoor lighting system, sign lighting, or envelope that is not an addition. Alterations or renovations to existing conditioned spaces have their own rules for energy compliance.

In summary, the alteration rules are:

1. The Energy Standards apply only to those portions or components of the systems being altered (altered component); untouched portions or components need not comply with the Standards.
2. If an indoor lighting, outdoor lighting, or sign lighting alteration increases the energy use of the altered systems, the alteration must comply with the current Standards.
3. Alterations must comply with the mandatory measures for the altered components.
4. New systems in the alteration must comply with the current Standards.
5. In an existing unconditioned building, where evaporative cooling is added to the existing unaltered envelope and lighting, does not need to be brought into compliance with current Standards.
6. Mechanical system alterations are governed primarily by the mandatory measures.

Beyond meeting all mandatory requirements, alterations must also comply either with applicable prescriptive requirements discussed in Chapters 3 through 8; or must comply using the performance path. Within the performance approach, changes to the existing building, such that the entire building (existing and alteration) may comply is explained in Chapter 11. Keep in mind that performance credit is given only for systems that are actually changed under the current permitted scope of work.

Example 1-2

Question

An owner wants to add less than 50 ft² of new glazing in an old nonresidential building in climate zone 3. What are the applicable requirements for the new glazing?

Answer

Exception to §141.0(b)2Ai exempts up to 50 ft² of added windows from the RSHGC and VT requirements in Table 141.0-A. Therefore, the new glazing must meet only the climate zone 3 U-factor requirement of 0.58.

Example 1-3

Question

A building owner wants to change existing lighting fixtures with new ones. Do the Energy Standards restrict the change in any way?

Answer

If more than 10 percent of the fixtures are replaced in the permitted space (excluding enclosed spaces where no new lighting fixtures are proposed), or the connected load is increased, the Standards will treat this as a new lighting system that must comply with §141.0(b)2I. Any applicable mandatory requirement affected by the alteration applies, and the mandatory switching requirements would apply to the improved system if the circuiting were altered. Appliance Efficiency Regulations requirements for ballasts would also apply.

Example 1-4

Question

A building owner wants to rearrange some interior partitions and re-position the light fixtures in the affected rooms. Do the Energy Standards apply to the work?

Answer

Each of the newly arranged rooms must have its own light switches. Since there is no change in the connected lighting load or the exterior envelope, only the mandatory light switching requirements would apply.

Example 1-5

Question

A building owner wants to rearrange some duct work and add some additional fan coils to an existing HVAC system to improve comfort. Do the Standards apply to the work?

Answer

There would be no change in the load on the system nor any increase in its overall capacity, so the Standards would not apply to the central system. Only the duct construction requirements apply to altered ducting.

Example 1-6

Question

A building owner wants to replace an existing chiller. No other changes will be made to the HVAC system. Do the Energy Standards restrict the change in any way?

Answer

The mandatory efficiency requirements would govern the efficiency of the new chiller. The other parts of the system are unchanged and therefore unaffected by the Energy Standards.

Example 1-7

Question

A building has a high ceiling space and the owner wants to build a new mezzanine space within it. There will be no changes to the building envelope or to the central HVAC system. There will be new lighting installed. How do the Energy Standards apply?

Answer

Since a mezzanine does not add volume, it is an alteration, not an addition. The existing systems are not affected unless they are altered. The new lighting must comply with all requirements of the Standards. The envelope is unchanged, so there are no requirements for it. The mechanical system duct work is simply extended without increase in system capacity, so only the duct construction and insulation requirements apply.

1.7.14 Additions

§141.0(a)

An addition is any change to a building that increases floor area and conditioned volume. Additions involve either:

- the construction of new, conditioned space and conditioned volume;
- the installation of space conditioning in a previously unconditioned space; or
- the addition of unconditioned space.

The mandatory measures and either the prescriptive or the performance requirements apply. For conditioned space, the heating, lighting, envelope, and water heating systems of additions are treated the same as for new buildings.

If the existing mechanical system(s) is simply extended into the addition, Exception 1 to §141.0(a) applies. Unconditioned additions shall only comply with indoor, outdoor lighting, and sign lighting requirements of the Standards. Refer above to Section 1.7.11 for further discussion of previously unconditioned space.

There are three options for the energy compliance of additions under the Energy Standards:

Option 1 – Addition Alone

Treat the addition as a stand-alone building with adiabatic walls to conditioned space, (§141.0(a)1 and §141.0(a)2Bi). This option can use either the prescriptive or the performance approach. Adiabatic means the common walls are assumed to have no heat transfer between the addition and the adjacent conditioned space, and are ignored entirely.

Option 2 – Existing-Plus-Addition

Model the combination of the existing building with the addition (§141.0(a)2Bii). This is a performance approach option only. Under this scenario, the proposed energy use is calculated based on existing building features that remain unaltered and all alterations (actual values of the proposed alterations) plus the proposed addition. The standard design (allowed) energy budget is calculated based on:

1. The existing building features that remain unaltered.; and
2. All altered features modeled to meet requirements of §141.0(b); and
3. The addition modeled to meet requirements of §141.0(a)1.

If the proposed building energy use is less than or equal to the standard design energy budget, then the building complies. The standard design for any alterations to the existing lighting or mechanical systems is based on the requirements for altered systems in §141.0(b).

This compliance option will generally ease the energy requirements of the addition only if there are energy improvements to the existing building. It may allow the designer to make a relatively energy inefficient addition comply depending on the nature and scope of the energy improvements to the existing building.

Option 3 – Whole Building as All New Construction

The existing structure combined with the addition can be shown to comply as a whole building meeting all requirements of the Energy Standards for new construction for envelope, lighting and mechanical. This method is only practical if the existing building is at or will be improved to the overall level of the current Energy Standards.

Example 1-8

Question

A restaurant adds a conditioned greenhouse-style dining area with very large areas of glazing. How can it comply with the Standards?

Answer

Because of its large glass area, it will not comply on its own. By making substantial energy improvements to the existing building (envelope, lighting, and mechanical features), or by upgrading the existing building so that the entire building meets the requirements for new construction, it is possible for the combined building to comply. The performance approach would be used to model the entire building as an existing-plus-addition.

To accumulate enough energy credit that can be used to offset (trade off against) the large glazing area in the addition, several design strategies are available including:

1) Envelope improvements to the existing building which exceed the performance of the requirements in §141.0(b)1 and §141.0(b)2A and B; and/or

2) New indoor lighting in the existing building which has a lower Installed Lighting Power Density (LPD) than the Allowed LPD in §140.6; and/or,

3) Existing building mechanical system improvements that exceed the requirements of §141.0(b)2C, D, and E.

1.7.15 Changes of Occupancy

A change of occupancy alone does not require any action under the Energy Standards. If changes (alterations) are made to the building, then the rules for alterations or additions apply (see Sections 1.7.13 and 1.7.14).

If the change in occupancy involves converting from a residential to a nonresidential occupancy or vice versa (changes defined by CBC occupancy), then the Standards applicable to the new occupancy would govern any alterations made to the building. For example, if a home is converted to law offices, and a new lighting system is installed, the Nonresidential Lighting Standards would apply. If a new HVAC system is installed, all the nonresidential HVAC requirements would have to be met.

If no changes are proposed for the building, it is advisable to consider the ventilation requirements of the new occupancy. For example, if a residence is converted to a hair salon, the ventilation rates of the building should be considered. With new sources of indoor pollution, the existing residential ventilation rates would likely not be adequate for the new uses. However, no change is required by the Energy Standards.

1.7.16 Repairs

A repair is the reconstruction or renewal of any part of an existing building for the purpose of its maintenance. Repairs shall not increase the preexisting energy consumption of the required component, system, or equipment. Therefore, the Energy Standards do not apply to repairs.

Example 1-9

Question

If a space were 1,000 ft², how large would the heating system have to be to make the space directly conditioned?

Answer

The heating system would have to be larger than 10 Btu/(hr-ft²) x 1,000 ft² = 10,000 Btu/hr output to meet the definition of directly conditioned space.

Example 1-10

Question

A water treatment plant has a heating system installed to prevent pipes from freezing. The heating system exceeds 10 Btu/(hr-ft²) and operates to keep the space temperature from falling below 50°F. Is this plant directly conditioned?

Answer

Not if the heating system is sized to meet the building load at 50°F and is thermostatically controlled to prevent operating temperatures above 50°F. The definition of directly conditioned space excludes Process Spaces that have space conditioning designed and controlled to be incapable of operating at temperatures above 55°F at design conditions. Under these conditions, the space is not directly conditioned.

Example 1-10

Question

A process load in a manufacturing facility is generating heat inside the building shell. The manufacturing facility will install space cooling to keep the temperature from exceeding 90°F. If the thermostat will not allow cooling below 90°F (i.e., the temperature is kept at 90°F all the time), is this facility directly conditioned, if the mechanical cooling exceeds 5 Btuh/hr-ft^2?

Answer

No, this facility is not a directly conditioned space. The definition of directly conditioned space excludes spaces where the space conditioning system is designed and controlled to be incapable of operating at temperatures below 90°F at design conditions.

Example 1-12

Question

A natural gas kiln in a factory is located within the building shell and its capacity exceeds 10 Btu/(hr-ft²). Is the space within the shell considered directly conditioned space if there is no HVAC system installed in the building?

Answer

No, since the heat from the kiln is an Exempt Process Load and not part of heat that is transferred across

the building envelope components, and there is no HVAC system installed, the space is not considered a directly conditioned space and the shell does not have to meet the Energy Standards envelope requirements; however, the space must still meet the lighting requirements of the Energy Standards.

Example 1-13

Question

If in example above mechanical cooling with the capacity that exceeds 5 Btuh/hr-ft^2 is added to the building to keep the temperature from exceeding 85°F, does the space considered directly conditioned and must the envelope meet the Energy Standards requirements?

Answer

No, the definition of Directly Conditioned Space excludes conditioning for Process Loads.

Example 1-14

Question

If a computer room is cooled with the capacity that exceeds 5 Btuh/hr-ft^2 and is controlled to a temperature of 75°F, does the space have to meet the envelope requirement of the Standards?

Answer

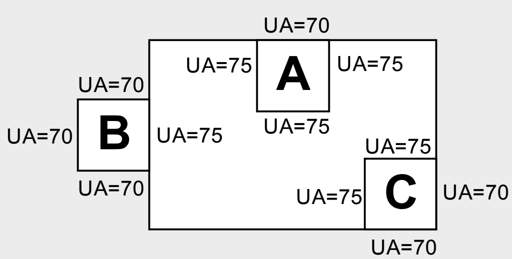
No. Computer rooms are a Covered Process. There are no envelope requirements in either §120.6 or §140.9.

Example 1-15

Question

The accompanying sketch shows a building with three unconditioned spaces (none has a direct source of mechanical heating or cooling). The air transfer rate from the adjacent conditioned spaces is less than three air changes per hour. The area weighted heat transfer coefficients of the walls (UA) are shown on the sketch. The roof/ceiling area weighted heat transfer coefficients (UA) for each of the three unconditioned spaces is 90 Btu/Hr -°F.

Are any of these spaces indirectly conditioned?



Answer

Because the air change rate is low, we evaluate each space on the basis of heat transfer coefficients through the walls and roof. It is further assumed that the floors are adiabatic. Therefore, the heat transfer will be proportional to the area weighted heat transfer coefficients of the walls and roof/ceilings.

SPACE A: The area weighted heat transfer coefficient to directly conditioned space is 3 x (75 Btu/Hr-°F) = 225 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is 70 Btu/Hr-°F + 90 Btu/Hr-°F = 160 Btu/Hr-°F. Since the heat transfer coefficient from Space A to the conditioned space is greater than heat transfer coefficient from Space A to outside, Space A is considered indirectly conditioned.

SPACE B: The area weighted heat transfer coefficient to directly conditioned space is 75 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (3 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 300 Btu/Hr-°F. Since the heat transfer coefficient from Space B to the conditioned space is less than the heat transfer coefficient from Space B to outside, Space B is considered unconditioned.

SPACE C: The area weighted heat transfer coefficient to directly conditioned space is (2 x 75 Btu/Hr-°F = 150 Btu/Hr-°F. The area weighted heat transfer coefficient to the outdoors or to unconditioned space is (2 x 70 Btu/Hr-°F) + 90 Btu/Hr-°F = 230 Btu/Hr-°F. Since the heat transfer coefficient from Space C to the conditioned space is less than the heat transfer coefficient from Space C to outside, Space C is considered unconditioned.

Example 1-116

Question

In a four-story building, first floor is retail, second and third floors are offices, and the fourth floor is residential (as defined in the CBC). Is the residential space high-rise or low-rise?

Answer

It is a high-rise residential space. Even though there is only one floor of residential occupancy, the building has four habitable stories, making it a high-rise building.

1.8 About the Energy Standards

1.8.1 History

Section 25402 of the Public Resources Code

The Legislature adopted the Warren-Alquist Act which created the California Energy Commission (Energy Commission) in 1975 to deal with energy-related issues, and charged the Energy Commission with the responsibility to adopt and maintain Energy Efficiency Standards for new buildings. The first Standards were adopted in 1978 in the wake of the Organization of Petroleum Exporting Countries (OPEC) oil embargo of 1973.

The Act requires that the Energy Standards be cost effective "when taken in their entirety and amortized over the economic life of the structure." It also requires that the Energy Commission periodically update the Standards and develop manuals to support the Energy Standards. Six months after publication of the manuals, the Act directs local building permit jurisdictions to withhold permits until the building satisfies the Standards.

The "First Generation" Standards for nonresidential buildings took effect in 1978, and remained in effect for all nonresidential occupancies until the late 1980s, when the "Second Generation" Standards took effect for offices, retail, and wholesale stores.

The next major revision occurred in 1992 when the requirements were simplified and consolidated for all building types. At this time, major changes were made to the lighting requirements, the building envelope, and fenestration requirements, as well as the HVAC and mechanical requirements. Structural changes made in 1992 led the way for national standards in other states.

The Standards went through minor revisions in 1995, but in 1998, lighting power limits were reduced significantly, because at that time, electronic ballasts and T-8 lamps were cost effective and becoming common practice in nonresidential buildings.

The California electricity crisis of 2000 resulted in rolling blackouts through much of the State and escalating energy prices at the wholesale market, and in some areas of the State in the retail market as well. The Legislature responded with AB 970, which required the Energy Commission to update the Energy Standards through an emergency rulemaking. This was achieved within the 120 days prescribed by the Legislature and the 2001

Standards (or the AB 970 Standards) took effect mid-year 2001. The 2001 Standards included requirements for high performance windows throughout the State, more stringent lighting requirements and miscellaneous other changes.

The Public Resources Code was amended in 2002 through Senate Bill 5X to expand the authority of the Energy Commission to develop and maintain standards for outdoor lighting and signs. The Energy Standards covered in this manual build from the rich history of Nonresidential Energy Standards in California and the leadership and direction provided over the years by the California Legislature.

The 2008 Standards were expanded to include refrigerated warehouses and steep-sloped roofs for the first time.

The 2013 Energy Standards reflected many significant changes as well as expanded its scope. Some changes included Fault Detection and Diagnostic devices, economizer damper leakage and assembly criteria, air handler fan control for HVAC systems, updates to the low-sloped cool roofs requirements for nonresidential buildings, and for the first time, set minimum mandatory measures for insulation in nonresidential buildings. Expanding the scope of the Standards included newly regulated covered processes such as: parking garage ventilation, process boiler systems, compressed air systems, commercial refrigeration, laboratory exhaust, data center (computer room) HVAC, and commercial kitchens.

The 2016 Energy Standards are current with ASHRAE 90.1 national consensus standards. Changes were made to clarify the Energy Standards and resolve compliance concerns.

Example 1-17

Question

If a building is LEED certified does it still need to meet the 2016 Energy Standards?

Answer

Yes.

1.8.2 California Climate Zones

Since energy use depends partly upon weather conditions, which vary throughout the State, the Energy Commission has established 16 climate zones representing distinct climates within California. These 16 climate zones are used with both the residential and the nonresidential Standards. The boundaries are shown in and detailed descriptions and lists of locations within each zone are available in Reference Joint Appendix JA2.

Cities may occasionally straddle two climate zones. In these instances, the exact building location and correct climate zone should be verified before any calculations are performed. If a climate zone boundary line splits a single building, it must be designed to the requirements of the climate zone in which 50 percent or more of the building is contained.

Figure 1-1: California Climate Zones

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2. Compliance and Enforcement

2.1 Overview

Primary responsibility for compliance and enforcement with the Building Energy Efficiency Standards (Energy Standards) rests with the local enforcement agency, typically associated with a city or county government. A building permit must be obtained from the local jurisdiction before the construction of:

- a new nonresidential or high-rise residential building,
- an outdoor lighting system,
- a sign,
- an addition,
- significant alterations (including tenant improvements)

Before a permit is issued, the local jurisdiction examines the building plans and specifications for the proposed building to verify compliance with all applicable codes and standards. Verification of compliance with the Energy Standards is the responsibility of the enforcement agency's plans examiner. This is done by comparing the requirements specified on the Certificate(s) of Compliance with the building plans and specifications for the building.

Once the enforcement agency has determined that the proposed building (as represented in the building plans and specifications) complies with all applicable codes and standards, a building permit may be issued at the request of the builder or the owner of the building. This is the first significant milestone in the compliance and enforcement process. After building construction is complete, if the enforcement agency's final inspection determines that the building still conforms to the building plans and specifications; Certificate(s) of Compliance are approved during plan check; and it complies with all applicable codes and standards, the enforcement agency may approve the building and issue the Certificate of Occupancy. The enforcement agency's final approval is also a significant milestone.

While obtaining the building permit and Certificate of Occupancy are important, the compliance and enforcement process is significantly more involved and requires participation by a number of other persons and organizations, including the architect or building designer, specialty engineers (mechanical, electrical, civil, etc.), building developers, purchasing agent, general contractor, subcontractors/installers, energy consultant, plans examiners, inspectors, realtors, the building owner, and third-party inspectors (HERS raters). This chapter describes the overall compliance and enforcement process and identifies the responsibilities for each person or organization.

Where the building construction is under the jurisdiction of a state agency, no construction of any state building can begin until the Department of General Services (DGS), or the state agency that has jurisdiction over the property, determines that:

- The construction is designed to comply with the requirements of Title 24, Part 6 (Energy Standards).
- The documentation requirements of §10-103(a)1 have been met (Certificate(s) of Compliance).
- The building plans indicate the features and performance specifications needed to comply with the Energy Standards.

The responsible state agency must notify the Commission's Executive Director of its determination.

2.1.1 Compliance Document Registration

§10-103 *Reference Joint Appendix JA7* *Reference Nonresidential Appendix NA1*

When a data registry service provider has been established, requirements for a documentation procedure called *registration* take effect. *Registration* documentation is required for the construction and alteration of nonresidential buildings. *Registration* requirements are described in this chapter and elsewhere in this manual. Also, *Reference Joint Appendix JA7* provides detailed descriptions of document registration procedures and individual responsibilities for registration of Certificate(s) of Compliance, Certificate(s) of Installation, and Certificate(s) of Acceptance Testing. More details regarding *registration* requirements are also found in *Reference Nonresidential Appendix NA1*.

When *registration* is required, parties responsible for completing and submitting compliance documents (Certificate(s) of Compliance, Certificate(s) of Installation, and Certificate(s) of Acceptance) must submit the compliance document(s) electronically to an approved nonresidential data registry for registration and retention. *Registration* of the nonresidential compliance documentation is in addition to registering Certificate(s) of Field Verification and Diagnostic Testing with an approved HERS provider data registry when HERS testing is required. (See Section 2.2.)

Compliance documents submitted to an approved nonresidential data registry shall be certified and signed by the applicable responsible person (§10-103). The nonresidential data registry shall assign a unique *registration* number to the document(s), provided the documents are completed correctly and a certification/signature is provided by the responsible person. The registered document is retained by the nonresidential data registry and copies are made available via secure internet website access to authorized registry users. These are used to make electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required, including posting copies in the field for enforcement agency inspections, and providing copies to the building owner. (See Section 2.3.2.)

Examples of authorized registry users include energy consultants, builders, building owners, construction contractors and installers, enforcement agencies, the Energy Commission, and parties to the compliance and enforcement process that the documents support. Authorized users of the nonresidential data registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

Note: Code compliance documents are considered public information.

This chapter is organized as follows:

- 2.1 Overview
- 2.2 The Compliance and Enforcement Process
- 2.3 Final Inspection by the Enforcement Agency and Issuance of the Certificate of Occupancy
- 2.4 Compliance Documentation
- 2.5 Roles and Responsibilities

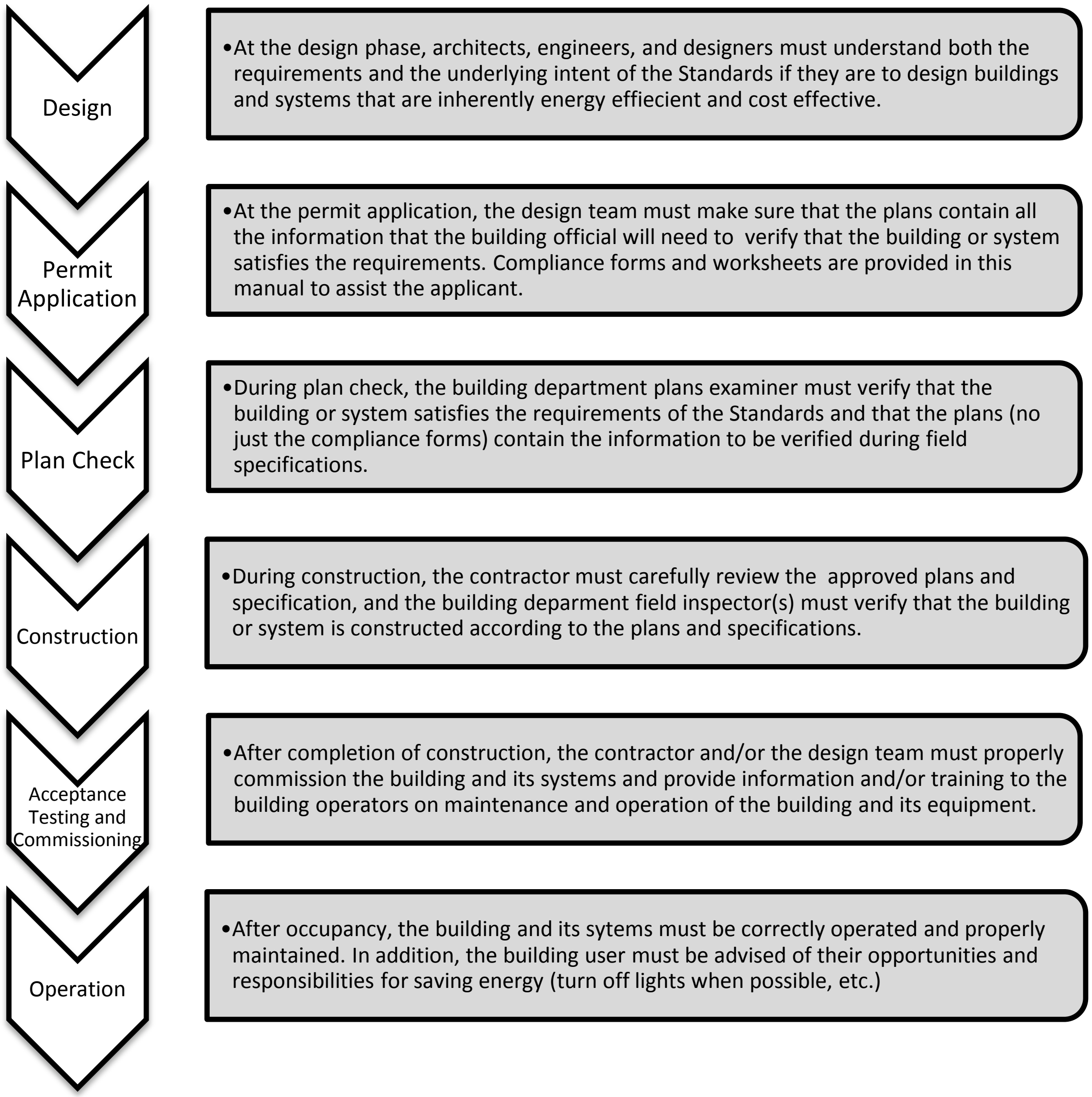
2.2 The Compliance and Enforcement Process

The process of complying with and enforcing the Energy Standards involves many parties. Those involved may include the architect or building designer, building developers, purchasing agent, general contractor, subcontractors/installers, energy consultant, plans examiners, inspectors, realtors, the building owner, and third party inspectors (HERS Raters). Communication between these parties is essential for the compliance/enforcement process to run smoothly.

The Energy Standards specify detailed reporting requirements that are intended to provide design, construction, and enforcement parties with information needed to complete the building process and ensure that the energy features are installed. Each party is accountable for ensuring that the building's energy features applicable to their area of responsibility are installed correctly. This section outlines and discusses the responsibilities and requirements during each phase of the compliance and enforcement process. (See Figure 2-1.)

Contingent upon approval of a nonresidential data registry by the Energy Commission, all nonresidential energy compliance documents will need to be registered with a nonresidential data registry prior to submittal to an enforcement agency. (See Section 2.1.1.) The registration of documents prior to submittal to an enforcement agency accomplishes the requirements for the retention of a completed and signed copy of the submitted energy compliance documentation. §10-103 of the Energy Standards outlines the registration requirements for compliance documents. Document retention is vital to compliance and enforcement follow-up actions and other quality assurance processes that help to ensure realization of energy savings from installed energy features. Although some local enforcement agencies elect to retain copies of submitted energy compliance documents, many jurisdictions do not retain these documents. Thus, the Energy Standards requirement for registration of the energy compliance documentation in a nonresidential data registry ensures that document retention is accomplished for all nonresidential construction projects. General information describing registration procedures that are specific to the design, construction, and inspection phases follow in this chapter. Refer also to Reference Joint Appendix JA7 and Reference Nonresidential Appendix NA1 for more detailed descriptions of these document registration procedures.

Figure 2-1: The Compliance and Enforcement Process



2.2.1 Certificate(s) of Compliance

§10-103(a); §120.8

2.2.1.1 Design Phase and Building Commissioning Certificate(s) of Compliance

During the design phase, the plans and specifications are developed that define the building or system that will be constructed or installed. The building or system's overall design must be detailed in the construction documents and specifications, and these documents must be submitted to the enforcement agency for approval. Parties associated with the design phase must ensure that the building or system design specifications comply with the Energy Standards, and that the energy features given on the construction documents are consistent with the Certificate(s) of Compliance for the building or system.

The Design Review Kickoff Certificate(s) of Compliance and the Construction Document Design Review Checklist Certificate(s) of Compliance must be reviewed and signed depending on the size of the building by the following person(s) (See Table 2-1):

- For buildings larger than 50,000 square feet, or for buildings with complex mechanical systems - an independent third party engineer, architect, or contractor.
- Buildings between 10,000 and 50,000 square feet – an in-house engineer or architect not associated with the project under review or a third party engineer.
- For buildings less than 10,000 square feet – the design engineer or architect of record.

The plans examiner will be responsible for verifying that these documents are submitted with the building plans and are complete when required. More details regarding these Design Review Certificate(s) of Compliance documents and the requirements for building commissioning are provided in Chapter 12.

2.2.1.2 **Building Plans and Specifications and Certificate(s) of Compliance**

During the design phase, the architect, mechanical engineer, and lighting designer must determine whether the building or system design complies with the Energy Standards. An energy consultant or other professional (Documentation Author) may assist the building designer(s) by providing calculations that determine the energy compliance impact of building features proposed for the design. Additionally, throughout the design phase, recommendations or alternatives may be suggested by energy consultants or energy documentation authors to assist the designer in achieving compliance with the Standards.

The building or system design plans and specifications are required to be complete with regard to specification of the energy efficiency features selected for compliance with the Energy Standards, which must be detailed on the Certificate(s) of Compliance submitted to the enforcement agency. (See Table 2-1 for a complete list of compliance documents.) It is the responsibility of the builder/designer to ensure that the energy efficiency features detailed on the Certificate(s) of Compliance are specified in the respective sections of the building plans. Some examples of these features in the respective sections of the building plans include:

1. Specifying the lighting fixtures and their wattages, lighting controls, etc., from the Lighting Certificate(s) of Compliance for each room in a lighting schedule, lighting fixture legend for the floor plan, etc., on the electrical plans.
2. Specifying the window and skylight U-Factor and SHGC values from the Envelope Certificate(s) of Compliance in a window/skylight schedule, window/skylight legend for the floor plan, etc., on the structural/architectural plans.
3. Specifying the wall, floor, and roof/ceiling insulation R-values from the Envelope Certificate(s) of Compliance in a framing plan, the structural details, etc., on the structural/architectural plans.
4. Specifying the HVAC equipment SEER, EER, AFUE, etc., and efficiency values, duct insulation values, etc., from the Mechanical Certificate(s) of Compliance in an equipment schedule on the mechanical plans.

Note: The builder/designer should consult with the enforcement agency regarding methods of specifying energy features on the building plans for approval.

Any change in the design specifications, during any phase of design or construction that changes the energy features specified for the design, necessitates recalculation of the energy code compliance and issuance of a revised Certificate(s) of Compliance. If recalculation indicates that the building no longer complies, alternate building features must be selected that bring the design back into compliance with the Standards. The building plans and specifications for the design must be revised to be consistent with the energy features shown on the revised Certificate(s) of Compliance, and must be resubmitted to the enforcement agency for approval.

It is essential to coordinate energy efficiency feature selection with other building design considerations as part of the overall design development process. This ensures that the completed design specifications represented on the final construction documents submitted to the enforcement agency are complete and consistent with the Certificate(s) of Compliance and in compliance with the Energy Standards.

The next section on Integrated Design discusses briefly how concurrent development of other aspects of the design can serve to improve the quality of the final design, and diminish the need for revision of the construction documentation later in the plan review or construction process.

2.2.1.3 **Integrated Design**

Integrated design is the consideration that brings the design of all related building systems and components together. It brings together the various disciplines involved in designing a building or system and reviews their recommendations as a whole. It recognizes that each discipline's recommendations have an impact on other aspects of the building project. This approach allows for optimization of both building performance and cost.

For example, many times HVAC systems are designed without regard for lighting systems or lighting systems are designed without consideration of daylighting opportunities.

The architect, mechanical engineer, electrical engineer, contractors, and other team members each have their scope of work and often pursue the work without adequate communication and interaction with other team members. This can result in improper system sizing, or systems that are optimized for non-typical conditions.

Even a small degree of integration provides some benefit, allowing professionals working in various disciplines to take advantage of design opportunities that are not apparent when they are working in isolation. This can also point out areas where trade-offs can be implemented to enhance energy efficiency. Design integration is the best way to avoid redundancy or conflicts with aspects of the building project planned by others. The earlier that integration is introduced in the design process, the greater the benefit that can be expected.

For a high performance school project, team collaboration and integration of design choices should begin no later than the programming phase. In addition, the project team is likely to be defined more broadly than in the past, and may include energy analysts, materials consultants, lighting designers, life-cycle cost consultants, and commissioning agents. Design activities may expand to include collaborative modeling exercises and simulations.

This manual provides details and implementation rules for individual design components and systems. Though these individual strategies can improve building or system energy efficiency, whole-building analysis and integrated design can balance energy and cost concerns more effectively.

2.2.2 Permit Application – Certificate(s) of Compliance

§10-103(a); §10-103(a)2

2.2.2.1 Submittal and Signatures

When the design is complete, construction documents are prepared, approvals (i.e., planning department, water) are secured, and the owner, developer, or architect submits an application for a building permit to the enforcement agency. Permit application is generally the last step in the process of planning and design. At this point, the infrastructure (i.e., streets, sewers, water lines, electricity, gas) is likely to be in place or is under construction, and the process of preparation for the construction or installation of the building or system design can begin.

Certificate(s) of Compliance must be submitted along with the construction documents, and these documents must be approved by the enforcement agency. If the prescriptive method is used for compliance, the Certificate(s) of Compliance documentation for the building envelope, mechanical systems, and the lighting systems must all be submitted. If the performance method is used for the entire building, a compiled set of Certificate(s) of Compliance documentation pages is prepared (the PERF-1C document) using one of the compliance software applications approved by the Energy Commission that summarizes the energy features for the building. The compliance software will still produce Certificate(s) of Compliance documentations for the building envelope, mechanical systems, and lighting systems in addition to the PERF-1C document. Certificate(s) of Compliance documentation requirements are specified in §10-103(a)1and §10-103(a)2 of the Energy Standards.

For all buildings, the Certificate(s) of Compliance must be signed by the person(s) eligible under Division 3 of the Business and Professions Code to accept responsibility for the building design to certify conformance with the Energy Standards. If more than one person has responsibility for the building design, each person must sign the Certificate of Compliance document(s) applicable to that portion of the design for which the person is responsible. Alternatively, the person with chief responsibility for the building design may prepare and sign the Certificate of Compliance document(s) for the entire design. The signatures must be original signatures on paper documents or electronic signatures on electronic documents when *registration* is required. (See Reference Joint Appendix JA7 for details on electronic signatures.)

2.2.2.2 **Design Review Certificate(s) of Compliance**

The Design Review Kickoff Certificate(s) of Compliance and Construction Document Design Review Certificate(s) of Compliance must be signed by the approved design reviewer, specified in §10-103(a)1, and submitted for approval by the enforcement agency. These documents are required for all projects regardless of the compliance method used (prescriptive or performance). To demonstrate compliance, all projects are required to complete Certificate(s) of Compliance documents NRCC-CXR-01 and NRCC-CXR-02. The Certificate(s) of Compliance documents NRCC-CXR-03 and NRCC-CXR-04 are required based on the HVAC system types included in the project, based on the definition of complex mechanical systems. The building owner, or representative, design engineer and design reviewer must all sign and date the Design Review Signature Certificate of Compliance document NRCC-CXR-05 once the design review has been completed. Contractors accepting the responsibilities of the engineer under the provision of the Business and Profession Code may sign the documents in place of the design engineer. All applicable design review compliance documents must be submitted. See Chapter 12 of for more details regarding which Design Certificate of Compliance documents are required.

2.2.2.3 **Preparation and Incorporation onto the Plans**

The length and complexity of the Certificate(s) of Compliance documentation may vary depending on the size and complexity of the building(s) or system(s) that are being permitted, regardless of which compliance method is used. The Certificate(s) of Compliance documents are commonly prepared by an energy consultant or energy compliance professional (Documentation Author). An energy consultant should be knowledgeable about the Standards and can benefit the design team by offering advice for the selection of the compliance method (prescriptive or performance), and the selection of the energy features utilized for compliance with the Energy Standards. An energy consultant may also provide recommendations for the most cost effective mix of building energy features for the design.

The Administrative Regulations, §10-103(a)2, require that the Certificate(s) of Compliance and any applicable supporting documentation be submitted with permit applications and that the Certificate(s) of Compliance be incorporated into the building plans. Many enforcement agencies require that all of the energy compliance documents be incorporated electronically onto the building plans. This enables the plans examiner to verify that the building or system design specifications shown on construction documentation are consistent with the energy features specified on the Certificate(s) of Compliance. The Certificate(s) of Compliance documents submitted to the enforcement agency to demonstrate compliance shall conform to a format and informational order and content approved by the Energy Commission. (See §10-103(a)1A.) Samples of the Energy Commission-approved documents are located in Appendix A of this manual. A listing of Certificate of Compliance documents is available in Table 2-1.

2.2.2.4 **Registration**

Once the Energy Commission has established a data registry, *registration* will be required for all Certificate(s) of Compliance submitted to the enforcement agency. The registration process requires the builder or designer to submit the Certificate(s) of Compliance information and an electronic signature to an approved nonresidential data registry in order to produce a completed, dated, and signed electronic Certificate(s) of Compliance that is retained by the registry. The Certificate of Compliance is assigned a unique registration number, and then copies of the unique registered Certificate of Compliance documents are made available to authorized users of the nonresidential data registry for use in making electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required.

Examples of authorized users of the nonresidential data registry may include energy consultants, builders, building owners, construction contractors and installers, enforcement agencies, the Energy Commission, and other parties to the compliance and enforcement process that the documents are designed to support. Authorized users of the nonresidential data registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

Table 2-1: Certificate of Compliance Documents

Design Review	Electrical	Envelope	Lighting	Outdoor Lighting	Sign Lighting
NRCC-CXR-01-E Design Review Kickoff **NRCC-CXR-02-E** Construction Documents– All Buildings **NRCC-CXR-03-E** Construction Document Review – HVAC Simple **NRCC-CXR-04-E** Construction Document Review – HVAC Complex **NRCC-CXR-05-E** Design Review Signature Page	**NRCC-ELC-01-E** Disaggregation of Electrical Circuits	**NRCC-ENV-01-E** Envelope Component Approach **NRCC-ENV-02-E** Fenestration Worksheet **NRCC-ENV-03-E** Roof Replacement Tradeoff Calculation **NRCC-ENV-04-E** Daylit Zone Worksheet **NRCC-ENV-05-E** Fenestration Certification Label **NRCC-ENV-06-E** Area Weighted Average Worksheet	***NRCC*-LTI-01-E** Certificate of Compliance and Field Inspection Checklist **NRCC-LTI-02-E** Lighting Controls Credit Worksheet **NRCC-LTI-03-E** Indoor Lighting Power Allowance **NRCC-LTI-04-E** Tailored Method Worksheet **NRCC-LTI-05-E** Line Voltage Track Lighting Worksheet	**NRCC-LTO-01-E** Certificate of Compliance and Field Inspection Checklist **NRCC-LTO-02-E** Outdoor Lighting Worksheet **NRCC-LTO-03-E** Outdoor Lighting Power Allowance	**NRCC-LTS-01-E** Certificate of Compliance

Mechanical	Plumbing	Covered Processes		Solar
NRCC-MCH-01-E Certificate of Compliance Declarations **NRCC-MCH-02-E** Dry ad Wet Systems **NRCC-MCH-03-E** Mechanical Ventilation and Reheat **NRCC-MCH-04-E** Single Zone Systems Declaration **NRCC-MCH-05-E** Single Zone Systems Requirements **NRCC-MCH-06-E** Maximum Cycles of Concentration Worksheet **NRCC-MCH-07-E** Prescriptive Requirements – Fan Power Consumption	**NRCC-PLB-01-E** Water Heating Systems	**NRCC-PRC-01-E** Covered Process **NRCC-PRC-02-E** Garage Exhaust **NRCC-PRC-03-E** Commercial Kitchens **NRCC-PRC-04-E** Data Centers **NRCC-PRC-05-E** Prescriptive/ Performance Commercial Refrigeration **NRCC-PRC-06-E** Refrigerated Warehouses **NRCC-PRC-07-E** Refrigerated Warehouses 3,000 ft^2 or greater	**NRCC-PRC-08-E** Refrigerated Warehouses 3,000 ft^2 or greater (served by same refrigeration system) **NRCC-PRC-09-E** Laboratory Exhaust **NRCC-PRC-10-E** Compressed Air Systems **NRCC-PRC-11-E** Process Boilers **NRCC-PRC-12-E** Elevator Lighting & Ventilation Controls **NRCC-PRC-13-E** Escalators & Moving Walkways Speed Control	**NRCC-SRA-01-E** Solar Ready Areas **NRCC-SRA-2-E** Minimum Solar Zone Area Worksheet **NRCC-STH-01-E** OG100 Solar Water Heating Systems Worksheet

Refer to Appendix A of this manual for a complete list and samples of Certificate of Compliance documents.

2.2.3 Plan Check

§10-103(d)1

2.2.3.1 **Plans and Specifications**

Local enforcement agencies are required to check submitted building plans and specifications to determine whether the design conforms to the applicable codes and standards, thus the plan check must include checking the energy efficiency specifications for the design to confirm compliance with the Energy Standards. Vague, missing, or incorrect information on the construction documents may be identified by the plans examiner as requiring correction, and the permit applicant must revise the construction documents to make the corrections or clarifications, and then resubmit the revised building plans and specifications for verification by the plans examiner. When the permit applicant submits comprehensive, accurate, clearly defined building plans and specifications, it helps to speed the plan review process.

During plan review, the enforcement agency must verify that the building's design details specified on the construction documents conform to the applicable energy code features information specified on the submitted Certificate(s) of Compliance documents. This is necessary since materials purchasing personnel and building construction craftsmen in the field may rely solely on a copy of the building plans and specifications approved by the enforcement agency for direction in performing their responsibilities.

It is worthwhile to mention that later in the construction/installation process, the person responsible for construction will be required to sign a Certificate(s) of Installation confirming that the installed features conform to the requirements specified in the building plans and the Certificate(s) of Compliance approved by the enforcement agency. If at that time it is determined that the actual construction/installation is not consistent with the approved building plans and specifications or Certificate(s) of Compliance, the applicable documentation is required to be revised to reflect the actual construction/installation specifications, which must indicate compliance with the energy code requirements. If necessary, corrective action must be taken to bring the construction/installation into compliance. It is of utmost importance that the building design features represented on the approved building plans and specifications for the proposed building comply with the Energy Standards' requirements specified on the approved Certificate(s) of Compliance, and that the actual construction/installation is consistent with those approved documents.

2.2.3.2 **Energy Plan Review**

The enforcement agency is responsible for verifying that all required compliance documents have been submitted for plan review and do not contain errors. When the compliance documents are produced by an Energy Commission-approved computer software application, it is unlikely that there will be computational errors on the Certificate(s) of Compliance documents. However, it is essential that the plans examiner verifies that the building design represented on the proposed building specifications is the same building design represented in the Certificate(s) of Compliance documents. Some examples of how the plans examiner will verify that the energy efficiency features detailed on the Certificate(s) of Compliance are specified in the respective sections of the building plans include:

1. Verifying the lighting fixtures and their wattages, lighting controls, etc., from the Lighting Certificate(s) of Compliance on the Electrical Plans in a lighting schedule, lighting fixture legend for the floor plan, etc.

2. Verifying the window and skylight U-Factor and SHGC values from the Envelope Certificate(s) of Compliance on the Structural/Architecture Plans in a window/skylight schedule, window/skylight legend for the floor plan, etc.
3. Verifying the wall, floor, and roof/ceiling insulation R-values from the Envelope Certificate(s) of Compliance on the Structural/Architecture Plans in a framing plan, the structural details, etc.
4. Verifying the HVAC equipment SEER, EER, AFUE, etc. efficiency values from the Mechanical Certificate(s) of Compliance on the Mechanical Plans in an Equipment Schedule.

Note: The enforcement agency should clearly articulate to the builder/designer the acceptable methods of specifying energy features on the building plans for approval.

To obtain a list of Energy Commission-approved energy code compliance software applications, visit the Commission Website at: http://www.energy.ca.gov/title24/2016standards/2016_computer_prog_list.html, or call the Energy Standards Hotline at 1-800-772-3300.

2.2.4 Building Permit

§10-103(d)1

After the plans examiner has reviewed and approved the building plans and specifications and energy compliance documentation for the project, a building permit may be issued by the enforcement agency at the request of the builder. Issuance of the building permit is the first significant milestone in the compliance and enforcement process. The building permit is the green light for the contractor to begin work. In many cases, building permits are issued in phases. Sometimes there is a permit for site work and grading that precedes the permit for actual construction. In large Type I or II buildings, the permit may be issued in phases such as site preparation or structural steel.

2.2.5 Construction Phase – Certificate(s) of Installation

§10-103(a)3

2.2.5.1 **Change Orders**

Upon receiving a building permit from the local enforcement agency, the general contractor can begin construction. The permit requires the contractor to construct the building or system in compliance with the approved building plans and specifications, but often there are variations. Some variations are formalized by the contractor through change orders. When change orders are issued, the design team and the local enforcement agency must verify that compliance with the energy code is not compromised by the change order. In some cases, it is obvious that a change order could compromise energy code compliance; for instance, when an inexpensive single glazed window is substituted for a more expensive high performance dual glazed window.

However, it could be difficult to determine whether a change order would compromise compliance; for instance, when the location of a window is changed or when the orientation of the building with respect to direction north is changed. Field changes that result in non-compliance require enforcement agency approval of revised building plans and energy compliance documentation to confirm that the building is still in compliance.

2.2.5.2 **Completion and Submittal**

During the construction process, the general contractor or specialty subcontractors are required to complete various construction certificates. These certificates verify that the contractor is aware of the requirements of the Energy Standards, and that the actual construction/installation meets the requirements.

Certificate(s) of Installation are required to be completed and submitted to certify compliance of regulated energy features such as windows and skylights, water heater, plumbing, HVAC ducts and equipment, lighting fixtures and controls, and building envelope insulation. The licensed person responsible for the building construction or for the installation of a regulated energy feature must ensure their work is done in accordance with the approved building plans and specifications for the building. The responsible person must complete and sign a Certificate of Installation to certify that the installed features, materials, components, or manufactured devices for which they are responsible conform to the building plans, specifications, and the Certificate(s) of Compliance documents approved by the enforcement agency for the building. A copy of the completed, signed, and dated Certificate of Installation must be posted at the building site for review by the enforcement agency, in conjunction with requests for final inspection of the building.

If construction on any regulated portion of the building will be impossible to inspect because of subsequent construction, the enforcement agency may require the Certificate(s) of Installation to be posted upon completion of that feature/portion of the building. The Certificate of Installation documents submitted to the enforcement agency shall conform to a format and informational order and content approved by the Energy Commission. (See §10-103(a)3A.) Samples of the Energy Commission-approved documents are located in Appendix A. A listing of Certificate of Installation documents is presented in Table 2-2. A copy of the Certificate(s) of Installation must be included with the documentation the builder provides to the building owner at occupancy as specified in §10-103(b).

If for any reason the actual construction/installation performed does not conform to the approved plans and specifications and Certificate(s) of Compliance, corrective action must be performed to bring the documentation and installation into compliance prior to completion and submittal of the Certificate(s) of Installation.

2.2.5.3 **Registration**

Once a data registry has been established, all of the Certificate of Installation documents must be registered documents from an approved nonresidential data registry. When registration is required, the builder or installing contractor must submit information to an approved nonresidential data registry to produce a completed, dated, and signed electronic Certificate of Installation that is retained by the registry for use by authorized users of the registry. The Certificate of Installation is assigned a unique registration number and copies of the unique registered Certificate of Installation documents are made available to authorized users of the nonresidential data registry. These are used for making electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required, including posting copies in the field for enforcement agency inspections, and providing copies to the building owner. (See Section 2.3.2 of this chapter.)

Examples of authorized users of the nonresidential data registry may include energy consultants, builders, building owners, construction contractors and installers, enforcement agencies, the Energy Commission, and other parties to the compliance and enforcement process that the documents are designed to support. Authorized users of the nonresidential data registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

Table 2-2: Certificate of Installation Documents

Component	Certificate of Installation Document Identifier
Electrical Power Distribution	NRCI-ELC-01-E
Envelope	NRCI-ENV-01-E
Mechanical	NRCI-MCH-01-E
Lighting Validation of Certificate of Compliance	NRCI-LTI-01-E
EMCS - Lighting Control System	NRCI-LTI-02-E
Line Voltage Track Lighting	NRCI-LTI-03-E
Two Interlocked Lighting Systems	NRCI-LTI-04-E
Power Adjustment Factors	NRCI-LTI-05-H
Additional Videoconference Studio Lighting	NRCI-LTI-06
Outdoor Lighting Validation of Certificate of Compliance	NRCI-LTO-01-E
EMCS - Lighting Controls System	NRCI-LTO-02-E
Sign Lighting	NRCI-LTS-01-E
Refrigerated Warehouse	NRCI-PRC-01-E
Water Heating Validation of Certificate of Compliance	NRCI-PLB-01-E
High Rise Residential/Hotel/Motel Central Hot Water System Distribution	NRCI-PLB-02-E
High Rise Residential/Hotel/Motel Single Dwelling Unit Hot Water System Distribution	NRCI-PLB-03-E
High Rise Multifamily Central Hot Water System Distribution	NRCI-PLB-21-H
High Rise Single Dwelling Unit Hot Water System Distribution	NRCI-PLB-22-H
Solar Photovoltaic	NRCI-SPV-01-E
Solar Water Heating	NRCI-STH-01-E
Refer to Appendix A of this manual for a complete list of the Nonresidential documents.	

2.2.6 Building Commissioning - Certificate of Compliance

Building Commissioning is required for all new nonresidential buildings equal to or greater than 10,000 ft^2. The Certificate(s) of Compliance for Building Commissioning document (see Chapter 12) must be signed by the owner/owner's representative, architect, engineer or designer of record, and the commissioning coordinator, and submitted for approval by the enforcement agency. For buildings that are less than 10,000 ft^2, only the design review sections must be completed. More details regarding the Building Commissioning Certificate(s) of Compliance documents and the requirements are provided in Chapter 12 of this manual.

2.2.7 Acceptance Testing – Certificate(s) of Acceptance

§10-103(a)4; §10-103.1; §10-103.2

2.2.7.1 Acceptance Tests

Acceptance testing or acceptance criteria verification is required for certain lighting, HVAC controls, air distribution ducts, and envelope features, and for equipment that requires proper calibration at the time of initial commissioning to ensure that operating conditions that could lead to premature system failure are prevented, and optimal operational efficiency is realized. The features that require acceptance testing are listed in Table 2-3 on the next page.

2.2.7.2 Acceptance Test Technician Certification Providers (ATTCP) and Certified Technicians

Technicians who conduct acceptance testing for lighting and mechanical systems, when required by the Energy Standards, will need to be trained and certified by an Energy Commission-approved Acceptance Test Technician Certification Provider (ATTCP). The Energy Commission verifies that the ATTCP applicant complies with the requirements of §10-103.1 or §10-103.2 prior to the issuance of a certification. Builders and installers will need to ensure that the technician conducting the required acceptance testing, and completing the required Certificate(s) of Acceptance for lighting and mechanical systems is certified by an approved ATTCP. Enforcement agency field inspectors will need to verify that the submitted Certificate(s) of Acceptance for lighting and mechanical systems are signed by a technician who is certified with an approved ATTCP at final inspection. More details regarding the requirements and certification process for ATTCPs are provided in Chapter 13 of this manual.

2.2.7.3 Registration

Once a data registry has been established, all of the Certificate of Acceptance documents must be registered documents from an approved nonresidential data registry. When registration is required, the builder, installing contractor, or certified technician must submit information to an approved nonresidential data registry in order to produce a completed, dated, and signed electronic Certificate of Acceptance that is retained by the registry for use by authorized users of the registry. The Certificate of Acceptance is assigned a unique registration number, then copies of the unique registered Certificate of Acceptance documents are made available to authorized users of the nonresidential data registry for use in making electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required, including posting copies in the field for enforcement agency inspections, and providing copies to the building owner. (See Section 2.3.2 of this chapter.)

Examples of authorized users of the nonresidential data registry may include energy consultants, builders, building owners, construction contractors and installers, certified technicians, enforcement agencies, the Energy Commission, and other parties to the compliance and enforcement process that the documents are designed to support. Authorized users of the nonresidential data registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

Table 2-3: Measures Requiring Acceptance Testing

Category	Measure
Envelope	
Fenestration Acceptance	Site-Built Fenestration – Label Certificate Verification
Mechanical	
Outdoor Air	Variable Air Volume Systems Outdoor Air Acceptance Constant Volume System Outdoor Air Acceptance
HVAC Systems	Constant- Volume Single Zone, Unitary A/C and Heat Pumps
Air Distribution Systems	Air Distribution Acceptance
Air Economizer Controls	Economizer Acceptance
Demand Control Ventilation (DCV) Systems	Packaged Systems DCV Acceptance
Variable Frequency Drive Systems	Supply Fan Variable Flow Controls
Hydronic System Controls Acceptance	Valve Leakage Test Hydronic Variable Flow Controls Supply Water Temperature Reset Controls
Mechanical Systems	Automatic Demand Shed Control Acceptance Fault Detection & Diagnostics for Packaged DX Units Automatic Fault Detection & Diagnostics for Air Handling & Zone Terminal Units Distributed Energy Storage DX AC Systems Test Thermal Energy Storage (TES) Systems Supply Air Temperature Reset Controls Condenser Water Supply Temperature Reset Controls Energy Management Control System
Indoor Lighting	
Indoor Lighting Control Systems	Automatic Daylighting Controls Acceptance • Occupancy Sensor Acceptance • Manual Daylighting Controls Acceptance • Automatic Time Switch Control Acceptance Demand Responsive Controls
Outdoor Lighting	
Outdoor Lighting Control	Outdoor Lighting Controls • Outdoor Photocontrol • Astronomical Time Switch • Standard (non-astronomical) Time Switch
Covered Processes	
Compress Air Systems	Compressed Air System Acceptance
Commercial Kitchens	Commercial Kitchen Exhaust System Acceptance
Enclosed Parking Garages	Ventilation System Acceptance Testing
Refrigerated Warehouses	Evaporators and Evaporator Fan Motor Variable Speed Controls Condensers and Condenser Fan Motor Variable Speed Controls Air-Cooled Condensers and Condenser Fan Motor Variable Speed Controls Variable Speed Screw Compressors Electric Resistance Underslab Heating Systems
Commercial Refrigeration	Air-Cooled Condensers and Fluid Coolers Evaporative Condensers, Fluid Coolers and Cooling Towers Compressor Floating Suction Controls

	Liquid Subcooling Display Case Lighting Controls Refrigeration Heat Recovery
Elevators	Elevator Lighting & Ventilation Controls
Escalators & Moving Walkways	Escalators & Moving Walkways Speed Control

2.2.7.4 Verification and Documentation

Acceptance testing must be conducted and a Certificate(s) of Acceptance must be completed and submitted before the enforcement agency can issue the Certificate of Occupancy. The procedures for performing the acceptance tests are documented in Reference Nonresidential Appendix NA7. Compliance with the acceptance requirements for a construction/installation project is accomplished by three categories of verification and documentation:

1. Plan review
2. Construction inspection and Certificate(s) of Installation verification
3. Functional testing and completion of the Certificate(s) of Acceptance

2.2.7.5 Plan Review

The installing contractor, engineer/architect of record, or owner's agent is responsible for reviewing the plans and specifications and ensuring they conform to the requirements of the Certificate(s) of Compliance and the acceptance requirements. Plan Review should be done prior to signing a Certificate(s) of Compliance for submittal to plan review, and also prior to completing and signing the Certificate(s) of Installation. The required acceptance tests shall be identified for the applicable building component or system on the respective Certificate(s) of Compliance. Examples of identifying the required acceptance tests on the Certificate(s) of Compliance include:

1. The fenestration acceptance test shall be identified as required for site-built fenestration on the NRCC-ENV-01 document.
2. The air economizer controls acceptance test shall be identified as required for HVAC systems with economizers on the NRCC-MCH-01 document.
3. The lighting controls acceptance test shall be identified as required for occupancy sensors, automatic time switches, etc. on the NRCC-LTI-01 document.
4. The outdoor lighting controls acceptance test shall be identified as required for motion sensors, photocontrols, astronomical time switches, etc. on the NRCC-LTO-01 document.

Since making changes on paper documents may be less costly as compared to the cost of altering or replacing a completed but non-compliant building energy feature construction/installation, attention should be given to plan review early in the process, and also at critical decision points such as during subcontractor bid proposal review and materials procurement activities. If design or material specification for the construction/installation is changed subsequent to plan check, revised building plans and Certificates of Compliance must be submitted for approval to the enforcement agency.

2.2.7.6 Construction Inspection and Certificate(s) of Installation Verification

The installing contractor, engineer/architect of record, or the owner's agent is responsible for performing construction inspection and completing the required Certificate(s) of Installation to confirm compliance of the regulated energy features. The certified technician (see Chapter 12) responsible for performing the acceptance tests is required to confirm that the Certificate(s) of Installation have been properly completed and posted at the building site prior to the issuance of a Certificate(s) of Acceptance.

All regulated components that were incorporated into the completed construction/ installation must be inspected to confirm that they conform to the requirements detailed on the building specifications and the Certificate(s) of Compliance approved by the local enforcement agency. Corrective action must be taken if the installation/construction is not in compliance with the building plans and specifications and Certificate(s) of Compliance approved by the enforcement agency, or if a Certificate of Installation has not been properly completed and posted. Corrective action must be performed prior to proceeding with the acceptance tests and the submittal or posting of the Certificate(s) of Acceptance.

2.2.7.7 Functional Testing and Completion of the Certificate(s) of Acceptance

The installing contractor, engineer/architect of record or the owner's agent is responsible for ensuring that all applicable acceptance requirement procedures identified in the building plans, on the Certificate(s) of Compliance, and in Reference Nonresidential Appendix NA7 are conducted by a certified technician. (See Chapter 12.) All performance deficiencies must be corrected by the builder or installing contractor and the certified technician must repeat the acceptance requirement verification procedures until the construction/installation of the specified systems conform to the required performance criteria and in compliance with the Energy Standards.

The certified technician who conducts the applicable acceptance testing is responsible for documenting their results on the required Certificate(s) of Acceptance document. After completion of the acceptance testing and documents, the certified technician shall provide completed, dated, and signed copies of the Certificate(s) of Acceptance to the builder or installing contractor. When *registration* is applicable, the Certificate(s) of Acceptance must be registered with an approved nonresidential data registry. The builder or installing contractor may facilitate the *registration* process by entering the certified technicians' data results on the Certificate(s) of Acceptance into the nonresidential data registry, but the certified technician responsible for the acceptance test must provide their electronic signature in the registry for the document to be complete and registered.

A copy of the Certificate(s) of Acceptance must be posted or made available to the enforcement agency with the building permit(s) issued for the construction/installation. If construction on any regulated feature or portion of the building will be impossible to inspect because of subsequent construction, the enforcement agency may require the Certificate(s) of Acceptance to be posted upon completion of that portion of the building. A copy of the Certificate(s) of Acceptance must be included with the documentation the builder provides to the building owner at occupancy as specified in §10-103(b).

2.2.7.8 Certificate(s) of Acceptance Documents

Acceptance tests are required to be documented using the applicable acceptance forms. Table 2-4 lists the Certificate of Acceptance documents and provides references to the applicable sections of the Energy Standards and in Reference Nonresidential Appendix NA7. The Certificate(s) of Acceptance documents submitted to the enforcement agency to demonstrate compliance shall conform to a format and informational order and content approved by the Energy Commission (see §10-103(a)1A for more details). Samples of the Energy Commission-approved documents are located in Appendix A of this manual.

Table 2-4: Certificate of Acceptance Documents

Component	Document Name	Energy Standards Reference	Reference Nonresidential Appendix
Envelope	NRCA-ENV-02-F – Fenestration Acceptance	§10-111 & §110.6	NA7.4
Mechanical	NRCA-MCH-02-A – Outdoor Air	§10-103(b)4 & §120.1(b)2 & §120.5(a)1	NA7.5.1.1 NA7.5.1.2
	NRCA-MCH-03-A – Constant Volume Single Zone HVAC	§120.1(b)2 & §120.5(a)2	NA7.5.2
	NRCA-MCH-04-A – Air Distribution Duct Leakage Testing	§120.5(a)3 & §140.4(l)	NA7.5.3 NA2.1
	NRCA-MCH-05-A – Air Economizer Controls	§120.5(a)4 & §140.4(e)	NA7.5.4
	NRCA-MCH-06-A – Demand Control Ventilation (DVC)	§120.1(c)3 & §120.5(a)5	NA7.5.5
	NRCA-MCH-07-A – Supply Fan Variable Flow Controls (VFC)	§120.5(a)6 & §140.4(c)	NA7.5.6
	NRCA-MCH-08-A – Valve Leakage Test	§120.5(a)7 & §140.4(k)6	NA7.5.7
	NRCA-MCH-09-A – Supply Water Temperature Reset Controls	§120.5(a)9 & §144(k)4	NA7.5.8
	NRCA-MCH-10-A – Hydronic System Variable Flow Controls	§120.5(a)7 & §144(k)1	NA7.5.9
	NRCA-MCH-11-A – Automatic Demand Shed Controls	§120.2(h) & §120.5(a)10	NA7.5.10
	NRCA-MCH-12-A – Fault Detection and Diagnostics for DX Units	§120.5(a)11	NA7.5.11
	NRCA-MCH-13-A – Automatic Fault Detection and Diagnostics for Air Handling and Zone Terminal Units	§120.5(a)12	NA7.5.12
	NRCA-MCH-14-A – Distributed Energy Storage DX AC Systems Test	§120.5(a)13	NA7.5.13
	NRCA-MCH-15-A – Thermal Energy Storage (TES) Systems	§120.5(a)14	NA7.5.14
	NRCA-MCH-16-A – Supply Air Temperature Reset Controls	§120.5(a)15	NA7.5.15
	NRCA-MCH-17-A – Condenser Water Temperature Reset Controls	§120.5(a)16	NA7.5.16
	NRCA-MCH-18-A – Energy Management Control System	§120.5(a)17	-----
Indoor Lighting	NRCA-LTI-02-A – Lighting Controls	§110.9(b) & §130.1(c) & §130.4(a)	NA7.6.2
	NRCA-LTI-03-A – Automatic Daylighting	§110.9(b) & §130.1(d) & §130.4(a)	NA7.6.1
	NRCA-LTI-04-A – Demand Responsive Controls	§130.1(e) & §130.4(a)	NA7.6.3

Outdoor Lighting	NRCA-LTO-02-A – Outdoor Motion Sensor and Lighting Shut-off Controls Acceptance	§110.9(b) & §130.2(c) & §130.4(a)	NA7.8
Covered Processes	NRCA-PRC-01-A – Compressed Air Systems	§120.6(e)	NA7.13
	NRCA-PRC-02-A – Parking Garage Exhaust	§120.6(c) & §120.6(c)8	NA7.12
	NRCA-PRC-03-F – Commercial Kitchen Exhaust System Acceptance	§140.9(b)	NA7.11
	NRCA-PRC-04-A – Refrigerated Warehouse Evaporator Fan Motor Controls	§120.6(a)3 & §120.6(a)7B	NA7.10.2
	NRCA-PRC-05-A – Refrigerated Warehouse Evaporative Condenser Controls	§120.6(a)4 & §120.6(a)7C	NA7.10.3.1
	NRCA-PRC-06-A – Refrigerated Warehouse Air-Cooled Condenser Controls	§120.6(a)4 & §120.6(a)7D	NA7.10.3.2
	NRCA-PRC-07-A – Refrigerated Warehouse Variable Speed Compressor	§120.6(a)5 & §120.6(a)7E	NA7.10.4
	NRCA-PRC-08-A – Refrigerated Warehouse Electric Resistance Underslab Heating System	§120.6(a) & §120.6(a)7A	NA7.10.1
	NRCA-PRC-12-F – Elevator Lighting & Ventilation Controls	§120.6(f)	NA7.14
	NRCA-PRC-13-F – Escalators & Moving Walkways Speed Control	§120.6(g)	NA7.15
Refer to Appendix A of this manual for a complete list of Certificate of Acceptance documents.			

2.2.8 HERS Verification – Certificate of Field Verification and Diagnostic Testing

When single-zone, constant volume space-conditioning systems (1) serving less than 5,000 ft² of floor area and (2) have more than 25 percent of the system surface duct area located in unconditioned space, duct sealing is prescriptively required by §140.4(l) for newly constructed buildings and by §141.0(b)2C, D, and E for HVAC alterations. A third-party inspection and diagnostic test of the duct system must be conducted by a certified HERS Rater to verify that the system's air distribution duct leakage is within specifications required by the Energy Standards.

2.2.9 HERS Providers

http://www.cheers.org
http://www.calcerts.com
http://www.cbpca-hers.org

The Energy Commission approves Home Energy Rating System (HERS) providers, subject to the Energy Commission's HERS Regulations (Title 20, Chapter 4, Article 8, Sections 1670 through 1675). Approved HERS providers are authorized to train and certify HERS Raters and are required to maintain quality control over HERS Rater field verification and diagnostic testing activities. In California, the certified HERS providers are:

1. ConSol Home Energy Efficiency Rating Services (CHEERS)
2. California Certified Energy Rating & Testing Services (CalCERTS)
3. U.S. Energy Raters Association (USERA) (formerly CBPCA)

The HERS provider must maintain a HERS provider data registry and database that incorporates an internet website-based user interface that has functionality to accommodate the needs of the authorized users of the data registry who must participate in the administration of HERS compliance, document registration, and Energy Standards enforcement activities.

The HERS provider data registry must receive and record information to identify and track measures that require HERS verification in a specific building/system, and must be capable of determining compliance based on the information from the results of testing or verification procedures input to the registry for the building/system. When the compliance requirements are met, the provider's data registry must make a unique registered Certificate of Field Verification and Diagnostic Testing available to enforcement agencies, builders, building owners, HERS raters, and other interested parties to show compliance with the document submittal requirements of §10-103. The HERS provider data registry must have the capability to facilitate electronic submittal of the registered Certificate(s) of Field Verification and Diagnostic Testing of an Energy Commission document repository for retention of the certificates for use in enforcement of the regulations.

The HERS provider must make available (via phone or internet communications) a way for building officials, builders, HERS raters, and other authorized users of the HERS provider data registry to verify the information displayed on copies of the submitted Certificate of Field Verification and Diagnostic Testing documentation. Refer to Reference Nonresidential Appendix NA1 and Reference Joint Appendix JA7 for additional information on the HERS provider's role and responsibilities.

An approved HERS provider may also be approved as a Registration Provider and facilitate the documentation registration process for nonresidential buildings and projects. Contingent upon approval of a nonresidential data registry by the Energy Commission, all nonresidential compliance documents will need to be registered. This requirement will apply to all Certificate(s) of Compliance, Certificate(s) of Installation, and Certificate(s) of Acceptance. The Registration Provider responsible for registering nonresidential compliance documents does not have to be an approved HERS provider and can be managed by any entity or organization meeting the nonresidential data registry requirements. However, an approved HERS provider may also manage a nonresidential data registry as an approved Registration Provider and register both residential and nonresidential compliance documentation.

2.2.10 HERS Raters

The HERS Rater is certified by an Energy Commission-approved HERS provider to perform the field verification and diagnostic testing that may be required to demonstrate and document compliance with the Energy Standards. HERS Raters receive special training in diagnostic techniques and building science as part of the HERS Rater certification process administered by the HERS provider. Thus, HERS Raters are considered special inspectors by enforcement agencies and shall demonstrate competence, to the satisfaction of the enforcement agency, to conduct the required visual inspections and diagnostic testing of the regulated energy efficiency features installed in the dwelling. HERS Raters should be aware that some enforcement agencies charge a fee for special inspectors to operate within their jurisdictions. Since HERS Raters are deemed to be special inspectors for the enforcement agency, a HERS Rater may be prohibited from performing HERS verifications within a jurisdiction if the agency determines that a HERS Rater willingly or negligently does not comply with the Energy Standards or the HERS Regulations' requirements.

If the documentation author who produced the Certificate of Compliance documentation for the building is not an employee of the builder or subcontractor, the documentation author for the building may also perform the responsibilities of a HERS Rater, provided the documentation author has met the requirements, and has been certified as a HERS Rater by an approved HERS provider.

The HERS Rater is responsible for:

- Conducting the field verification and diagnostic testing of the air distribution ducts.
- Transmitting all required data describing the results to a HERS provider data registry.
- Confirming that the air distribution ducts conform to the design detailed on the building plans and specifications and the mechanical Certificate(s) of Compliance (NRCC-MCH-01-E) approved by the enforcement agency for the building.
- Verifying that the information on the Certificate(s) of Installation and Certificate(s) of Acceptance is consistent with the Certificate(s) of Compliance.

The test results reported on the Certificate of Acceptance (NRCA-MCH-04-A) by the certified technician (see Chapter 12) for the air distribution ducts must be consistent with the test results determined by the HERS Rater's diagnostic verification and meet the criteria for compliance with the Energy Standards. HERS testing shall be conducted in accordance with the HERS procedures in Nonresidential Reference Appendix NA2.

Results from the HERS Rater's field verification and diagnostic testing must be reported to the HERS provider Data registry, including failures. If the results indicate compliance, the HERS provider data registry will make available a registered copy of the Certificate of Field Verification and Diagnostic Testing. A copy must be posted at the building site for review by the enforcement agency, made available for all applicable inspections, and included with the documentation that the builder provides to the building owner at occupancy as specified in §10-103(b).

A listing of Certificate of Field Verification and Diagnostic Testing documents is available in Table 2-5. The Certificate of Field Verification and Diagnostic Testing documents submitted to the enforcement agency to demonstrate compliance shall conform to a format and informational order and content approved by the Energy Commission (See §10-103(a)1A.) Samples of the Energy Commission-approved documents are located in Appendix A.

Table 2-5: Certificate of Verification Documents

Component	Documents Name		Energy Standards Reference	Reference Nonresidential Appendix
Mechanical	NRCV-MCH-04-H	Air Distribution System Leakage Diagnostic	§10-103(a)5; §140.4(l); §141.0(b)2C, D, and E	NA1; NA2
Plumbing	NRCV-PLB-21-H	High Rise Multifamily Central Hot Water System Distribution	§140.5; §150.1(c)8	RA3.6;RA4.4
	NRCV-PLB-22-H	High Rise Single Dwelling Unit Hot Water System Distribution	§140.5; §150.1(c)8	RA3.6;RA4.4

2.2.11 Verification, Testing and Sampling

At the builder’s option, HERS field verification and diagnostic testing shall be completed either for each constant volume, single zone, space conditioning unit in the building or for a sample from a designated group of units. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from the fan pressurization of ducts procedure in Reference Nonresidential Appendix NA2. If the builder chooses the sampling option, the applicable procedures described in NA1.6.1, NA1.6.2,and NA1.6.3 shall be followed.

The builder or subcontractor shall provide a copy of the Certificate(s) of Compliance signed by the principal designer/owner and a copy of the Certificate(s) of Installation to the HERS Rater as required in NA1.4. Prior to completing field verification and diagnostic testing, the HERS rater shall confirm that the Certificate(s) of Installation and Certificate(s) of Acceptance has been completed as required and shows compliance consistent with the Certificate(s) of Compliance.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall transmit the test results to the HERS provider data registry, whereupon the provider makes a copy of the registered Certificate of Field Verification and Diagnostic Testing for the HERS rater, the builder, the enforcement agency, and other authorized users of the data registry. Printed copies, electronic or scanned copies, and photocopies of the completed, signed, and registered Certificate of Field Verification and Diagnostic Testing shall be allowed for document submittals, subject to verification that the information contained on the copy conforms to the registered document information currently on file in the provider data registry for the space conditioning unit.

The HERS Rater shall provide copies of the registered Certificate of Field Verification and Diagnostic Testing to the builder, and post a copy of the Certificate of Verification at the building site for review by the enforcement agency in conjunction with requests for final inspection.

The HERS provider shall make available (via phone or internet communications) a way for enforcement agencies, builders, and HERS raters to verify that the information displayed on copies of the submitted Certificate of Field Verification and Diagnostic Testing documents conform to the registered document information currently on file in the provider data registry for the registered Certificate of Field Verification and Diagnostic Testing.

2.2.12 Initial Model Field Verification and Diagnostic Testing

The HERS Rater shall diagnostically test and field verify the first constant, single zone, space conditioning unit of each building. This initial testing allows the builder to identify and correct any potential duct installation and sealing flaws or practices before other units are installed. If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall transmit the test results to the HERS provider registry, whereupon the provider shall make available a copy of the registered Certificate of Field Verification and Diagnostic Testing to the HERS rater, the builder, and the enforcement agency.

2.2.13 Re-sampling, Full Testing and Corrective Action

“Re-sampling” refers to the procedure that requires testing of additional units within a sample group when the selected sample unit within a group fails to comply with the HERS verification requirements. When a failure is encountered during sample testing, the failure shall be entered into the provider’s data registry. Corrective action shall be taken and the unit shall be retested to verify that corrective action was successful. Corrective action and retesting on the unit shall be repeated until the testing indicates compliance and the results have been entered into the HERS provider data registry. Whereupon, a registered Certificate of Field Verification and Diagnostic Testing for the unit shall be made available to the HERS rater, the builder, the enforcement agency, and other authorized users of the HERS provider data registry.

In addition, the HERS Rater shall conduct re-sampling to assess whether the first failure in the group is unique or if the rest of the units in the group are likely to have similar failings. The HERS rater shall randomly select for re-sampling one of the remaining untested units in the group for testing of the feature that failed. If testing in the re-sample confirms that the requirements for compliance credit are met, then the unit with the failure shall not be considered an indication of failure in the other units in the group. The HERS rater shall transmit the re-sample test results to the HERS provider data registry for each of the remaining units in the group including the dwelling unit that was re-sampled.

If field verification and diagnostic testing in the re-sample results in a second failure, the HERS rater shall enter the second failure into the HERS provider data registry, and report it to the builder and the enforcement agency. All dwelling units in the group must thereafter be individually field verified and diagnostically tested. The builder shall take corrective action in all space conditioning units in the group that have not been tested. In cases where corrective action would require destruction of building components, the builder may choose to reanalyze compliance and choose different measures that will achieve compliance. In this case, a new Certificate(s) of Compliance shall be registered to the HERS provider data registry and a copy shall be submitted to the enforcement agency and HERS rater. The HERS rater shall conduct field verification and diagnostic testing for each of these space conditioning units to verify that problems have been corrected and that the requirements for compliance have been met. Upon verification of compliance, the HERS rater shall enter the test results into the HERS provider data registry. Whereupon, a copy of the Certificate of Field Verification and Diagnostic Testing for each individual unit in the group is made available to the HERS rater, the builder, the enforcement agency, and other authorized users of the HERS provider data registry.

The HERS provider shall file a report with the enforcement agency explaining all action taken (including field verification, diagnostic testing, and corrective action) to bring into compliance units for which full testing has been required. If corrective action requires work not specifically exempted by the California Mechanical Code (CMC) or the California Building Code (CBC), the builder shall obtain a permit from the enforcement agency prior to commencement of any of the work.

2.2.14 Third Party Quality Control Program (TPQCP)

The Energy Commission may approve Third Party Quality Control Programs (TPQCP) that serve some of the functions of HERS Raters for field verification purposes, but do not have the authority to sign compliance documentation as a HERS Rater. Third Party Quality Control Programs do the following:

A. Provide training to installers, participating program installing contractors, installing technicians and specialty TPQCP subcontractors regarding compliance requirements for measures for which diagnostic testing and field verification is required.

B. Collect data from participating installers for each installation completed for compliance credit.

C. Perform data checking analysis of information from diagnostic testing performed on participating TPQCP contractor installation work to evaluate the validity and accuracy of the data and to independently determine whether compliance has been achieved.

D. Provide direction to the installer to retest and correct problems when data checking determines that compliance has not been achieved.

E. Require resubmission of data when retesting and correction is directed.

F. Maintain a database of all data submitted by the participating TPQCP contractor in a format that is acceptable and made available to the Energy Commission upon request.

The HERS provider must arrange for the services of an independent HERS rater to conduct field verification and diagnostic testing of the installation work performed by the participating TPQCP contractor. If group sampling is utilized for HERS verification compliance for jobs completed by a participating TPQCP contractor, the sample from the group that is tested for compliance by the HERS rater may be selected from a group composed of up to 30 units for which the TPQCP contractor has performed the installation work. For alterations, the installation work performed by TPQCP contractors may be approved at the enforcement agency's discretion, based upon a properly completed Certificate(s) of Installation (NRCI-MCH-01) and Certificate(s) of Acceptance (NRCA-MCH-04-A). If subsequent HERS compliance verification procedures determine that re-sampling, full testing or corrective action is necessary for such conditionally-approved dwellings in the group, and then the corrective work must be completed. If the Energy Standards require registration of the compliance documents, the Certificate(s) of Installation and Certificate(s) of Acceptance must be a registered copy from a nonresidential data registry and a HERS provider data registry, respectively.

Refer to Reference Nonresidential Appendix NA1 for additional information about the Third Party Quality Control Program and for additional information about document registration.

2.2.15 For More Information

More details on field verification and diagnostic testing and the HERS provider data registry are provided in the *2016 Reference Nonresidential Appendices* and *2016 Reference Joint Appendices*, as described below:

- Reference Nonresidential Appendix NA1 – Nonresidential HERS Verification, Testing, and Documentation Procedures
- Reference Nonresidential Appendix NA2 – Nonresidential Field Verification and Diagnostic Test Procedures
- Reference Joint Appendix JA7 – Data Registry Requirements

2.3 Final Inspection by the Enforcement Agency and Issuance of the Certificate of Occupancy

§10-103(d)2

Local enforcement agencies or their representatives must inspect all new buildings and systems to ensure conformance with applicable codes and standards. The inspector may require that corrective action be taken to bring the construction/installation into compliance. Thus, the total number of inspection visits and the timing of the inspections that may be required before passing the final inspection may depend on the size and complexity of the building or system.

Enforcement agencies are required to withhold issuance of a final Certificate of Occupancy until all compliance documentation is submitted, certifying that the specified systems and equipment conform to the requirements of the Energy Standards. When *registration* is required, all Certificate(s) of Installation and Certificate(s) of Acceptance must be registered copies from an approved nonresidential data registry. All Certificate(s) of Field Verification and Diagnostic Testing must be registered copies from an approved HERS provider data registry.

2.3.1 Occupancy Permit

The final step in the compliance and enforcement process is when an Occupancy Permit is issued by the enforcement agency. This is the green light for the building to be occupied. Although a developer may lease space prior to the issuance of the occupancy permit, the tenant cannot physically occupy the space until the enforcement agency issues the occupancy permit. The building is not legally habitable until the Occupancy Permit is issued.

2.3.2 Occupancy – Compliance, Operating, and Maintenance Information

§10-103(b)

At the occupancy phase, the general contractor and/or design team is required to provide the owner with copies of the energy compliance documents, including: Certificate(s) of Compliance; Certificate(s) of Installation; Certificate(s) of Acceptance, and Certificate(s) of Field Verification and Diagnostic Testing. Documents for the construction/installation, operating, maintenance, ventilation information, and instruction for operating and maintaining the features of the building efficiently shall also be included.

2.3.3 Compliance Documentation

Compliance documentation includes the documents, reports, and other information that are submitted to the enforcement agency with an application for a building permit (Certificate of Compliance). Compliance documentation also includes documentation completed by the installing contractor, engineer/architect of record, owner’s agent, or certified technician to verify that certain systems and equipment have been correctly installed and commissioned (Certificate(s) of Installation and Certificate(s) of Acceptance). Compliance documentation will also include reports and test/inspection results by third-party HERS raters (Certificate(s) of Field Verification and Diagnostic Testing) when duct sealing/leakage testing is required.

Each portion of the applicable compliance documentation must be completed and/or submitted during:

1. The building permit phase (Certificate of Compliance).
2. The construction phase (Certificate[s] of Installation).
3. The testing and verification phase (Certificate of Field Verification and Diagnostic Testing).
4. The final inspection phase (Certificate[s] of Acceptance).

All submitted compliance documentation is required to be compiled by the builder or general contractor. A copy of the compliance documentation is required to be provided to the building owner so that the end user has information describing the energy features that are installed in the building.

2.4 Construction Documents

Construction documentation consists of the building plans and specifications for construction of the building or installation of the system, and also includes the energy calculations and the energy compliance (Certificate(s) of Compliance) documents necessary to demonstrate that the building complies with the Energy Standards. The plans and specifications, referred to as the construction documents, define the scope of work to be performed by the general contractor and the subcontractors.

2.4.1 Signing Responsibilities

The Certificate(s) of Compliance must be signed by the documentation author and the person responsible for the preparation of the building plans and specifications. The principal designer is also responsible for the energy compliance documentation, even if the actual work of filling out the documents for the energy compliance documentation is delegated to someone else (the Documentation Author). See Section 2.5 for more details regarding the roles and responsibilities of the designers and documentation author.

The Certificate(s) of Compliance is utilized by the building permit applicant, the enforcement agency plans examiner, and the field inspector. This way, the permit application can call the plans examiner's attention to the relevant drawing sheets and other information and the plans examiner can call the field inspector's attention to items that may require special attention in the field. The compliance documents and worksheets encourage communication and coordination within each discipline. The Certificate(s) of Compliance documentation approved by the enforcement agency is required to be consistent with the building plans and specifications approved by the enforcement agency.

The Business and Professions Code specifies the requirements for professional responsibility for design and construction of buildings. Energy code compliance documentation certification require that a person who signs a compliance document shall be a licensed professional who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the applicable design or construction information contained on the submitted compliance document. The Certificate(s) of Compliance must be signed by an individual eligible to accept responsibility for the design. Certificate(s) of Installation and Certificate(s) of Acceptance (Envelope) must be signed by the individual eligible to take responsibility for construction, or their authorized representative. Indoor Lighting, Outdoor Lighting, and Mechanical, Certificate(s) of Acceptance must be signed by a certified technician. (See Chapter 13.)

Applicable sections from the Business and Professions Code (based on the edition in effect as of January 2011), are provided as follows:

2.4.1.1 **5537 Structure exemption:**

(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of wood framed construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of wood frame construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to four dwelling units each to document apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of wood framed construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of wood framed construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety, or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for wood framed construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for wood framed construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible control of, a licensed architect or registered engineer. The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation. Substantial compliance for purposes of this section is not intended to restrict the ability of the building officials to approve plans pursuant to existing law and is only intended to clarify the intent of Chapter 405 of the Statutes of 1985.

5537.2. This chapter shall not be construed as authorizing a licensed contractor to perform design services beyond those described in Section 5537 or in Chapter 9 (commencing with Section 7000), unless those services are performed by or under the direct supervision of a person licensed to practice architecture under this chapter, or a professional or civil engineer licensed pursuant to Chapter 7 (commencing with Section 6700) of Division 3, insofar as the professional or civil engineer practices the profession for which he or she is registered under that chapter.

However, this section does not prohibit a licensed contractor from performing any of the services permitted by Chapter 9 (commencing with Section 7000) of Division 3 within the classification for which the license is issued. Those services may include the preparation of shop and field drawings for work which he or she has contracted or offered to perform, and designing systems and facilities which are necessary to the completion of contracting services which he or she has contracted or offered to perform.

However, a licensed contractor may not use the title "architect," unless he or she holds a license as required in this chapter.

5538. This chapter does not prohibit any person from furnishing either alone or with contractors, if required by Chapter 9 (commencing with Section 7000) of Division 3, labor and materials, with or without plans, drawings, specifications, instruments of service, or other data covering such labor and materials to be used for any of the following:

(a) For nonstructural or nonseismic storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, or other appliances or equipment.

(b) For any nonstructural or nonseismic work necessary to provide for their installation.

(c) For any nonstructural or nonseismic alterations or additions to any building necessary to or attendant upon the installation of those storefronts, interior alterations or additions, fixtures, cabinetwork, furniture, appliances, or equipment, provided those alterations do not change or affect the structural system or safety of the building.

2.4.1.2 **6737.1. Structure exemption**

(a) This chapter does not prohibit any person from preparing plans, drawings, or specifications for any of the following:

(1) Single-family dwellings of wood framed construction not more than two stories and basement in height.

(2) Multiple dwellings containing no more than four dwelling units of wood framed construction not more than two stories and basement in height. However, this paragraph shall not be construed as allowing an unlicensed person to design multiple clusters of up to

four dwelling units each to form apartment or condominium complexes where the total exceeds four units on any lawfully divided lot.

(3) Garages or other structures appurtenant to buildings described under subdivision (a), of wood framed construction not more than two stories and basement in height.

(4) Agricultural and ranch buildings of wood framed construction, unless the building official having jurisdiction deems that an undue risk to the public health, safety or welfare is involved.

(b) If any portion of any structure exempted by this section deviates from substantial compliance with conventional framing requirements for wood framed construction found in the most recent edition of Title 24 of the California Code of Regulations or tables of limitation for wood framed construction, as defined by the applicable building code duly adopted by the local jurisdiction or the state, the building official having jurisdiction shall require the preparation of plans, drawings, specifications, or calculations for that portion by, or under the responsible charge of, a licensed engineer, or by, or under the responsible control of, an architect licensed pursuant to Chapter 3 (commencing with Section 5500). The documents for that portion shall bear the stamp and signature of the licensee who is responsible for their preparation.

2.4.1.3 **6737.3. Exemption of contractors**

A contractor, licensed under Chapter 9 (commencing with Section 7000) of Division 3, is exempt from the provisions of this chapter relating to the practice of electrical or mechanical engineering so long as the services he or she holds himself or herself out as able to perform or does perform, which services are subject to the provisions of this chapter, are performed by, or under the responsible charge of a registered electrical or mechanical engineer insofar as the electrical or mechanical engineer practices the branch of engineering for which he or she is registered.

This section shall not prohibit a licensed contractor, while engaged in the business of contracting for the installation of electrical or mechanical systems or facilities, from designing those systems or facilities in accordance with applicable construction codes and standards for work to be performed and supervised by that contractor within the classification for which his or her license is issued, or from preparing electrical or mechanical shop or field drawings for work which he or she has contracted to perform. Nothing in this section is intended to imply that a licensed contractor may design work which is to be installed by another person.

2.5 Roles and Responsibilities

Effective compliance and enforcement requires coordination and communication between the architects, engineers, lighting and HVAC designers, permit applicant, contractors, plans examiner, and the field inspector.[1] This manual recommends procedures to improve communication and, therefore, compliance with the Energy Standards.

The building design and construction industry, as well as enforcement agencies are organized around engineering disciplines:[2]

[1] For small projects, an architect or engineer may not be involved and the contractor may be the permit applicant.

[2] Small enforcement agencies may not have this type of specialization.

- The design of the building's electrical and lighting system is typically the responsibility of the **lighting designer, electrical engineer, or electrical contractor**. This person is responsible for designing a system that meets the Energy Standards, producing the building plans and specifications, and for completing the compliance documents and worksheets.
- In larger enforcement agencies, an **electrical plans examiner** is responsible for reviewing the electrical plans, specifications, and compliance documents and an electrical field inspector is responsible for verifying the correct installation of the systems in the field.
- The **mechanical plans examiner** is responsible for reviewing the mechanical plans.
- The **mechanical field inspector** is responsible for verifying correct construction in the field.
- For the building envelope, the **architect** is typically responsible for designing the building and completion of the documents.
- The **enforcement agency** is responsible for reviewing the design and documents.
- The **enforcement agency field inspector** is responsible for verifying the construction in the field.

Unless the whole building performance approach is used, the compliance and enforcement process can be completed separately for each discipline. This enables each discipline to complete its work independently of others. To facilitate this process, compliance documents have been grouped by discipline. These groupings include Energy Standards worksheets for calculations and a summary document which includes a checklist.

2.5.1 Designer

5537 and 6737.1 of California Business and Professions Code

The designer is the person responsible for the overall building design. As such, the designer is responsible for specifying the building features that determine compliance with the Energy Standards and other applicable building codes. The designer is required to provide a signature on the respective Certificate(s) of Compliance (see Table 2-1.) to certify that the building has been designed to comply with the Standards.

The designer may be an architect, engineer, or other California-licensed professional and may personally prepare the Certificate(s) of Compliance documents. They may delegate preparation of the energy analysis and Certificate(s) of Compliance documents to an energy documentation author or energy consultant. If preparation of the building energy Certificate of Compliance documentation is delegated, the designer must remain in responsible charge of the building design specifications, energy calculations, and all building feature information represented on the Certificate of Compliance. The designer's signature on the Certificate of Compliance affirms responsibility for the information submitted on the Certificate of Compliance. When the designer is a licensed professional, the signature block on the Certificate(s) of Compliance must include the designer's license number.

When Certificate(s) of Compliance document registration is required, the Certificate(s) of Compliance must be submitted to and registered with an approved nonresidential data registry before submittal to the enforcement agency for approval. All submittals to the nonresidential data registry must be made electronically.

2.5.2 Documentation Author

§10-103(a)1

The person responsible for the design of the building may delegate the energy analysis and preparation of the Certificate(s) of Compliance documentation to a building energy consultant or documentation author. Completed Certificate(s) of Compliance documentation must be submitted to the enforcement agency during the building permit phase. The Certificate(s) of Compliance demonstrates to the enforcement agency plans examiner that the building design complies with the Energy Standards. Moreover, the building energy features information submitted on the Certificate(s) of Compliance must be consistent with the building plans and specifications.

The documentation author is not subject to the same limitations and restrictions of the *Business and Professions Code* as is the building designer because the documentation author is not responsible for specification of the building design features. The documentation author may provide the building designer with recommendations for building energy features that must be incorporated into the building design plans and specification documents submitted to the enforcement agency at plan check. The documentation author's signature on the Certificate(s) of Compliance certifies that the documentation he/she has prepared is accurate and complete, but does not indicate his/her responsibility for the specification of the features that define the building design. The documentation author provides completed Certificate(s) of Compliance documents to the building designer who must sign the Certificate(s) of Compliance prior to submittal of the Certificate(s) of Compliance to the enforcement agency at plan check. If registration of the Certificate of Compliance is required, the Certificate(s) of Compliance must be submitted to an approved nonresidential data registry prior to submittal to the enforcement agency. When document registration is required, only registered Certificates of Compliance that display the registration number assigned to the certificate by a data registry are acceptable for submittal to the enforcement agency at plan check.

For a list of qualified documentation authors, visit the *California Association of Building Energy Consultants (CABEC)* website at: http://www.cabec.org/.

2.5.3 Builder or General Contractor

The term builder refers to the general contractor responsible for construction. During the construction process, the builder or general contractor usually hires specialty subcontractors to provide specific services, such as installing insulation, designing and installing HVAC systems. The builder or general contractor must ensure that the Certificate(s) of Installation is submitted to the enforcement agency by the person(s) responsible for construction/installation of regulated features, materials, components, or manufactured devices. The builder or general contractor may sign the Certificate(s) of Installation (as the responsible person) on behalf of the specialty subcontractors they hire, but generally, Certificate(s) of Installation preparation and signature responsibility resides with the specialty subcontractor who provided the installation services. The Certificate(s) of Installation document identifies the installed features, materials, components, or manufactured devices detailed in the building plans and specifications, and the Certificate(s) of Compliance approved by the local enforcement agency. A copy of the Certificate(s) of Installation is required to be posted at the building site for review by the enforcement agency in conjunction with requests for final inspection.

When the Energy Standards require *registration* of the compliance documents, the builder or general contractor must ensure the transmittal/submittal of the required Certificate(s) of

Installation information to an approved nonresidential data registry. When registration of the Certificate(s) of Installation is required, the completed and signed copies that are posted at the building site for review by the enforcement agency, in conjunction with requests for final inspection, are required to be registered copies.

At final inspection, the builder or general contractor is required to leave in the building all applicable completed and signed compliance documents for the building owner at occupancy. Such information must, at a minimum, include information indicated on the following documents: Certificate(s) of Compliance; Certificate(s) of Installation; Certificate(s) of Acceptance; and Certificates of Field Verification and Diagnostic Testing. These documents may be in paper or electronic format and must conform to the applicable requirements of §10-103(a).

2.5.4 Specialty Subcontractors

Specialty subcontractors provide the builder with services from specific building construction trades for installation of features such as wall and ceiling insulation, windows, HVAC systems and/or duct systems, water heating and plumbing systems, and these subcontractors may perform other trade-specific specialty services during the building construction process. The builder has ultimate responsibility for all aspects of the building's construction and has the authority to complete and sign/certify all sections of the required Certificate(s) of Installation documents. However, the licensed specialty subcontractor should be expected to complete and sign/certify all applicable Certificate(s) of Installation that document the completion of the installation work they have performed for the builder. The subcontractor's responsibility for Certificate(s) of Installation documentation should include providing a signed and registered copy of all applicable Certificate of Installation documents to the builder, and posting a signed and registered copy of all applicable Certificate of Installation documents at the building site for review by the enforcement agency.

When the Energy Standards require document registration, all copies of the Certificate(s) of Installation submitted to the builder and to the enforcement agency are required to be registered copies from an approved nonresidential data registry and prepared in accordance with the procedures described in Reference Joint Appendix JA7.

2.5.5 Enforcement Agency

§10-103

The enforcement agency is the local agency with responsibility and authority to issue building permits and verify compliance with applicable codes and standards. The enforcement agency performs several key roles in the compliance and enforcement process.

A. **Plan check:** The enforcement agency performs plan review of the Certificate(s) of Compliance documentation and the plans and specifications that define the building design. During plan review, the Certificate(s) of Compliance documentation is compared to the plans and specifications for the building design in order to confirm that the building are specified consistently in all of the submitted documents. If the specifications for the building design features shown on the Certificate(s) of Compliance do not conform to the specifications shown on the designer's submitted plans and specifications for the building, revision of the submitted documents must be performed to make the design specification consistent in all documents. Thus, if the features on the Certificate(s) of Compliance are consistent with the features given in the plans and specifications for the building design and indicates that the building complies, then the enforcement agency may issue a building permit.

When the Energy Standards require document *registration*, the Certificate(s) of Compliance documentation that is submitted to plan review must be a registered document from an approved nonresidential data registry.

B. Construction inspection: During the construction of the building, the enforcement agency should make several visits to the construction site to verify that the building is being constructed in accordance with the approved plans and specifications, and energy compliance documentation. As part of this process, at each site visit, the enforcement agency should review any applicable Certificate(s) of Installation that have been posted or made available with the building permit(s). The enforcement agency should confirm that:

- The energy efficiency features installed in the building are consistent with the requirements given in the plans and specifications for the building approved during plan review.
- The installed features are described accurately on the Certificate(s) of Installation.
- All applicable sections of the Certificate(s) of Installation have been signed by the responsible licensed person(s).

The enforcement agency shall not approve a building until they have received all applicable Certificate(s) of Installation.

When the Energy Standards require *registration* of the energy compliance documents, the Certificate(s) of Installation must be registered with an approved nonresidential data registry.

C. Final approval: The enforcement agency may approve the building at the final inspection phase of the process if the enforcement agency field inspector determines that the building conforms to the requirements of the building's plans and specifications, the Certificate(s) of Compliance documents are approved by the enforcement agency at plan review, and it meets the requirements of all other applicable codes and standards. For buildings that have used an energy efficiency compliance feature that requires Certificate(s) of Installation documentation, the enforcement agency shall not approve the building until they have received a Certificate(s) of Installation that meets the requirements of §10-103(a) and has been completed and signed by the builder or subcontractor. The builder must ultimately take responsibility to ensure that all required energy compliance documentation has been completed properly and posted at the job site or submitted to the enforcement agency in conjunction with any of the enforcement agency's required inspections. However, the enforcement agency, in accordance with §10-103(d), as a prerequisite to the approval of the building, must examine all required copies of Certificate(s) of Installation, Certificate(s) of Acceptance, and Certificate(s) of Field Verification and Diagnostic Testing documentation made available with the building permits for the required inspections. They must confirm that these documents have been properly prepared and are consistent with the plans and specifications and the Certificate(s) of Compliance documentation approved by the enforcement agency for the building at plan review.

D. Corroboration of information provided for the owner/occupant: At final inspection, the enforcement agency shall require the builder to leave energy compliance, operating, maintenance, and ventilation information documentation in the building (for the building owner at occupancy) as specified by §10-103(b).

Compliance documents for the building shall, at a minimum, include information indicated on:

- Certificate(s) of Compliance
- Certificate(s) of Installation
- Certificate of Acceptance
- Certificate(s) of Field Verification and Diagnostic Testing

These documents shall be copies of the documentation submitted to or approved by the enforcement agency, and the copies must conform to the applicable requirements of §10-103(a).

Operating information shall include instructions on how to operate or maintain the buildings energy features, materials, components, and mechanical devices correctly and efficiently. Such information shall be contained in a folder or manual which provides all information specified in §10-103(b). This operating information shall be in paper or electronic format. For dwelling units, buildings, or tenant spaces that are not individually owned and operated, or are centrally operated, this information shall be provided to the person(s) responsible for operating the feature, material, component, or mechanical device installed in the building.

Maintenance information shall be provided for all features, materials, components, and manufactured devices that require routine maintenance for efficient operation. Required routine maintenance actions shall be clearly stated and incorporated on a readily accessible label. The label may be limited to identifying, by title and/or publication number, the operation and maintenance manual for that particular model and type of feature, material, component, or manufactured device. For dwelling units, buildings or tenant spaces that are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for maintaining the feature, material, component, or mechanical device installed in the building. This maintenance information shall be in paper or electronic format.

Ventilation information shall include a description of the quantities of outdoor air that the ventilation system(s) are designed to provide to the building's conditioned space, and instructions for proper operation and maintenance of the ventilation system. For buildings or tenant spaces that are not individually owned and operated, or are centrally operated, such information shall be provided to the person(s) responsible for operating and maintaining the feature, material, component, or mechanical ventilation device installed in the building. This information shall be in paper or electronic format.

2.5.6 Permit Applicant

The permit applicant is responsible for:

1. Providing information on the plans and/or specifications to enable the enforcement agency to verify that the building complies with the Energy Standards. It is important to provide all necessary detailed information on the plans and specifications. The plans are the official record of the permit. The design professional is responsible for certifying that the plans and specifications are consistent with the energy features listed on the Certificate(s) of Compliance, and that the design is in compliance with the Standards.
2. Performing the necessary calculations to show that the building or system meets the Energy Standards. These calculations may be documented on the drawing or on the worksheets provided in the manual and supported, when necessary, with data from national rating organizations or product and/or equipment manufacturers.
3. Completing the Certificate(s) of Compliance. The Certificate(s) of Compliance is a listing of each of the major requirements of the Standards. The summary document

includes information from the worksheets and references to the plans where the plans examiner can verify that the building or system meets the Energy Standards.

2.5.7 Plans Examiner

The plans examiner is responsible for:

1. Reviewing the plans and supporting material to verify that they contain the necessary information for a plan review.
2. Checking the calculations and data contained on the worksheets.
3. Indicating by checking a box on the summary documents that the compliance documentation is acceptable.
4. Making notes for the field inspector about which items require special attention.

2.5.8 Field Inspector

The field inspector is responsible for:

1. Verifying that the building or system is constructed according to the plans.
2. Checking off appropriate items on the summary document at each relevant inspection.
3. Verifying that all of the required compliance documentation (Certificate(s) of Installation, Acceptance, and Field Verification and Diagnostic Testing) is completed, dated, signed, and registered (when applicable).

The Certificate(s) of Compliance may be used by the building permit applicant, the plans examiner and the field inspector. This way, the permit application can call the plans examiner's attention to the relevant drawings sheets and other information and the plans examiner can call the field inspector's attention to items that may require special attention in the field. The compliance documents and worksheets encourage communications and coordination within each discipline.

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3. Building Envelope

This chapter describes the requirements for efficiency measures used for the building envelope of nonresidential, high-rise residential, and hotel/motel occupancy buildings. Building energy use is affected by heating and cooling loads. Heating and cooling loads reflect the amount of energy needed, such as HVAC equipment size (capacity), to provide sufficient heating and cooling to meet inside temperature setpoints. The principal elements affecting heating loads are infiltration through the building and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors. Cooling loads, however, are dominated by solar gains through windows and skylights; from internal gains due to lighting, plug loads, and occupant use; and from additional ventilation loads needed for indoor air quality. For example, light entering the building through windows and skylights for daylighting can add to the internal gains incurred by indoor lighting specified for various occupancy uses if both are not properly controlled.

Outside air ventilation and lighting loads are addressed in Chapter 4, Mechanical Systems, and Chapter 5 and 6, Lighting Systems.

The design of the building envelope is usually the responsibility of the architect, but the design team may receive significant input from the contractor, engineer, or other design professionals. The designer is responsible for making sure that the building envelope complies with the Energy Standards. In addition, the building official is responsible for making sure that the building envelope shown on construction documents is designed and built in conformance with the Energy Standards. This chapter is written for the designer and the building official, as well as other specialists who participate in the design and construction of the building envelope.

3.1 Chapter Overview

3.1.1 What's New for 2016

The *2016 Building Energy Efficiency Standards* (Energy Standards) include several important changes to the building envelope component requirements, as described below:

A. Revised the minimum mandatory requirements for insulation (§120.7) that apply to wall and roof/ceiling insulation:

a. Metal building.

b. Demising walls.

c. Placement of insulation in the roof/ceiling to limit heat loss and gain from conditioned to unconditioned spaces.

B. Revised prescriptive requirements of §140.3 that apply to:

a. Metal building roofs, and wood-framed and other roofs.

b. Metal-framed walls and wood-framed walls.

C. Requirements for additions, alterations, and repairs (§141.0) that apply to:

a. Mandatory insulation requirements for alterations.

b. Maximum U-factor and shading requirements for fenestration in alterations.

c. Roof/ceiling insulation tradeoff for aged solar reflectance of roofing being replaced, recovered, or recoated.

d. Window films.

D. Requirements for additions and alterations applying to covered processes, §141.1.

3.1.1.1 **Mandatory Measures**

§120.7

When compliance is being demonstrated with either the prescriptive or performance compliance paths, there are mandatory measures that must always be met. If the prescriptive compliance approach is used, the prescriptive efficiency levels are required; if the performance approach is used, the prescriptive requirements establish the baseline for comparison for the proposed building.

The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance approach requirements. For example, the mandatory measures specify a weighted average U-factor of a metal framed wall insulation to be U-0.151 but, if compliance is being demonstrated with the prescriptive approach for a nonresidential building, Table 140.3-B of the Energy Standards is used to establish the minimum wall thermal compliance level, which in some cases exceeds the mandatory insulation requirements.

3.1.1.2 **Prescriptive Approach**

Energy Standards Table 140.3-B, C, and D

The prescriptive requirements are the simplest way to comply with the building envelope requirements, but offer little flexibility. If each and every prescriptive requirement is met, the building envelope complies with the Energy Standards.

The prescriptive compliance approach consists of specific requirements for each envelope component, in which minimum mandatory levels of insulation must be met. Prescriptive requirements apply to:

- roofs and ceilings
- exterior roofing products
- exterior walls
- demising walls
- floors and soffits
- fenestration products

Envelope requirements vary by climate zone and occupancy type. The prescriptive requirements are located in §140.3 which includes Table 140.3-B for all nonresidential buildings; Table 140.3-C for high-rise residential buildings and hotel/motel buildings; and Table 140.3-D for relocatable public school buildings.

3.1.1.3 **Performance Approach**

§140.1

The performance approach is a more sophisticated compliance method that offers design flexibility. It may be used for:

- Envelope-only compliance
- Envelope and lighting compliance
- Envelope and partial lighting compliance (where some tenant spaces are not yet defined)
- Envelope and mechanical compliance
- Envelope, lighting, and mechanical compliance

The performance approach allows for energy tradeoffs between building features, such as increasing envelope insulation levels or improving window performance to allow more lighting power or a less efficient space-conditioning system. Under this method, energy use of the building is modeled by compliance software approved by the Energy Commission. See Section 3.5 and Chapter 11 for a more complete discussion of the performance approach.

3.1.2 Envelope Definitions and Features

Elements of the building envelope contribute significantly to the energy efficiency of the building and its design intent. Several features are important to note when a method is chosen to demonstrate compliance. Components of the building shell include the walls, floor, the roof or ceiling, doors, and fenestration. Details for fenestration compliance for windows, skylights, and doors are addressed in Section 3.3.

3.1.2.1 **Walls and Space(s) Surrounding Occupancy Uses**

Envelope and other building component definitions are listed in §100.1.

A. Envelope requirements vary by envelope component and are a function of their type of construction and the space conditions on either side of the envelope surface.

B. An **exterior partition** is an envelope component (roof, wall, floor, window, etc.) that separates conditioned space from ambient (outdoor) conditions. A demising partition is an envelope component that separates conditioned space from an enclosed unconditioned space.

C. A **conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1 for full definition.) Indirectly conditioned space is influenced more by directly adjacent conditioned space than it is by ambient (outdoor) conditions. An unconditioned space is an enclosed space within a building that is not directly conditioned or indirectly conditioned.

Example − A plenum space below an insulated roof and above an uninsulated ceiling is an indirectly conditioned space as there is less thermal resistance to the directly conditioned space below than to the ambient air outside. In comparison, an attic below an uninsulated roof having insulation on the attic floor is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below.

D. An **exterior wall** is considered separate from a demising wall or demising partition and has more stringent thermal requirements.

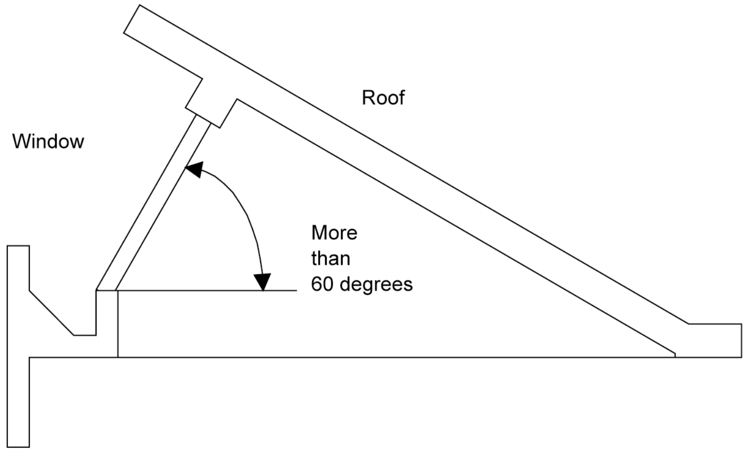
E. **Sloping surfaces** are considered either a wall or a roof, depending on the slope. (See Figure 3-1.) If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.

F. **Floors and roof/ceilings** do not differentiate between demising and exterior. Thus, an exterior roof/ceiling “is an exterior partition, or a demising partition, that has a slope less than 60 degrees from horizontal, that has conditioned space below,” ambient conditions or unconditioned space above, “and that is not an exterior door or skylight.”

G. Similarly an “exterior floor/soffit is a **horizontal exterior partition**, or a horizontal demising partition, under conditioned space” and above an unconditioned space or above ambient (outdoor) conditions.

H. **Windows** are considered part of the wall because the slope is more than 60°. Where the slope is less than 60°, the glazing indicated as a window is considered a skylight.

Figure 3-1: Slope of a Wall or Window (Roof or Skylight Slope Is Less Than 60°)



3.1.2.2 **Roofing Products (Cool Roof)**

Roofing products with a high solar reflectance and thermal emittance are referred to as "cool roofs." This roofing type absorbs less solar heat and gives off more heat to the surroundings than traditional roofing material. The roofs are cooler and reduce air-conditioning loads by reflecting and emitting energy from the sun. Roof radiative properties are rated and listed by the Cool Roof Rating Council (CRRC) (http://www.coolroofs.org/).

Light-colored, high-reflectance surfaces reflect solar energy (visible light, invisible infrared, and ultraviolet radiation) and stay cooler than darker surfaces that absorb more of the sun's energy.

Thermal emittance refers to the ability of heat to escape from a surface once heat energy is absorbed. Both solar reflectance and thermal emittance are measured from 0 to 1; the higher the value, the cooler the roof. There are numerous roofing materials in a range of colors that have relatively good cool roof properties. Surfaces with low emittance (usually shiny metallic surfaces) contribute to the transmission of heat into components under the roof surface. Excess heat can increase the air-conditioning load of a building, resulting in increased energy needed for maintaining occupant comfort. High-emitting roof surfaces reject absorbed heat faster (upward and out of the building) than roof surfaces with low-emitting properties that are usually darker.

The Energy Standards prescribe cool roof radiative properties differently for low-sloped and steep-sloped roofs (§140.3(a)1A). A *low-sloped roof* is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a *steep-sloped roof* is a surface with a pitch greater than 2:12 (9.5 degrees from the horizon). Because heat solar gain is based on the sun's angle of incidence on a surface, low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer, when the sun is high in the sky.

The Energy Standards specify radiative properties that represent minimum "cool roof performance" qualities of roofing products. Performance values are established based on "initial" testing of the roofing product and for the "aged" value, which accounts for the effects of weathering due to climate conditions:

- Solar reflectance: The fraction of solar energy that is reflected by the roof surface.
- Thermal emittance: The fraction of thermal energy that is emitted from the roof surface.

- Solar reflectance index (SRI): The relative surface temperature of a surface with respect to standard white (SRI=100) and standard black (SRI=0) under the standard solar and ambient conditions. This combined metric is a function of both solar reflectance and thermal emittance. The same SRI can be achieved if the roofing product has a higher solar reflectance but a lower thermal emittance. The SRI metric is a prescriptive alternative to reflectance and emittance requirements and is not used with the performance compliance method.

3.1.2.3 **Infiltration and Air Leakage**

Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. Poor construction detailing at interfacing points of different construction materials, particularly in extreme climates, can significantly affect heating and cooling loads. Air leakage can occur through holes and cracks in the building envelope, and around doors and fenestration areas. Ventilation is the *intentional* replacement of conditioned air with unconditioned air through open windows or mechanical ventilation.

Reducing air leakage in the building envelope can result in significant energy savings, especially in climates with more severe winters and summers. It can also result in improved building comfort, reduced moisture intrusion, and fewer air pollutants.

An **air barrier** that inhibits air leakage is critical to good building design and is a prescriptive requirement. (See Section 3.2.1.2.)

3.1.2.4 **Thermal Properties of Opaque Envelope Components**

Typical opaque envelope assemblies are made up of a variety of components, such as wood or metal framing, masonry or concrete, insulation, and various membranes for moisture and/or fire protection, and may have a variety of interior and exterior sheathings even before the final exterior façade is placed. Correctly calculating assembly U-factors is critical to the selection of equipment to meet the heating and cooling loads of the building. Performance compliance software automatically calculates the thermal effects of component layers making up the envelope assembly, but software programs may use different user input hierarchies. The Reference Appendices, Joint Appendix JA4, “U-factor, C-factor, and Thermal Mass Data,” provide detailed thermal data for many wall, roof/ceiling, and floor assemblies. However, this reference cannot cover every possible permutation of materials, thickness, and so forth, that might be used in a building; thus, the Energy Commission has incorporated a program for calculating material properties of typical envelope assemblies that may not be found from the JA4 reference data into the public domain software CBECC-COM.

Key terms of assembly thermal performance are:

A. **Btu** (British thermal unit): The amount of heat required to raise the temperature of 1 pound of water 1°F.

B. **Btuh or Btu/hr** (British thermal unit per hour): The rate of heat flow during an hour. The term is used to rate the output of heating or cooling equipment or the load that equipment must be capable of handling; that is, the capacity needed for satisfactory operation under stated conditions.

C. **R or R-value** (thermal resistance): The ability of a material or combination of materials to retard heat flow. As the resistance increases, the heat flow is reduced. The higher the **“R-value”**, the greater the insulating value. R-value is the reciprocal of the conductance, **“C-value.”**

R-value = hr x ft^2 x ^oF/Btu
R = inches of thickness/k

D. **U or U-factor** (thermal transmittance or coefficient of heat transmission): The rate of heat transfer across an envelope assembly per degree of temperature difference on either side of the envelope component. U-factor is a function of the materials and related thickness. U-factor includes air film resistances on inside and outside surfaces. U-factor applies to heat flow through an assembly or system, whereas "**C**" has the same dimensional units and applies to individual materials. The lower the "**U**" the higher the insulating value.

U-factor = Btu/(hr x ft^2 x ^oF)

E. **k or k-value** (thermal conductivity): The property of a material to conduct heat in the number of Btu that pass through a homogeneous material 1 inch thick and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The lower the "**k"** the greater the insulating value.

k = Btu x in/(hr x ft^2 x °F)

F. **C or C-value** (thermal conductance): The number of Btu that pass through a material of any thickness and 1 square foot in area in an hour with a temperature difference of 1°F between the two surfaces. The time rate of heat flow through unit area of a body induced by a unit temperature difference between the body surfaces. The C-value does not include the air film resistances on each side of the assembly. The term is applied usually to homogeneous materials but may be used with heterogeneous materials such as concrete block. If **"k"** is known, the **"C"** can be determined by dividing **"k"** by inches of thickness. The lower the "C", the greater the insulating value.

C = Btu/(hr. x ft^2 x °F) or C = k/inches of thickness

G. **HC** (heat capacity – thermal mass): The ability to store heat in units of Btu/ft^2 and is a property of specific heat, density, and thickness of a given envelope component. High thermal mass building components, such as tilt-up concrete walls, can store heat and release stored heat later in the day or night. The thermal storage capability of high mass walls, floors, and roof/ceilings can slow heat transfer and shift heating and cooling energy affecting building loads throughout a 24-hour period, depending on the design, location, and occupancy use of a building.

3.2 Opaque Envelope Assembly

This section addresses the requirements for thermal control of the opaque portion of the building shell or envelope.

3.2.1 General Envelope Requirements

This section contains mandatory measures that are not specific to one envelope component.

3.2.1.1 **Mandatory Requirements**

A. Certification of Insulation Materials

§110.8(a), §140.3(a)1B

Manufacturers must certify that insulating materials comply with the *California Quality Standards for Insulating Materials*, which became effective January 1, 1982. It ensures that insulation sold or installed in the state performs according to the stated R-value and meets minimum quality, health, and safety standards.

Builders may not install insulating materials, unless the product has been certified by the Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Materials* to verify certification of the insulating material. If an insulating product is not listed in the most recent edition of the directory, contact the Department of Consumer Affairs, Bureau of Electronic and Appliance Repair, Home Furnishing and Thermal Insulation Program, at (916) 999-2041 or by email: HomeProducts@dca.ca.gov.

Where applicable, the R-value of cavity and/or continuous insulation, or the overall assembly U-factor, may be used to demonstrate compliance with required insulation levels. Reference insulation values are provided in the Reference Appendix JA4, where assembly U-factors are shown for various assemblies and components. U-factors represent the actual thermal conductance of the assembly, including air film coefficients, framing factors, and all layers used to construct the assembly. Assemblies not listed in JA4 tables may calculate U-factors using the assembly calculator in the public domain software, CBECC-COM.

B. Urea Formaldehyde Foam Insulation

§110.8(b)

The mandatory measures restrict the use of urea formaldehyde foam insulation. The restrictions are intended to limit human exposure to formaldehyde, which is a volatile organic chemical known to be harmful to humans.

If foam insulation is used that has urea formaldehyde, it must be installed on the exterior side of the wall (not in the cavity of framed walls), and a continuous barrier must be placed in the wall construction to isolate the insulation from the interior of the space. The barrier must be 4-mil (0.1 mm) thick, polyethylene or equivalent.

C. Flame Spread Rating of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* also require that all exposed installations of faced mineral fiber and mineral aggregate insulations use fire-retardant facings that have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, floor surface, and faced batts on the underside of roofs with an air space between the ceiling and facing are considered exposed applications.

Flame spread ratings and smoke density ratings are shown on the insulation or packaging material or may be obtained from the manufacturer.

D. Infiltration and Air Leakage

§110.7

All joints and other openings in the building envelope that are potential sources of air leakage must be caulked, gasketed, weatherstripped, or otherwise sealed to limit air leakage into or out of the building. This applies to penetrations for pipes and conduits, ducts, vents, and other openings. It means that all gaps between wall panels, around doors, and other construction joints must be well sealed. Ceiling joints, lighting fixtures, plumbing openings, doors, and windows should all be considered as potential sources of unnecessary energy loss due to infiltration.

No special construction requirements are necessary for suspended (T-bar) ceilings, provided they meet the requirements of §110.8(e). Standard construction is typically adequate for meeting the infiltration/exfiltration requirements unless an air barrier is required. (See Section 3.2.1.2.)

E. Mandatory Insulation Requirements (Newly Constructed Buildings)

§120.7

Newly constructed nonresidential and high-rise residential buildings and hotels/motels must meet mandatory insulation requirements for opaque portions of the building that separate conditioned spaces from unconditioned spaces or ambient air. The U-factor for each assembly type shall not exceed the values listed in Table 3-2. Determining the total weight-averaged U-factor is allowed for all assembly types except for light and heavy mass walls. Joint Appendix JA-4 of the Reference Appendices illustrates the allowed procedure for calculating U-factors. The representative constructions that meet these requirements are shown in parentheses. U-factors allow greater flexibility in the design choice of components making up a given assembly that meet the maximum U-factor requirement and design conditions of the envelope.

An exception is specified that exempts buildings designed as data centers with high, constant server loads from the mandatory minimum requirements. To qualify for this exception, it should have a design computer room process load of 750 kW or greater.

3.2.1.2 Prescriptive Requirements

A. Air Barrier

§140.3(a)9

Table 140.3-B of the Energy Standards specifies requirements for air barriers in nonresidential buildings. Air barrier requirements apply to nonresidential buildings, but not relocatable public school buildings, and are effectively mandatory requirements, since they cannot be traded off in the performance approach. These requirements reduce the overall building air leakage rate. The reduction in air leakage can be met with a continuous air barrier that seals all joints and openings in the building envelope and is composed of one of the following:

1. Materials having a maximum air permeance of 0.004 cfm/ft2 (see Table 3-1 below).
2. Assemblies of materials and components having an average air leakage not exceeding 0.04 cfm/ft2.
3. An entire building having an air leakage rate not exceeding 0.40 cfm/ft^2.

The air leakage requirements stipulated in §140.3 must be met, either by demonstrating that component air leakage or whole-building air leakage of 0.4 cfm/ft2 is not exceeded. This requirement must be met regardless of the compliance path chosen, so it is effectively mandatory.

Table 3-1: Materials Deemed to Comply As Air Barrier

	MATERIALS AND THICKNESS		MATERIALS AND THICKNESS
1	Plywood – min. 3/8 inches thickness	9	Built up roofing membrane
2	Oriented strand board – min. 3/8 inches thickness	10	Modified bituminous roof membrane
3	Extruded polystyrene insulation board – min. ½ inches thickness	11	Fully adhered single-ply roof membrane
4	Foil-back polyisocyanurate insulation board – min. ½ inches thickness	12	A Portland cement or Portland sand parge, or a gypsum plaster, each with min. 5/8 inches thickness
5	Closed cell spray foam with a minimum density of 2.0 pcf and a min. 1½ inches thickness	13	Cast-in-place concrete, or precast concrete
6	Open cell spray foam with a density no less than 0.4 pcf and no greater than 1.5 pcf, and a min. 5½ inches thickness	14	Fully grouted concrete block masonry
7	Exterior or interior gypsum board min. 1/2 inches thickness	15	Sheet steel or sheet aluminum
8	Cement board – min. 1/2 inches thickness	_____	________________________

3.2.2 Roofs

3.2.2.1 **Mandatory Measures**

A. Roof/Ceiling Insulation

§120.7(a)

1. Metal Building: Weighted average U-factor of U-0.098 (R-19 screw down roof, no thermal blocks).
2. Wood-Framed and Others: Weighted average U-factor of U-0.075 (2x4 rafter, R-19 insulation).

B. Insulation Placement on Roof/Ceilings

§120.7(a)3

Insulation installed on top of suspended (T-bar) ceilings with removable ceiling panels may not be used to comply with the Energy Standards unless the installation meets the criteria described in the *Exception* to §120.7(a)3 below. Insulation may be installed in this location for other purposes such as for sound control, but it will have no value in terms of meeting roof/ceiling insulation requirements of the Energy Standards.

Acceptable insulation installations include placing the insulation in direct contact with a continuous roof or ceiling that is sealed to limit infiltration and exfiltration as specified in §110.7, including, but not limited to, placing insulation either above or below the roof deck or on top of a drywall ceiling.

When insulation is installed at the roof in nonresidential buildings, the space between the ceiling and the roof is considered to be either directly or indirectly conditioned space. Therefore, this space must not include fixed vents or openings to the outdoors or to unconditioned spaces. This space is not considered an attic for complying with California

Building Code (CBC) attic ventilation requirements. Vents that do not penetrate the roof deck and that are designed for wind resistance for roof membranes are acceptable.

Exception to §120.7(a)3: When there are conditioned spaces with a combined floor area no greater than 2,000 square feet in an otherwise unconditioned building, and when the average height of the space between the ceiling and the roof over these spaces is greater than 12 feet, insulation placed in direct contact with a suspended ceiling with removable ceiling panels shall be an acceptable method of reducing heat loss from a conditioned space and shall be accounted for in heat loss calculations.

C. Wet Insulation Systems

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the roof's waterproof membrane. Water can penetrate this insulation material and affect the energy performance of the roofing assembly in wet and cool climates. In Climate Zones 1 and 16, the insulating R-value of continuous insulation materials installed above the waterproof membrane of the roof must be multiplied by 0.8 before choosing the table column in Reference Appendix JA4 for determining assembly U-factor. See the footnotes in the Reference Appendix JA4 for Tables 4.2.1 through 4.2.7.

D. Roofing Products: Solar Reflectance and Thermal Emittance

§110.8(i)

Roofing products must be tested and labeled by the Cool Roof Rating Council (CRRC), and liquid-applied products must meet minimum standards for performance and durability per §110.8(i)4. Installing cool roofs is **not** a mandatory measure. However, to receive credit for product performance, the reflectance and thermal emittance of a roofing product must be tested and certified according to CRRC procedures. If a CRRC rating is not obtained for roofing products, default values for reflectance and emittance must be used.

1. Rating and Labeling

§10-113

When a cool roof is installed to meet the prescriptive requirement or when it is used for compliance credit, the products must be tested and labeled by the CRRC as specified in §10-113. The CRRC is the supervisory entity responsible for certifying cool roof products. The CRRC test procedure is documented in CRRC-1, the *CRRC Product Rating Program Manual.* This test procedure includes tests for both solar reflectance and thermal emittance. See Figure 3-2 for an example of an approved CRRC product label.

Figure 3-2: Sample CRRC Product Label and Information

CRRC
COOL ROOF RATING COUNCIL ®

	Initial	Weathered
Solar Reflectance	0.00	Pending
Thermal Emittance	0.00	Pending

Rated Product ID Number	_ _ _ _
Licensed Seller ID Number	_ _ _ _
Classification	Production Line

Cool Roof Rating Council ratings are determined for a fixed set of conditions, and may not be appropriate for determining seasonal energy performance. The actual effect of solar reflectance and thermal emittance on building performance may vary.

Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.

2. Solar Reflectance, Thermal Emittance, and Solar Reflectance Index (SRI)

§110.8(i)1,2, and 3

To demonstrate compliance with the Energy Standards, all cool roofing products must be certified and labeled according to CRRC procedures. The CRRC certification includes solar reflectance and thermal emittance. There are three kinds of solar reflectance listed in the CRRC's Rated Product Directory:

1. Initial solar reflectance.
2. 3-year aged solar reflectance.
3. Accelerated aged solar reflectance.

All requirements of the Energy Standards are based on the 3-year aged solar reflectance. However, if the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC initial value or an accelerated testing process. Until the appropriate aged rated value for the reflectance is posted in the directory, the equation below can be used to calculate the aged rated solar reflectance or a new method of testing is used to find the accelerated solar reflectance.

$$\text{Aged Reflectance}_{calculated}=(0.2+ \beta[\rho_{initial} - 0.2])$$

Where,

$\rho_{initial}$ = Initial Reflectance listed in the CRRC Rated Product Directory

β= 0.65 for Field Applied Coating, or 0.70 for Not a Field-Applied Coating

The Energy Standards do not distinguish between initial and aged thermal emittance, meaning that either value can be used to demonstrate compliance with the Energy Standards. If a manufacturer fails to obtain CRRC certificate for its roofing products, the following default aged solar reflectance and thermal emittance values must be used for compliance:

a. For asphalt shingles, 0.08/0.75.
b. For all other roofing products, 0.10/0.75.

The temperature of a surface depends on the solar radiation incident, surface reflectance, and emittance. The SRI measures the relative steady-state surface temperature of a surface with respect to standard white (SRI=100) and standard black

(SRI=0) under the standard solar and ambient condition. A calculator has been produced by Lawrence Berkeley National Laboratory that calculates the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at http://www.energy.ca.gov/title24/2016standards/documents/solar_reflectance/. To calculate the SRI, the 3-year aged value of the roofing product must be used. By using the SRI calculator, a cool roof may prescriptively comply with an emittance lower than 0.85, as long as the aged solar reflectance is higher or a lower aged solar reflectance with a much higher than 0.85 emittance.

3. *Field-Applied Liquid Coatings*

§110.8(i)4, Table 110.8-C

Liquid roof coatings applied to low-sloped roofs in the field as the top surface of a roof covering shall comply with the following mandatory requirements and descriptions. There are several liquid products, including elastomeric coatings and white acrylic coatings that qualify for field-applied liquid coatings. The Energy Standards specify minimum performance and durability requirements for field-applied liquid coatings in Table 110.8-C. These requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail below.

a. *Aluminum-Pigmented Asphalt Roof Coatings*

Aluminum-pigmented coatings are silver-colored coatings that are commonly applied to modified bitumen and other roofing products. The coating has aluminum pigments that float to the surface of the coating and provides a shiny, surface. Because of the shiny surface and the physical properties of aluminum, these coatings have a thermal emittance below 0.75, which is the minimum rating for prescriptive compliance. The performance approach is typically used to achieve compliance with these coatings.

This class of field-applied liquid coatings shall be applied across the entire surface of the roof and meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM D2824[1]. Standard specification is also required for aluminum-pigmented asphalt roof coatings, nonfibered, asbestos-fibered, and fibered without asbestos that are suitable for applying to roofing or masonry surfaces by brush or spray. Use ASTM D6848, Standard Specification for Aluminum Pigmented Emulsified Asphalt used as a Protective Coating for Roofing, installed in accordance with ASTM

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1 A. This specification covers asphalt-based, aluminum roof coatings suitable for application to roofing or masonry surfaces by brush or spray.
B. The values stated in SI units are to be regarded as the standard. The values in parentheses are for information only.
C. The following precautionary caveat pertains only to the test method portion, Section 8, of this specification: This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

D38052, Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

b. Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for a number of years in California's Central Valley and other regions. These coatings may be applied to almost any type of roofing product. Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based coatings shall be manufactured to contain no less than 20 percent Portland cement and meet the requirements of ASTM D8223, ASTM C1583, and ASTM D5870.

c. Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire surface of the roof to meet the dry mil thickness or coverage recommended by the coating manufacturer, taking into consideration the substrate on which the coating will be applied. The field-applied liquid coatings must be tested to meet performance and durability requirements as specified in Table 110.8-C of the Energy Standards or the minimum performance requirements of ASTM C836, D3468, D6083, or D6694, whichever are appropriate to the coating material.

3.2.2.2 **Prescriptive Measures**

A. Insulation Requirements − Exterior Roofs and Ceilings

§140.3(a)1B

Under the prescriptive requirements, roofs or ceilings must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential or high-rise residential buildings. (See Table 3-2.) The U-factor values for exterior roofs and ceilings from Reference Appendix JA4 must be used to determine compliance with the maximum assembly U-factor requirements. Alternatively, the assembly calculator that is incorporated into CBECC-COM, the public domain program, can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

The metal building roof prescriptive requirement has been updated in the 2016 Energy Standards to require a filled cavity insulation technique for improved performance. In the past, a common technique for standing seam metal roofs is to drape a layer of insulation

2 A. This guide covers the application methods for Specification D 2824 Aluminum-Pigmented Asphalt Roof Coatings, Non-Fibered (Type I), Asbestos Fibered (Type II), and Fibered without Asbestos (Type III), for application on asphalt built-up roof membranes, modified bitumen roof membranes, bituminous base flashings, concrete surfaces, metal surfaces, emulsion coatings, and solvent-based coatings. This guide does not apply to the selection of a specific aluminum-pigmented asphalt roof coating type for use on specific projects.
B. The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.
C. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given in Section 4.
3 A. This guide is intended for the evaluation of clear and pigmented coatings designed for use on rigid or semi rigid plastic substrates. Coated film and sheeting are not covered by this guide.
B. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

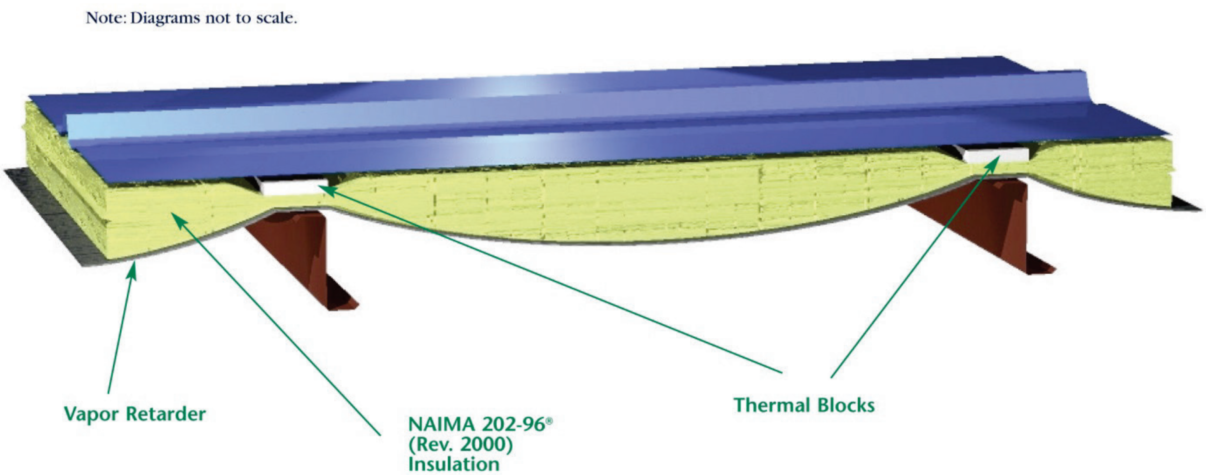
over the purlins, using thermal blocks where the insulation is compressed at the supports. (See Figure 3-3.)

Table 3-2: Roof/Ceiling U-Factor Requirements

Building Type		**Climate Zones**							
		1	2	3	4	5	6	7	8
Nonresidential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.034	0.034	0.034	0.034	0.034	0.049	0.049	0.049
High-Rise Residential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.028	0.028	0.034	0.028	0.034	0.034	0.039	0.028
Relocatable Public School Buildings	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Bldg	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
Building Type		**Climate Zones**							
		9	10	11	12	13	14	15	16
Nonresidential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
High-Rise Residential	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Wood-framing & Other framing type	0.028	0.028	0.028	0.028	0.028	0.028	0.028	0.028
Relocatable Public School Buildings	Metal Bldg	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Bldg	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034

Summary of Tables 140.3-B, 140.3-C, and 140.3-D of the Energy Standards

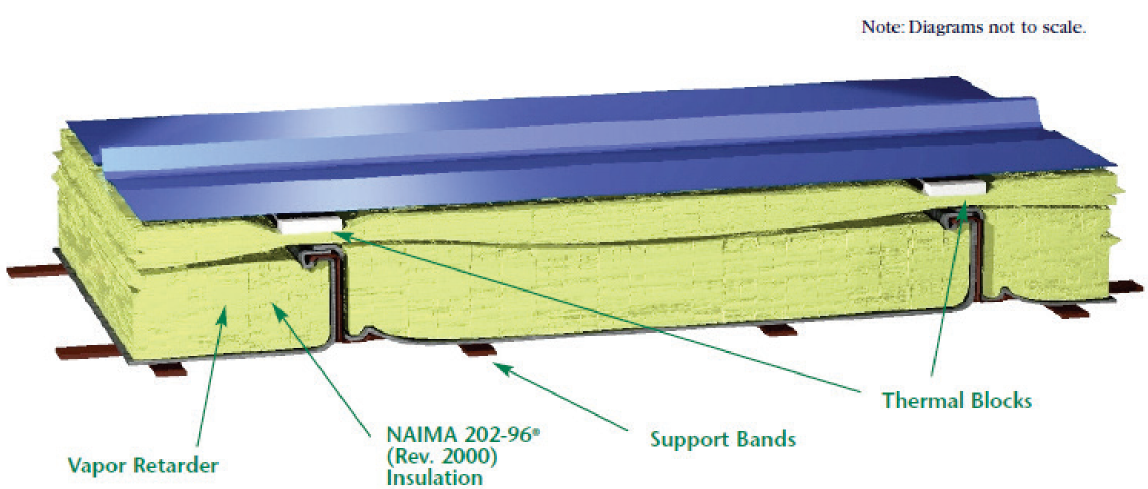
Figure 3-3: Standing Seam Metal Building Roof With Single Insulation Layer



Source: North American Insulation Manufacturers Association (NAIMA)

Recent studies show that the thermal performance of this assembly is not as good as estimated. Therefore, there are significant benefits to using the “filled cavity” approach, shown below.

Figure 3-3A – Filled Cavity Insulation for Metal Building Roofs



Source: North American Insulation Manufacturers Association (NAIMA)

A rigid polyisoyanurate (“polyiso”) thermal block with a minimum R-value of R-3.5 should be installed at the supports (a 1-inch-thick thermal block is recommended). The first rated R-value of the insulation is for faced insulation installed between the purlins. The second rated R-value of insulation represents unfaced insulation installed above the first layer, perpendicular to the purlins and compressed when the metal roof panels are attached. A supporting structure retains the bottom of the first layer at the prescribed depth required for the full thickness of insulation.

The bottom layer of insulation should completely fill the space between the purlins, and the support bands should be installed tightly to prevent the insulation from sagging.

The configuration above, which corresponds to two layers of R-19 and R-10 insulation, corresponds to the prescriptive requirement of U-0.041, but other insulation combinations exceeding the minimum requirement are readily achievable.

B. Thermal Emittance and Solar Reflectance

§140.3(a)1A

The prescriptive requirements call for roofing products to meet the solar reflectance and thermal emittance in both low-sloped and steep-sloped roof applications for nonresidential buildings. A qualifying roofing product under the prescriptive approach for a nonresidential building must have an aged solar reflectance and thermal emittance greater than or equal to that the values indicated in Table 3-3 below. Table 3-4 is for high-rise residential buildings and hotel/motel guest rooms, and Table 3-5 is for relocatable public school buildings where the manufacturer certifies use in all climate zones.

Table 3-3: Prescriptive Criteria for Roofing Products for Nonresidential Buildings

			Climate Zones															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofing Products	Low-sloped	Aged Reflectance	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
	Steep-Sloped	Aged Reflectance	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Energy Standards Table 140.3-B

Table 3-4: Prescriptive Criteria for Roofing Products for High-Rise Residential Buildings and Guest Rooms of Hotel/Motel Buildings (Energy Standards Table 140.3-C)

			Climate Zones															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Roofing Products	Low-sloped	Aged Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	0.55	0.55	0.55	NR	0.55	0.55	0.55	NR
		Emittance	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	NR	0.75	0.75	0.75	NR
		SRI	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
	Steep-Sloped	Aged Reflectance	NR	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	NR
		Emittance	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		SRI	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16

Energy Standards Table 140.3-C

Table 3-5: Prescriptive Criteria for Roofing Products for Relocatable Public School Buildings, Where Manufacturer Certifies Use in All Climate Zones

Roofing Products	**Aged Reflectance**	**Emittance**
Low-Sloped	0.63	0.75
SRI	75	
Steep-Sloped	0.20	0.75
SRI	16	

If the aged value for the solar reflectance is not available in the *CRRC Rated Product Directory*, then the equation in Section 3.2.2.1D (Aged Reflectance$_{calculated}$=(0.2+ β[$\rho_{initial}$ – 0.2])) can be used until the aged rated value for the reflectance is posted in the directory.

There are three exceptions to the minimum prescriptive requirements for solar reflectance and thermal emittance:

1. Roof area covered by building-integrated photovoltaic panels and building-integrated solar thermal panels is not required to meet the cool roof requirements.
2. If the roof construction has a thermal mass like gravel, concrete pavers, stone, or other materials with a weight of at least 25 lb/ft² over the roof membrane, then it is exempt from the above requirements for solar reflectance and thermal emittance.
3. Wood-framed roofs in climate zones 3 and 5 with a U- factor of 0.034 are exempt from the low-sloped cool roof requirement.

Where a low-sloped nonresidential roof's aged reflectance is less than the prescribed requirement, insulation tradeoffs are available. By increasing the insulation level of a roof, a roofing product with a lower reflectance than the prescriptive requirements can be used to meet the cool roof requirements. The appropriate U-factor can be determined from Table 3-6 for nonresidential buildings based on roof type, climate zone and aged reflectance of at least 0.25.

Table 3-6: Roof/Ceiling Insulation Tradeoff for Aged Solar Reflectance

Aged Solar Reflectance	Metal Building Climate Zone 1-16 U-factor	Wood-Framed and Other Climate Zone 6 & 7 U-factor	Wood Framed and Other All Other Climate Zones U-factor
0.62-0.56	0.038	0.045	0.032
0.55-0.46	0.035	0.042	0.030
0.45-0.36	0.033	0.039	0.029
0.35 -0.25	0.031	0.037	0.028

Energy Standards Table 140.3

3.2.2.3 **Performance Approach – Compliance Options**

The compliance options process allows the Energy Commission to review and gather public input regarding the merits of new compliance techniques, products, materials, designs, or procedures to demonstrate compliance for newly constructed buildings and additions and alterations to existing buildings.

A. Aggregate Default Roof Reflectance Properties

Some low-sloped roofs of nonresidential buildings use aggregate material made of gravel or crushed stone that is 3/4" or smaller, as the surface layer under a ballasted roof. Such roofing cannot be accurately tested via CRRC procedures because some of the aggregate can become damaged in transit, affecting the performance.

The Energy Commission has stipulated aged reflectance and emittance values that can be used for these types of products that have been tested via ASTM procedures. The default reflectance and emittance values may be used below in the performance compliance approach or prescriptive tradeoff with increased insulation (Table 140.3 of the Energy Standards).

Table 3-7: Default Solar Reflectance on Thermal Emittance for Aggregate Materials Based on Size

Aggregate Size	Required Tested Initial Solar Reflectance	Default Aged Solar Reflectance	Default Thermal Emittance
Built - Up Roofs Size 6 - 8 conforming to ASTM D448 and ASTM D1863	0.50	0.48	0.85
Ballasted Roofs Size 2 - 4 conforming to ASTM D448	0.45	0.40	0.85

For example, aggregate with size 2-4 meeting the requirements must have a tested solar reflectance of at least 0.45 to use a default aged reflectance value of 0.40 in the performance method.

Eligibility criteria for aggregate used as the surface layer of low-sloped roofs:

1. Aggregate shall have a tested initial solar reflectance that meets or exceeds 0.50 for built-up roofs and 0.45 for ballasted roofs using the ASTM E1918 test procedure conducted by an independent laboratory meeting the requirement of §10-113(d)4
2. Aggregate shall have a label on bags or containers of the aggregate material stating

(a) the tested initial solar reflectance of the material conforming to ASTM D1863, and
(b) the size of the material conforming to ASTM D448.

Example 3-1

Question:

According to the provisions of the Energy Standards, are cool roofs optional for nonresidential buildings or high-rise residential buildings?

Answer:

The answer depends on the compliance approach you chose. For prescriptive compliance, compliance with solar reflectance and thermal emittance, or SRI is required where indicated in Energy Standards Tables 140.3-B, C, and D. In the performance approach, reflectance, and emittance values less than the minimum prescriptive requirements may be used; however, any deficit that results from this choice must be made up by improving other energy efficiency features in the building, which include envelope, space-conditioning system, and lighting systems.

Example 3-2

Question:

Must all roofing materials used in California, whether cool roof or not, be certified by the CRRC and labeled accordingly?

Answer:

No, but it does depend on the compliance approach you are using. A roof repair, such as for a leak, does not require the roofing product to be cool roof and/or certified by the CRRC.

If you are altering your roof, such as a new reroof, then either the prescriptive envelope component approach or the performance approach can be used for compliance.

In these compliance cases, the answer is yes, the roof must be certified and labeled by CRRC for nonresidential roofs. If you are using the performance approach to receive compliance credit, you can either obtain a CRRC certification, **or** use a default solar reflectance of 0.10 and thermal emittance of 0.75. Using default values instead of CRRC certificates may result in a significant energy penalty that must be made up by increasing energy efficiency in other building features. The default reflectance for asphalt roofs is different than tile and metal roofing products.

Example 3-3

Question:

Can I use solar reflectance and thermal emittance data generated by any nationally recognized and well-respected laboratory in lieu of CRRC ratings? Can in-house testing by the manufacturer be used to qualify my product?

Answer:

No. Only CRRC ratings from the product directory list can be used to establish cool roof product qualification for standards compliance. The CRRC process requires use of a CRRC-accredited laboratory (under most circumstances, an "Accredited Independent Testing Laboratory (AITL) defined by the CRRC program.) Any testing laboratory can become an AITL by following the CRRC accreditation process and satisfying the requirements. The roster of CRRC-accredited laboratories is posted on the CRRC website (http://www.coolroofs.org).

Example 3-4

Question:

Can the reflectance and emittance requirements of ENERGY STAR® cool roofs be substituted for standards requirements?

Answer

No. Only roofing products which are listed by the CRRC in its Rated Product Directory can be used to the standards. CRRC is the only organization that has met the criteria set in §10-113.

Example 3-5

Question:

Can I claim to have a cool roof, or can I get anything higher than a default reflectance, if my roof does not meet the field-applied coating performance requirements of the Energy Standards?

Answer:

No, you cannot claim to have a cool roof and you cannot claim higher energy credits if your roof does not meet the coating performance requirements of the Energy Standards for field-applied coatings.

Example 3-6

Question:

How does a product get CRRC cool roof certification?

Answer:

Any party wishing to have a product or products certified by CRRC should contact the CRRC toll-free (866) 465-2523 from inside the United States or (510) 482-4420, ext. 215, or email info@coolroofs.org. In addition, CRRC publishes the procedures in the *CRRC-1 Program Manual*, available for free on http://www.coolroofs.org or by calling the CRRC. However, working with CRRC staff is strongly recommended.

Example 3-7

Question:

Do alterations to the roof of an unconditioned building trigger cool roof requirements?

Answer:

No, alterations to the roof of an unconditioned building do not trigger cool roof requirements. In general, the lighting requirements are the only requirements applicable for both newly constructed and altered unconditioned buildings; this includes §140.3(c), the skylight requirements. Building envelope (other than skylight requirements) and space-conditioning requirements do not apply to unconditioned buildings.

Example 3-8

Question:

What happens if I have a low-sloped roof on most of my buildings and steep-sloped roof on another portion of the roof? Do I have to meet the two different sets of rules in §140.3(a)1Ai and ii?

Answer:

Yes, your building would have to meet both the low-sloped requirement and the steep-sloped roof requirements for the respective area.

Example 3-9

Question:

I am installing a garden roof (roofs whose surface is composed of soil and plants) on top of an office building. Although garden roofs are not cool roofs by their reflectance properties, will they be allowed under the Energy Standards?

Answer:

Yes, the Energy Commission considers a garden roof as a roof with thermal mass on it.

Under *Exception* 4 to §140.3(a)1Ai, if a garden roof has a dry unit weight of 25 lb/ft², then the garden roof is equivalent to cool roof.

3.2.3 Exterior Walls

3.2.3.1 **Mandatory Requirements**

A. Wall Insulation

§120.7(b)

1. Metal Building: Weighted average U-factor of U-0.113 (single layer of R-13 batt insulation).
2. Metal-Framed: Weighted average U-factor of U-0.151 (R-8 continuous insulation, or R-13 batt insulation between studs and 1/2" of continuous rigid insulation of R-2). It may be possible to meet the area-weighted average U-factor without continuous insulation, if the appropriate siding materials are used.
3. Light Mass Walls: 6 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.440 (partially grouted with insulated cells).
4. Heavy Mass Walls: 8 inches or greater hollow core concrete masonry unit having a U-factor not exceeding 0.690 (solid grout concrete, normal weight, 125 lb/ft3).
5. Wood-Framed and Others: Weighted average U-factor of U-0.110 (R-11 batt insulation).
6. Glass Spandrel Panels and Glass Curtain Wall: Weighted average U-factor of U-0.280.

   Exception: Buildings designed as data centers with high, constant server loads from the mandatory minimum requirements are exempt. To qualify for this exception, it should have a design computer room process load of 750 kW or greater.

3.2.3.2 **Prescriptive Requirements**

§140.3(a)2

Under the prescriptive requirements, exterior walls must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential and high-rise residential buildings in Table 3-8.

The U-factor for exterior walls from Reference Appendix JA4 must be used to determine compliance with the assembly U-factor requirements. The Energy Standards no longer allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of Reference Appendix JA4; only U-factors may be used to demonstrate compliance.

For metal-framed walls with insulation between the framing sections, continuous insulation may need to be added to meet the U-factor requirements of the Energy Standards. For light mass walls, insulation is not required for buildings in South Coast climates but is required for other climates. For heavy mass walls, insulation is not required for buildings in Central Coast or South Coast climates but is required for other climates.

Table 3-8: Wall U-Factor Requirements

Building Type		1	2	3	4	5	6	7	8
Nonresidential	Metal Bldg	0.113	0.061	0.113	0.061	0.061	0.113	0.113	0.061
	Metal- Frame	0.069	0.062	0.082	0.062	0.062	0.069	0.069	0.062
	Mass Light	0.196	0.170	0.278	0.227	0.44	0.44	0.44	0.44
	Mass Heavy	0.253	0.650	0.650	0.650	0.650	0.690	0.690	0.690
	Wood-Frame	0.095	0.059	0.110	0.059	0.102	0.110	0.110	0.102
Residential High-Rise	Metal bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.061	0.061
	Metal-frame	0.069	0.069	0.069	0.069	0.069	0.069	0.105	0.069
	Mass Light	0.170	0.170	0.170	0.170	0.170	0.227	0.227	0.227
	Mass Heavy	0.160	0.160	0.160	0.184	0.211	0.690	0.690	0.690
	Wood-Frame	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
Relocatable Public Schools	Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Metal - Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
	All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

Building Type		9	10	11	12	13	14	15	16
Nonresidential	Metal Bldg	0.061	0.061	0.061	0.061	0.061	0.061	0.057	0.061
	Metal-Frame	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062
	Mass Light	0.44	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.650	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Frame	0.059	0.059	0.045	0.059	0.059	0.059	0.042	0.059
Residential High-Rise	Metal Bldg	0.061	0.061	0.057	0.057	0.057	0.057	0.057	0.057
	Metal-Frame	0.069	0.069	0.069	0.069	0.069	0.069	0.048	0.069
	Mass Light	0.196	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Mass Heavy	0.690	0.690	0.184	0.253	0.211	0.184	0.184	0.160
	Wood-Frame	0.059	0.059	0.042	0.059	0.059	0.042	0.042	0.042
Relocatable Public Schools	Metal Building	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Metal - Frame	0.057	0.057	0.057	0.057	0.057	0.057	0.057	0.057
	Mass /7.0<HC	0.170	0.170	0.170	0.170	0.170	0.170	0.170	0.170
	Wood Frame	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
	All Other Walls	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Appendix JA4. Alternatively, the assembly calculator that is incorporated into CBECC-COM can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

There are five classes of wall constructions: wood-framed, metal-framed, metal building walls, light mass, and heavy mass. The following provides additional information about each type of wall system:

1. **Wood-framed walls:** As defined by the 2013 California Building Code, Type IV buildings typically have wood-framed walls. Framing members typically consist of 2x4 or 2x6 framing members spaced at 24 inch or 16 inch OC. Composite framing members and engineered wood products also qualify as wood framed walls if the framing members are nonmetallic. Structurally insulated panels (SIPs) are another construction type that qualifies as wood-framed. SIPs panels typically consist of rigid foam insulation sandwiched between two layers of oriented strand board (OSB). Reference Appendix JA4, Table 4.3.1 has data for conventional wood-framed walls, and Table 4.3.2 has data for SIPs panels.
2. **Metal-framed walls:** Many nonresidential buildings and high-rise residential buildings require noncombustible construction, and this is achieved with metal-framed walls. Often metal-framed walls are not structural and are used as infill panels in rigid framed steel or concrete buildings. Batt insulation is less effective for metal-framed walls (compared to wood-framed walls) because the metal framing members are more conductive. In most cases, continuous insulation is required to meet prescriptive U-factor requirements. Reference Appendix JA4, Table 4.3.3, has data for metal-framed walls.

   For 2016, the continuous insulation requirements for steel-framed walls have increased for climate zones 1, 6, and 7. Two inches of rigid polyisocyanurate insulation (with no cavity insulation) will meet the new requirement.
3. **Metal building walls:** Metal building walls consist of a metal building skin that is directly attached to metal framing members. The framing members are typically positioned in a horizontal direction and spaced at about 4 ft. A typical method of insulating metal building walls is to drape the insulation over the horizontal framing members and to compress the insulation when the metal exterior panel is installed.
4. **Light-mass walls:** Light-mass walls have a heat capacity (HC) greater or equal to 7.0 but less than 15.0 Btu/°F-ft². See the definition below for heat capacity. From Reference Appendix JA4, Tables 4.3.5 and 4.3.6 have U-factor, C-factor, and heat capacity data for hollow unit masonry walls, solid unit masonry and concrete walls, and concrete sandwich panels.
5. **Heavy-mass walls:** Have an HC equal to or greater than 15.0 Btu/°F-ft². See Reference Appendix JA4 for HC data on mass walls.

   Note: For light- and high-mass walls, ***heat capacity (HC)*** *is the amount of heat required to raise the temperature of the material by 1 degree F. In the Energy Standards, it is defined as the product of the density (lb/ft3), specific heat (Btu/lb-F), and wall thickness (ft). For instance, a 6" medium weight concrete hollow unit masonry wall has a heat capacity of 11.4 and is considered a light mass wall. The same masonry wall with solid grout that is 10 inches thick has a heat capacity of 19.7 and is considered a heavy mass wall.*

6. **Furred walls:** Are a specialty wall component, commonly applied to a mass wall type. See Figure 3-4 below. The Reference Appendix JA4 Table 4.3.5, 4.3.6, or other masonry tables list alternative walls. Additional continuous insulation layers are selected from Reference Appendix JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from the JA4. The effective R-value of the furred component depends upon the framing thickness, type, and insulation level.

Figure 3-4: Brick Wall With Furring Details

7. **Spandrel panels** and **glass curtain walls:** These wall types consist of metalized or glass panels often hung outside structural framing to create exterior wall elements around fenestration and between floors. See Reference Appendix JA4, Table 4.3.8 for U-factor data.

8. **Continuous insulation:** For some climate zones, mass walls and metal-framed walls require continuous insulation to meet the prescriptive U-factor requirements. When this is the case, the effect of the continuous insulation is estimated by Equation 4-1 in Reference Appendix JA4.

$$U_{prop} = 1 / [(1/U_{col,A}) + R_{cont,insul}]$$

Example 3-10

Question :

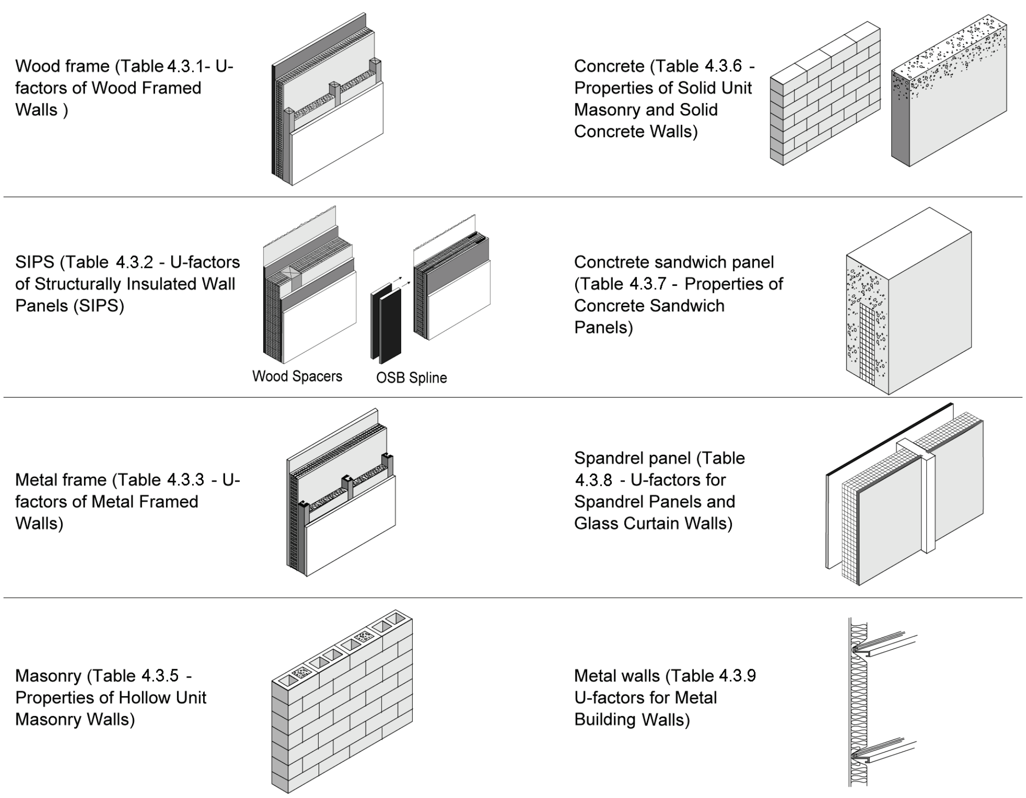
An 8-inch (20 cm) medium-weight concrete block wall with uninsulated cores has a layer of 1 inch (25 mm) thick exterior polystyrene continuous insulation with an R-value of R-5. What is the U-factor for this assembly?

Answer:

From Reference Appendix Table 4.3.5, the U-factor for the block wall is 0.53. From Equation 4-1, the U-factor is calculated as:

U= 1 / [(1/0.53) + 5] = 0.145

Figure 3-5: Classes of Wall Construction



Source: Reference Appendices JA4.3

Framed or block walls can also have insulation installed between interior or exterior furring strips. The effective continuous R-value of the furring/insulation layer is shown in Table 4.3.13 of Reference Appendix JA4.

3.2.4 Demising Walls

3.2.4.1 **Mandatory Insulation for Demising Walls**

§120.7(b)7, §140.3(a)3 and Exception to §140.3(a)5A

Demising walls separate conditioned space from enclosed unconditioned space. The insulation requirements include:

- Wood-framed: minimum of R-13 insulation (or have an equivalent U-factor of 0.099) between framing members.
- Metal-framed: minimum R-13 insulation (or a U-factor no greater than 0.151) between framing members plus R-2 continuous insulation.
- If it is not a framed assembly (constructed of brick, concrete masonry units, or solid concrete), then no insulation is required.

This requirement applies to buildings meeting compliance with either the prescriptive or performance approach.

3.2.5 Doors

3.2.5.1 **Mandatory Requirements**

§110.6(a)1

Manufactured exterior doors shall have an air infiltration rate not exceeding:

- 0.3 cfm/ft2 of door area for nonresidential single doors (swinging and sliding).
- 1.0 cfm/ft2 of door area for nonresidential double doors (swinging).

3.2.5.2 **Prescriptive Requirements**

§140.3(a)7

The Energy Standards define prescriptive requirements for exterior doors in Tables 140.3-B and 140.3-C. For swinging doors, the maximum U-factor is 0.70, and for nonswinging doors, the maximum allowed U-factor is 1.45 in Climate Zones 2 through 15 and 0.50 in Climate Zones 1 and 16. (See Table 3-9)

The swinging door requirement corresponds to uninsulated double-layer metal swinging doors. The 1.45 swinging door U-factor requirement corresponds to insulated single-layer metal doors or uninsulated single-layer metal roll-up doors and fire-rated doors. The 0.50 U-factor requirement for Climate Zones 1 and 16 corresponds to wood doors with a minimum nominal thickness of 1 ¾ inches. For more information, consult Reference Appendix JA4, Table 4.5.1.

When glazing area exceeds one-half of the entire door area, it is then defined as a fenestration product in the Energy Standards, and the entire door area is modeled as a fenestration unit. (See Section 3.3.2.) If the glazing area is less than half the door area, the glazing must be modeled as the glass area plus 2 inches in each direction of the opaque door surface (to account for a frame). However, exterior doors are part of the gross exterior wall area and must be considered when calculating the window-wall-ratio.

Table 3-9: Door Requirements Summary

Building Type	Door Type	Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
High-Rise Residential	Non-Swinging	0.50	1.45	1.45	1.45	1.45	1.45	1.45	1.45
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Relocatable Public Schools	Non-Swinging	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Building Type	**Door Type**	**Climate Zones**							
		9	10	11	12	13	14	15	16
Nonresidential	Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
High-Rise Residential	Non-Swinging	1.45	1.45	1.45	1.45	1.45	1.45	1.45	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Relocatable Public Schools	Non-Swinging	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
	Swinging	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70

Energy Standards Table 140.3-B, 140.3-C, and 140.3-D

3.2.6 Floors

3.2.6.1 Mandatory Requirements

A. Insulation Requirements for Heated Slab Floors

§110.8(g)

Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A of the Energy Standards (Table 3-10). The top of the insulation must be protected with a rigid shield to prevent intrusion of insects into the building foundation, and the insulation must be capable of withstanding water intrusion.

A common location for the slab insulation is on the foundation perimeter. Insulation that extends downward to the top of the footing is acceptable. Otherwise, the insulation must extend downward from the level of the top of the slab, down 16 inches (40 cm) or to the frost line, whichever is greater.

For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.

Another option is to install the insulation inside the foundation wall and between the heated slab. In this case insulation must extend downward to the top of the footing and then extend horizontally inward, under the slab, a distance of 4 ft toward the center of the slab. R-5 vertical insulation is required in all climates except Climate Zone 16, which requires R-10 of vertical insulation and R-7 horizontal insulation.

Figure 3-6: Perimeter Slab Insulation

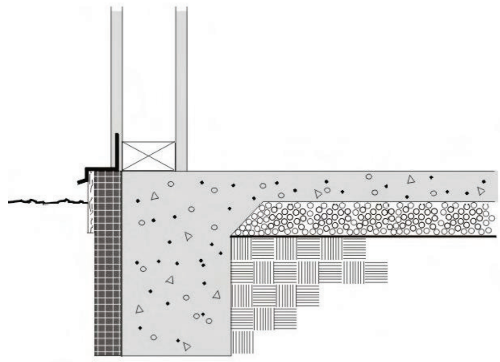


Table 3-10: Slab Insulation Requirements for Heated Slab Floors

Insulation Location	Insulation Orientation	Installation Requirements	Climate Zone	Insulation R-Value
Outside edge of heated slab, either inside or outside the foundation wall	Vertical	From the level of the top of the slab, down 16 inches or to the frost line, whichever is greater. Insulation may stop at the top of the footing where this is less than the required depth. For below-grade slabs, vertical insulation shall be extended from the top of the foundation wall to the bottom of the foundation (or the top of the footing) or to the frost line, whichever is greater.	1 – 15	5
			16	10
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from top of slab at inside edge of outside wall down to the top of the horizontal insulation. Horizontal insulation from the outside edge of the vertical insulation extending 4 feet toward the center of the slab in a direction normal to the outside of the building in plain view.	1 – 15	5
			16	10 vertical and 7 horizontal

Energy Standards Table 110.8-A

B. Floor and Soffit Insulation

§120.7(c)

1. Raised Mass Floors: A minimum of 3 inches of lightweight concrete over a metal deck or the weighted average U-factor of the floor assembly shall not exceed U-0.269.
2. Other Floors: Weighted average U-factor of U-0.071.
3. Heated Slab Floor: A heated slab floor shall be insulated to meet the requirements of §110.8(g). See Section 3.2.6.1A above for more information.

3.2.6.2 **Prescriptive Requirements**

A. Exterior Floors and Soffits

§140.3(a)4

Under the prescriptive requirements, exterior floors and insulated soffits must have an assembly U-factor equal to or lower than the U-factor criterion for nonresidential, high-rise residential buildings and relocatable public school buildings in Table 3-11below. The U-factor for exterior floors and soffits from Reference Appendix JA4 shall be used to determine compliance with the maximum assembly U-factor requirements. The Energy Standards no longer allow using the R-value of the cavity or continuous insulation to demonstrate compliance with the insulation values of the Reference Appendix JA4; only U-factors may be used to demonstrate compliance. For metal-framed floors, batt insulation between framing section may need continuous insulation to be modeled and installed on the interior or exterior to meet the U-factor requirements of the Energy Standards.

Table 3-11: Floor/Soffit U-Factor Requirements

Building Type	**Floor Type**	**Climate Zones**							
		1	2	3	4	5	6	7	8
Nonresidential	Mass	0.092	0.092	0.269	0.269	0.269	0.269	0.269	0.269
	Other	0.048	0.039	0.071	0.071	0.071	0.071	0.071	0.071
High-Rise Residential	Mass	0.045	0.045	0.058	0.058	0.058	0.069	0.092	0.092
	Other	0.034	0.034	0.039	0.039	0.039	0.039	0.071	0.039
Relocatable Public Schools	All	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Building Type	**Floor Type**	**Climate Zones**							
		9	10	11	12	13	14	15	16
Nonresidential	Mass	0.269	0.269	0.092	0.092	0.092	0.092	0.092	0.058
	Other	0.071	0.071	0.039	0.071	0.071	0.039	0.039	0.039
High-Rise Residential	Mass	0.092	0.069	0.058	0.058	0.058	0.045	0.058	0.037
	Other	0.039	0.039	0.039	0.039	0.039	0.034	0.039	0.034
Relocatable Public Schools	All	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48

Summary from Energy Standards Tables 140.3-B, 140.3-C, and 140.3-D

The U-factor criteria for concrete raised floors depend on whether the floor is a mass floor or not. A mass floor is one constructed of concrete with a heat capacity (HC) greater than or equal to 7.0 Btu/°F-ft².

Insulation levels for nonresidential concrete raised floors with HC ≥ 7.0 using U-factor for compliance, from Reference Appendix JA4, Table 4.4.6, are equivalent to no insulation in Climate Zones 3-10 and associated U-factors to continuous insulation of R-8 in Climate Zones 1, 2, 11 through 15; and R-15 in Climate Zone 16.

To determine the U-factor insulation levels for high-rise residential concrete raised floors, use the U-factors that are associated with R-8 continuous insulation in Climate Zones 7 through 9; R-15 in Climate Zones 3-5 and 11-13; with additional insulation required in the desert and mountain Climate Zones 1, 2, 14 and 16.

Table 4.4.6 from Reference Appendix JA4 is used with mass floors while Tables 4.4.1 through 4.4.5 are used for nonmass floors. (See Figure 3-8.)

Figure 3-7: Requirements for Floor/Soffit Surfaces

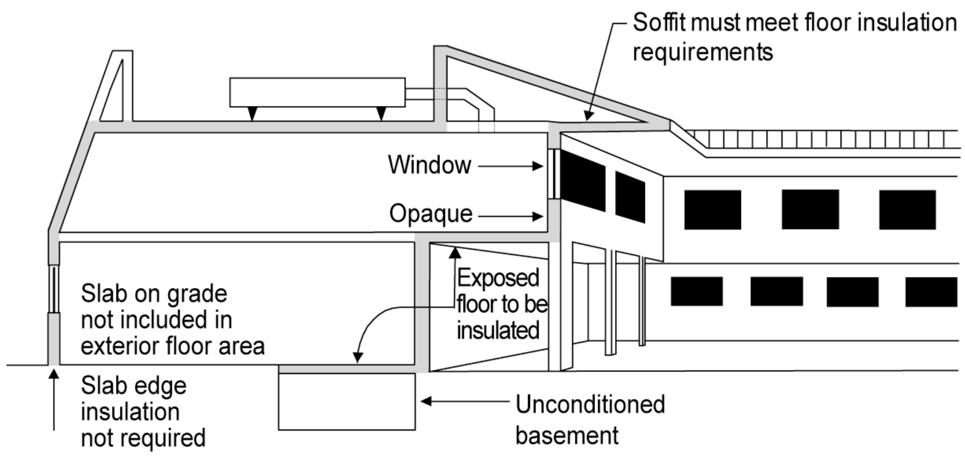
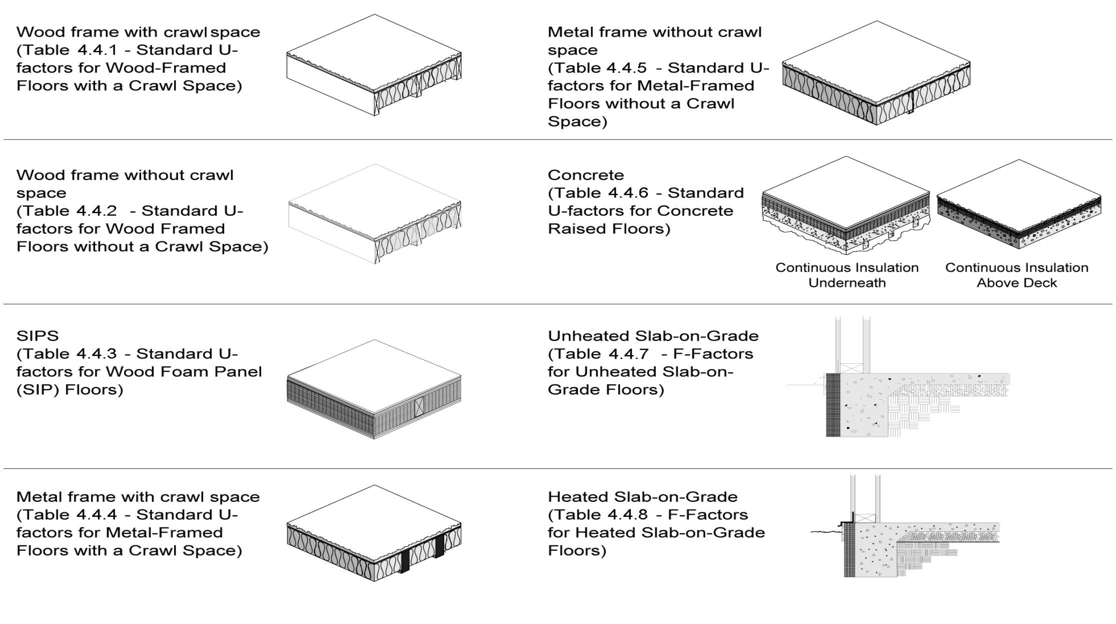


Figure 3-8: Classes of Floor Constructions



Source: Reference Appendix JA4.4

3.3 Fenestration

Choosing the proper windows, glazed doors, and skylights is one of the most important decisions for any high-performance project. The use of high-performance fenestration can actually reduce energy consumption by decreasing the lighting and heating and cooling loads in nonresidential and high-rise residential buildings. The size, orientation, and types of fenestration products can dramatically affect overall energy performance.

This section will specify the mandatory and prescriptive features of fenestration products, the performance of fenestration, ratings and labeling by the National Fenestration Rating Council (NFRC), and details on daylighting through skylights.

3.3.1 General Mandatory Measures

§110.6(a)

The mandatory measures for windows, glazed doors, and skylights address the air-tightness of the units (air leakage), how the U-factor and solar heat gain coefficient (SHGC) are determined, as well as the visible transmittance (VT).

Any fenestration product or glazed door, other than field-fabricated fenestration products and field-fabricated glazed doors, may be installed if the manufacturer has certified to the Energy Commission by using a default label, or if an independent certifying organization approved by the Energy Commission has certified that the product complies.

3.3.1.1 Determining Fenestration Performance

§110.6

A. U-Factor

The *U-factor* describes the rate of heat flow through the entire unit, not just the glass or plastic glazing material. The U-factor includes the heat flow effects of the glass, the frame, and the edge-of-glass conditions. (There also may be spacers, sealants and other elements that affect heat conduction.) The lower the U-factor, the lower the amount of heat loss.

Reference Appendix JA1 lists many of the terms and product characteristics that relate to fenestration U-factors. In particular, see the definitions for window, skylight, window area, skylight area, site-built fenestration, and field-fabricated fenestration.

The preferred methods for determining fenestration U-factor are those in NFRC 100 for manufactured windows and for site-built fenestration. The default U-factors in Table 110.6-A of the Energy Standards (reproduced in Table 3-14 below) must be used when a NFRC label for the U-factor is not available. The U-factors in Table 110.6-A represent the most inefficient possible values, thereby encouraging designers to obtain ratings through NFRC test procedures, when they are available.

Table 3-12: Methods for Determining U-Factor

	Fenestration Category				
SHGC Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration (Vertical& Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA)	✓	✓	✓	N/A	N/A
NFRC-100	✓	✓	✓	N/A	N/A
Default Table 110.6-A of the Energy Standards	✓	✓	✓	✓	✓
NA6[1]	N/A	N/A	✓	N/A	N/A
The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 1,000ft².					

B. Solar Heat Gain Coefficient (SHGC)

The SHGC measures the rate of heat gain from solar energy passing through a product. The lower the SHGC, the lower the amount of heat gain. SHGC is measured for the whole window, including the effects of the frame. For the SHGC, the methods determining the preferred values are in NFRC 200. If they are not available, Table 110.6-B of the Energy Standards (Table 3-15 below) must be used for default values.

Table 3-13: Acceptable Methods for Determining SHGC

	Fenestration Category				
SHGC Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration (Vertical& Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA)[1]	✓	✓	✓	N/A	N/A
NFRC-200	✓	✓	✓	N/A	N/A
Standards Default Table 110.6-B	✓	✓	✓	✓	✓
NA6[2]	N/A	N/A	✓	N/A	N/A
The NFRC Residential CMA method is an option that may be available in the Energy Standards. *The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 1,000ft².*					

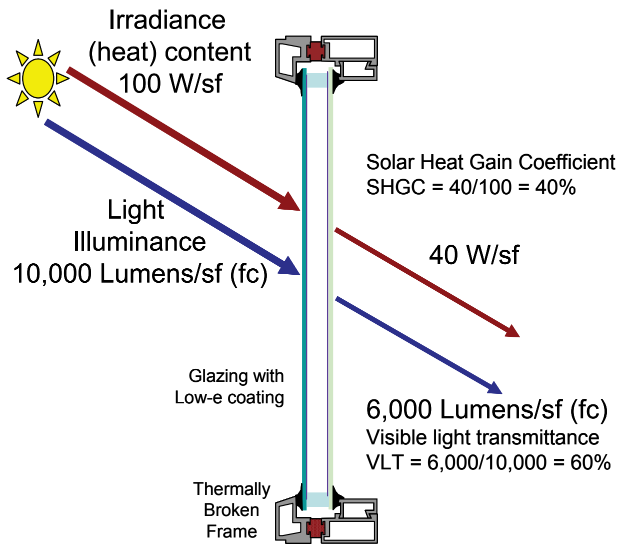
C. Visible Transmittance (VT)

VT is the ratio of light that passes through the glazing material to the light that is incident outside the glazing. VT affects the amount of daylight that enters the space and how well views through windows are rendered. Glazing materials with a very low VT have little daylighting benefit and views appear dark, even on bright days.

The VT of the fenestration shall be rated in accordance with NFRC 200 or ASTM E972. More specifically, the NFRC 200 test method is appropriate only for flat, clear glazing and does not cover curved glazing or diffusing glazing. NFRC 202 is the approved test method for rating the visible transmittance of planar diffusing glazing such as is used in fiberglass insulating fenestration. NFRC 203 is the approved test method for rating the visible transmittance of tubular skylights, also known as tubular daylighting devices (TDDs). For other types of fenestration, including dome skylights, use ASTM E972 to rate the visible transmittance.

Visible transmittance (VT) is a property of glazing materials that has a varying relationship to SHGC (Figure 3-9). The ideal glazing material for most of California's summer climates would have a high VT and a low SHGC. Such a glazing material allows solar radiation in the visible spectrum to pass while blocking radiation in the infrared and ultraviolet spectrums. Materials that have this quality are labeled "spectrally selective" and have a VT that is up to 2.2 times the SHGC.

Figure 3-9: Solar Heat Gain Coefficient and Visible Transmittance



3.3.1.2 Field-Fabricated Fenestration Product or Exterior Door

Field-fabricated fenestration is fenestration assembled on site that does not qualify as site-built fenestration. It includes windows where wood frames are constructed from raw materials at the building site, salvaged windows that do not have an NFRC label or rating, and other similar fenestration items.

For field-fabricated fenestration, the U-factor and SHGC are default values that can be found in Table 3-14 and Table 3-15, respectively, below. Values are determined by frame type, fenestration type, and glazing composition.

Exterior doors are doors through an exterior partition. They may be opaque or have a glazed area that is less than or equal to one-half of the door area. U-factors for opaque exterior doors are listed in Reference Appendix JA4, Table 4.5.1. Doors with glazing for more than one-half of the door area are treated as fenestration products and must meet all requirements and ratings associated with fenestration.

When a door has glazing of less than one-half the door area, the portion of the door with fenestration must be treated as part of the envelope and fenestration independent of the remainder of the door area.

A field-fabricated product may become a site-built product if all the requirements for receiving a label certificate required of site-built products are met.

Table 3-14: Default Fenestration Product U-Factors

FRAME	PRODUCT TYPE	SINGLE PANE 3, 4	DOUBLE PANE 1, 3, 4	GLASS BLOCK 2,3
Metal	Operable	1.28	0.79	0.87
	Fixed	1.19	0.71	0.72
	Greenhouse/garden window	2.26	1.40	N.A.
	Doors	1.25	0.77	N.A.
	Skylight	1.98	1.30	N.A.
Metal, Thermal Break	Operable	N.A.	0.66	N.A.
	Fixed	N.A.	0.55	N.A.
	Greenhouse/garden window	N.A.	1.12	N.A.
	Doors	N.A.	0.59	N.A.
	Skylight	N.A.	1.11	N.A.
Nonmetal	Operable	0.99	0.58	0.60
	Fixed	1.04	0.55	0.57
	Doors	0.99	0.53	N.A.
	Greenhouse/garden windows	1.94	1.06	N.A.
	Skylight	1.47	0.84	N.A.

1. For all dual-glazed fenestration products, adjust the listed U-factors as follows:
   a. Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide.
   b. Add 0.05 to any product with true divided lite (dividers through the panes).
2. Translucent or transparent panels shall use glass block values when not rated by NFRC 100.
3. Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6.
4. Windows with window film applied that is not rated by NFRC 100 shall use the default values from this table.

Table 110.6-A of the Energy Standards

Table 3-15: Default Solar Heat Gain Coefficient (SHGC)

FRAME TYPE	PRODUCT	GLAZING	FENESTRATION PRODUCT SHGC		
			SINGLE PANE[2,3]	DOUBLE PANE[2,3]	GLASS BLOCK[1,2]
Metal	Operable	Clear	0.80	0.70	0.70
	Fixed	Clear	0.83	0.73	0.73
	Operable	Tinted	0.67	0.59	N.A.
	Fixed	Tinted	0.68	0.60	N.A.
Metal, Thermal Break	Operable	Clear	N.A.	0.63	N.A.
	Fixed	Clear	N.A.	0.69	N.A.
	Operable	Tinted	N.A.	0.53	N.A.
	Fixed	Tinted	N.A.	0.57	N.A.
Nonmetal	Operable	Clear	0.74	0.65	0.70
	Fixed	Clear	0.76	0.67	0.67
	Operable	Tinted	0.60	0.53	N.A.
	Fixed	Tinted	0.63	0.55	N.A.

Translucent or transparent panels shall use glass block values when not rated by NFRC 200.
Visible transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6.
Windows with window film applied that is not rated by NFRC 200 shall use this table's default values

Table 110.6-B of the Energy Standards

3.3.1.3 **Certification and Labeling**

§10-111 and §110.6
Reference Nonresidential Appendices NA6

The Administrative Regulations §10-111 and §110.6 require that fenestration products have labels that list the U-factor, SHGC, VT and the method used to determine those values. The label must also certify that the fenestration product meets the requirements for air leakage from §110.6(a)1.

A. Manufactured (Factory-Assembled) Fenestration Label Certificates

Each manufactured (factory-assembled) fenestration product must have a clearly visible temporary label attached to it, which is not to be removed before inspection by the enforcement agency. For rating and labeling manufactured fenestration products, the manufacturer rates its products for U-factor, SHGC and VT.

The manufacturer can choose to have the fenestration product rated and labeled in accordance with the NFRC Rating Procedure (NFRC 100 for U-factors and NFRC 200 for SHGC and VT) shown in Figure 3-10. If the manufactured fenestration product is rated using the NFRC rating procedure, it must also be permanently labeled in accordance with NFRC procedures.

Where possible, it is best to select a fenestration product that is NFRC-rated and to do so before completing compliance documents. This selection enables the use of NFRC-certified data for compliance.

Figure 3-10: NFRC Manufactured Label

B. Default Temporary Label

Fenestration product manufacturers can choose to use default performance values listed in Tables 110.6-A and 110.6-B in §110.6 for U-factors and SHGC in lieu of testing. For fenestration products requiring a VT value, assume a value of 1.0 as specified in the Reference Nonresidential Appendix NA6. If default values are used, the manufacturer must attach a temporary label to each window (See Figure 3-11), and manufacturer specification sheets or cut sheets must be included with compliance documentation. A NRCC-ENV-05-E will be required to document the thermal performance if no default temporary labels are attached to the window units.
Although there is no exact format for the default temporary label, it must be clearly visible and large enough to be clearly visible from 4 feet so the enforcement agency field inspectors are able to read easily, and it must include all information required by the regulations.

The minimum suggested label size is 4 in. x 4 in., and the label must have the words at the bottom of the label, as noted in the example in Figure 3-11.

> *"This product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2016 California Building Energy Efficiency Standards for Residential and Nonresidential Buildings."*

If the product claims the default U-factor for a thermal-break product, the manufacturer must certify that the thermal-break criteria upon which the default value is based are met by placing a check in the check box:

1. Air space 7/16 in. or greater
2. For skylights, the label must indicate the product was rated with a built-in curb
3. Meets thermal-break default criteria

Figure 3-11: Sample Default Temporary Label

2013 California Energy Commission Default Label XYZ Manufacturing Co.		
Key Features:	☐ Doors	☐ Double-Pane
	☐ Skylight	☐ Glass Block
Frame Type	**Product Type:**	**Product Glazing Type:**
☐ Metal	☐ Operable	☐ Clear
☐ Non-Metal	☐ Fixed	☐ Tinted
☐ Metal, Thermal Break	☐ Greenhouse/Garden Window	☐ Single-Pane
☐ Air space 7/16 in. or greater ☐ With built-in curb ☐ Meets Thermal-Break Default Criteria	----------	To calculate VT see NA6
California Energy Commission Default U-factor =	**California Energy Commission** Default SHGC =	**California Energy Commission** Calculated VT =
Product meets the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, SHGC criteria of §110.6(a)3 and VT criteria of §110.6(a)4 of the 2016 Energy Standards for Residential and Nonresidential Buildings.		

The person taking responsibility for fenestration compliance may choose to attach default temporary labels to each fenestration product as described instead of providing a default label certificate for each product line.

For the visible transmittance (VT) of diffusing skylights that is not covered by NFRC 200 or NFRC 203, a test report should be included using the ASTM E972 method. Manufacturers, specifiers, or a responsible party should include the report with the energy documentation.

C. Field-Fabricated Fenestration

Field-fabricated fenestration is not the same as site-built fenestration. *Field-fabricated fenestration* is a very limited category of fenestration that is made at the construction site out of materials that were not previously formed or cut with the intention of being used to fabricate a fenestration product. No attached labeling is required for field-fabricated fenestration products; only a NRCC-ENV-05-E is needed. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the compliance performance documentation has demonstrated compliance. The field inspector is responsible for ensuring field-fabricated fenestration meets the specific U-factor, SHGC, and VT, as listed on the NRCC-ENV-05-E. Thermal break values do not apply to field-fabricated fenestration products.

D. Site-Built Label Certificates

The designer should select a U-factor, SHGC, and VT for the fenestration system that meets the design objectives and occupancy needs for the building. Site-built fenestration is field-assembled using specific factory-cut or factory-formed framing and glazing units that are manufactured with the intention of being assembled at the construction site or glazing contractor’s shop. Site-built certificates should be filed at the contractor’s project office during construction or in the building manager’s office. (See the CMA sample on Figures 3-12 and 3-12A and discussion of CMA in subsection F below.)

Note: The highlighted circles in the figures indicate the field inspector's area to inspect and compare to the energy compliance submittal and building plans.

Figure 3-12: NFRC - CMA Label Certificate Page 1

NATIONAL FENESTRATION RATING COUNCIL
LABEL CERTIFICATE

PROJECT INFORMATION

LABEL CERTIFICATE ID: *XYZ-001* Issuance Date: mm/dd/yyyy

This is to be completed by an NFRC Approved Calculation Entity (ACE), based on information provided by the Specifying Authority and calculated in accordance with NFRC procedures.

PROJECT LOCATION:

Address: ____________________________

City: ____________, **State,** ____________, **Zip code:** ________

Contact person:____________________, **Title:** ____________

Phone: ________, **Facsimile:** ________, **Email:** ________________

Project name (optional): ____________, **Designer (optional):** ____________

Figure 3-12A: NFRC - CMA Label Certificate Page 2

PRODUCT LISTING

FOR CODE COMPLIANCE

LABEL CERTIFICATE ID: *XYZ-001* Issuance Date: mm/dd/yyyy

NFRC CERTIFIED PRODUCT RATING INFORMATION:*

The NFRC Certified Product Rating Information listed here is to be used to verify that the ratings meet applicable energy code requirements.

PRODUCT LISTING:

						CERTIFIED Performance Rating at NFRC Model Size		
CPD ID	Total Area ft^2	Name	Framing Ref	Glazing Ref	Spacer Ref	U** Btu/hr·ft²·°F	SHGC** -	VT** -
P-PL-010	88.89	PL-2200 / PL-2210	FA-PL2210	GA-TT-001	SA-AM-001	0.53	0.58	0.66
P-PL-005	192.67	PL-3400 / PL-3401	FA-PL3401	GA-TT-001	SA-AM-002	0.56	0.57	0.65
P-PL-012	382.22	PL-5700 / PL-5720	FA-PL5720	GA-TO-002	SA-AM-001	0.52	0.21	0.30
P-PL-002	60.00	PL-1100 / PL-1152	FA-PL1152	GA-TT-001	SA-AM-001	0.42	0.51	0.62
P-PL-022	525.00	PL-9900 / PL-9915	FA-PL9915	GA-TO-003	SA-AM-002	0.45	0.15	0.19

1. For site-built fenestration totaling 1,000 ft^2 or greater, the glazing contractor or specifier must generate a NFRC label certificate from either approach listed below:
   a. A NFRC label certificate generated by the CMA computer program.
   b. Default to the U-factor values from Table 110.6-A, the SHGC values from 110.6-B, and for VT values, use the method specified in NA6.
2. For site-built fenestration totaling less than 1,000 ft² or any area of replacement of site-built fenestration that includes vertical windows, glazed doors, and skylights, the glazing contractor or specifier must comply with one of the following:
   a. A NFRC label certificate generated by the CMA computer program.
   b. The center-of-glass values from the manufacturer's product literature to determine the total U-factor, SHGC and VT. (See Reference Nonresidential Appendix NA6 - the *Alternative Default Fenestration Procedure*).
   c. The U-factor values from Table 110.6-A and SHGC values from Table 110.6-B. For VT values, use the method specified in NA6.

NA6 calculations are based on center-of-glass (COG) values from the manufacturer. For example, when using a manufacturer's SHGC center-of-glass specification of 0.27, the NA6 calculation results in an overall SGHC value of 0.312, which may be rounded to 0.31. Rounding to the nearest hundredth decimal place is acceptable to determine the overall fenestration efficiency value with either the prescriptive or performance approach.

E. Fenestration Certificate NRCC-ENV-05-E

For nonrated products where no default label certificates are placed on the fenestration product, use Fenestration Certificate NRCC-ENV-05-E to document thermal performances of each fenestration product that results in a different U-factor, SHGC, and VT. Alternatively, one certificate will suffice when all the windows are the same.

The NRCC-ENV-05-E should indicate the total amount of non-NFRC-rated fenestration products throughout the project. The locations and orientations where fenestration products are being installed should be indicated on the drawings and in a fenestration schedule that lists all fenestration products.

The NRCC-ENV-05-E should clearly identify the appropriate table or equation that is used to determine the default U-factor and SHGC and, if applicable, the center of glass, $SHGC_C$, used in calculating the $SHGC_{fen}$. Manufacturer's documentation of these product characteristics that list the center-of-glass values must also be attached to the NRCC-ENV-05-E and located at the job site for verification.

F. Component Modeling Approach (CMA)

NFRC has developed a performance base calculation, the *component modeling approach* (CMA), to make the rating process quicker and simpler and serve as an energy ratings certification program for windows and other fenestration products used in nonresidential projects. This approach allows users to assemble fenestration products in a virtual environment. The approach draws data for NFRC-approved components from online libraries choosing from preapproved glazing, frame, and spacer components. CMA users are able to obtain preliminary ratings for various configurations of their designs. CMA is a fair, accurate, and credible method based on NFRC 100 and 200 program documents, which are verified by third-party rating procedures.

Architects and others can use this tool to:

1. Help design energy-efficient windows, curtain wall systems, and skylights for high-performance building projects.
2. Determine whether a product meets the specifications for a project and local/state building energy codes.
3. Model different fenestration designs to compare energy performance.

Once the user is satisfied with the product, he or she creates a bid report containing the data for all fenestration products to be reviewed. This report can serve as an indication that the products comply with the energy-related requirements of the project and building energy codes. The windows are then built, either on-site or in a factory. The final products are reviewed and are rated by an NFRC-approved calculation entity (ACE); then a license agreement is signed with NFRC.

At this point, NFRC issues a CMA label certificate for the project. This label certificate, unlike NFRC's residential window label that is applied to individual units, is a document that lists the certified fenestration ratings at the NFRC standard testing size for the entire building project. Once approved, the CMA label certificate is available online immediately. This certificate serves as code compliance documentation for fenestration energy performance, and the certified products may be applied to future projects without repeating the certification process.

Benefits of CMA

CMA provides facility managers, specifiers, building owners, and design teams with a simple method for designing and certifying the energy performance of fenestration systems for their buildings without having to test every possible permutation of glazing and framing. This is significantly less expensive than building sample wall sections and testing them in a large test enclosure. However, there are several additional advantages gained by using the CMA:

1. CMA's online tool has the ability to output a file with values for use in building energy analysis software programs.
2. The program can export detailed information for angular-dependent SHGC and VT values, seamlessly transferring the data to the analytical software.
3. A 2010 study[1] conducted in California demonstrated that fenestration modeled with the CMA program can provide an increase in compliance margins by as much as 11.7 percent over the Energy Commission's default calculation methods.
4. CMA can help demonstrate above-code performance, which is useful for environmental rating programs such as Leadership in Energy and Environmental Design (LEED™) or local green building programs.

Use of the CMA can help lead to a more efficient building and enable cost savings due to more accurate fenestration performances and potential energy benefits from above-code utility incentives. Details are available at [www.NFRC.org/.](http://www.NFRC.org/)

1 Study conducted by the Heschong Mahone Group for NFRC, "Compared to alternative fenestration rating values detailed in California's Title 24, Using CMA provides a maximum increase of 11.7% in energy compliance margins. This means that compared to other available options, CMA provides the most accurate values on window energy and visible performance."

3.3.1.4 Air Leakage

§110.6(a)1

Manufactured and site-built fenestration such as doors and windows must be tested and shown to have infiltration rates not exceeding the values shown in Table 3-16. For field-fabricated products or an exterior door, the Energy Standards require that the unit be caulked, gasketed, weatherstripped, or otherwise sealed. Unframed glass doors and fire doors are the two exceptions to these air leakage requirements. Field-fabricated fenestration and field-fabricated exterior doors are not required to comply with Table 3-16.

Table 3-16: Maximum Air Infiltration Rates (§110.6(a)1)

Class	Type	Rate
Windows (cfm/ft²) of window area	All	0.3
Residential Doors (cfm/ft²) of door area	Swinging, Sliding	0.3
All Other Doors (cfm/ft²) of door area	Sliding, Swinging (single door)	0.3
	Swinging (double door)	1.0

Example 3-11

Question:

A 150,000 ft² "big box" retail store has 800 ft² of site-built vertical fenestration at the entrance. An operable double-pane aluminum storefront framing system is used without a thermal break. What are the acceptable methods for determining the fenestration U-factor and SHGC? What are the labeling requirements assuming a center of glass U-factor of 0.50 and SHGC of 0.70 and a center glass visible transmittance of 0.75?

Answer:

For site-built fenestration less than 1,000 ft^2 then one of the following three methods may be used:

1. The easiest method for site-built fenestration is to rate the fenestration using the component modeling approach (CMA), which will yield the most efficient values possible.
2. In this case, use the default U-factor and SHGC values from equations in Reference Nonresidential Appendix NA6 as described in the following bullets:

- The Alternate U-factor may be calculated from the Reference Nonresidential Appendix NA6, Equation NA6-1, $U_T = C_1 + C_2 \text{ X } U_C$. From Table NA-1 for metal–framed, site-built fenestration, C_1= 0.311 and C_2 = 0.872, therefore the overall U-factor is calculated to be 0.311 + 0.872 x 0.50 = 0.47.
- Likewise, the SHGC is determined from the Reference Nonresidential Appendix, NA6, Equation NA6-2, $SHGC_T = 0.08 + 0.86 \times SHGC_C$. Therefore, the SHGC is calculated to be 0.08 + 0.86 x 0.70 = 0.68.
- For VT, from Appendix NA6, the visible transmittance of the frame is 0.88 for a curtain wall, so the $VT_T = VT_F \text{ X } VT_C = 0.88 \text{ X } 0.75 = 0.66$.

3. The third option for determining U-factor and SHGC may be to select from Default Table 110.6-A and 110.6-B of the Energy Standards. From these tables, the U-factor is 0.79 and the SHGC is 0.70. An Energy Commission Default Label Certificate, NRCC-ENV-05-E, should be completed for each fenestration product unless the responsible party chooses to attach a default temporary label to each fenestration unit throughout the building.

Example 3-12

Question:
What constitutes a “double-pane” window?

Answer:
Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by a space [generally ¼ inch (6 mm) to ¾ inch (18 mm)] filled with air or other inert gases. Two panes of glazing laminated together do not constitute double-pane glazing, but are treated as single pane.

3.3.2 Vertical Fenestration (Windows and Doors)

3.3.2.1. Site-Built Fenestration

§110.6

Manufactured fenestration products are factory-assembled as a unit, and the manufacturer is able to assume the burden of testing and labeling. However, with site-built fenestration, multiple parties are responsible. The steps of producing site-built fenestration are as follows:

1. Architects and/or engineers design the basic glazing system by specifying the components, the geometry of the components, and, sometimes, the assembly method.
2. An extrusion manufacturer provides the mullions and frames that support the glazing and is responsible for thermal breaks.
3. A glazing manufacturer provides the glazing units, cut to size and fabricated as insulated glass (IG) units. The glazing manufacturer is responsible for tempering or heat strengthening, the tint of the glass, any special coatings, the spacers, and the sealants.
4. A glazing contractor (usually a subcontractor to the general contractor) puts the system together at the construction site, or the contractor’s shop and is responsible for many quality aspects. Predetermining the energy performance of site-built fenestration as a system is more challenging than for manufactured units.
5. One of the parties (architect, glazing contractor, extrusion manufacturer, IG fabricator, or glass manufacturer) must take responsibility for testing and labeling of the site-built fenestration system under the most recent NFRC 100 procedure. The responsible party must obtain a label certificate as described in §10-111.
6. The glazing contractor or other appropriate party assumes responsibility for acquiring the NFRC label certificate. Each label certificate has the same information as the NFRC temporary label for manufactured products but includes other information specific to the project, such as the name of the glazing manufacturer, the extrusion contractor, the places in the building where the product line is used, and other details.

It is typical for the glazing contractor to assume responsibility for the team and to coordinate the certification and labeling process. A common procedure is for the design team to include language in the contract with the general contractor that requires that the general contractor be responsible; the general contractor typically assigns this responsibility to the glazing contractor, once the responsible party has established a relationship with an NFRC.

It is not necessary to complete the NFRC testing and labeling prior to completing the compliance documentation and filing the building permit application. However, plans examiners should verify that the fenestration performance shown in the plans and specifications and used in the compliance calculations is “reasonable” and achievable. This requires some judgment and knowledge on the part of the plans examiner. Generally, designers will know the type of glass that they plan to use and whether the frame has a thermal break or is thermally improved. This information is adequate to consult the default values for U-factor and SHGC in Reference Nonresidential Appendix NA6.

The label certificate remains on file in the construction office for the building inspector to view. After construction is complete, the label certificate should be filed in the building office with the as-built drawings and other operations and maintenance data. This will give building managers the information needed for repairs or replacements.

3.3.2.2. **Prescriptive Measures**

There are four aspects of the envelope component approach for windows:

1. Maximum total area plus west-facing.
2. Maximum U-factor.
3. Maximum relative solar heat gain coefficient (RSHGC).
4. Minimum visible transmittance (VT).

A. Window Area

§140.3(a)5.A.

In the prescriptive approach, the total window area may not exceed 40 percent of the gross wall area (encompassing total conditioned space) for the building. Likewise, the west-facing window area may not exceed 40 percent of the west gross wall area (encompassing total conditioned space for the building). This maximum area requirement will affect those buildings with very large glass areas, such as high-rise offices, automobile showrooms, or airport terminals.

The maximum area may be determined by multiplying the length of the display perimeter (see definition below in this section) by 6 ft in height and use the larger of the product of that multiplication or 40 percent of gross exterior wall area.

Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the prescriptive U-factor, relative solar heat gain coefficient (RSHGC), and visible light transmittance (VT) requirements for the climate zone.

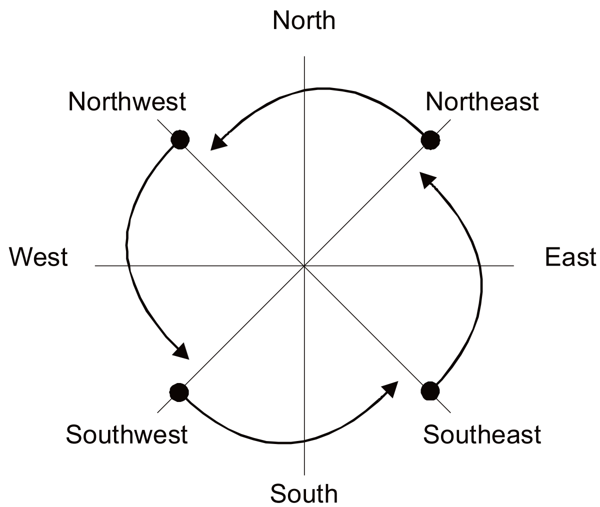
As a practical matter, window area is generally taken from the rough opening dimensions. To the extent this opening is slightly larger than the frame, the rough opening area will be slightly larger than the formally defined window area.

For glazed doors, also use the rough opening area, except where the door glass area is less than 50 percent of the door, in which case the glazing area may be either the entire door area or the glass area plus 2 inches added to all four sides of the glass (to represent the “window frame”) for a window in a door. Calculate the window area from the rough opening dimensions and divide by the gross exterior wall area, which does not include demising walls.

Display perimeter is the length of an exterior wall in a Group B; Group F, Division 1; or Group M occupancy that immediately abuts a public sidewalk, measured at the sidewalk level for each story that abuts a public sidewalk. This generally refers to retail display windows, although other occupancies such as offices can also have a display perimeter. Public sidewalks are accessible to the public at large (no obstructions, limits to access, or intervening nonpublic spaces). Demising walls are not counted as part of the display perimeter.

In general, any orientation within 45° of true north, east, south, or west will be assigned to that orientation. The orientation can be determined from an accurate site plan. Figure 3-13 demonstrates how surface orientations are determined and what to do if the surface is oriented exactly at 45° of a cardinal orientation. For example, an east-facing surface cannot face exactly northeast, but it can face exactly southeast. If the surface were facing exactly northeast, it would be considered north-facing.

Figure 3-13: Four Surface Orientations



B. Window U-Factor

§140.3(a)5B

Fenestration products are required to use default U-factors and SHGC (see Tables 110.6-A (Table 3-14) and Table 110.6-B (Table 3-15) of the Energy Standards) or have the performance characteristics certified by NFRC. However, each window must meet the prescriptively required maximum U-factor criteria in Tables 140.3-B and 140.3-C of the Energy Standards (see Table 3-17 below) for each climate zone. In general, most NFRC-rated double-glazed windows with a low-e coating and a thermally broken frame will comply with the U-factor criterion; however, other window constructions may also comply. See http://www.nfrc.org/, Certified Product Directory database, or use Equation NA6-1in Reference Appendix NA6.

Table 3-17: Window Prescriptive Requirements U-factors

	All Climate Zones				
Space Type	**Criterion**	**Fixed Window**	**Operable Window**	**Curtainwall/Storefront**	**Glazed Doors**
Nonresidential	Max U-factor	0.36	0.46	0.41	0.45
	Max Relative Solar Heat Gain (RSHGC)	0.25	0.22	0.26	0.23
	Min VT	0.42	0.32	0.46	0.17
	Maximum WWR%	40%			
	All Climate Zones				
Residential High-Rise	Max U-Factor	0.36	0.46	0.41	0.45
	Max Relative Solar Heat Gain (RSHGC)	0.25	0.22	0.26	0.23
	Min VT	0.42	0.32	0.46	0.17
	Maximum WWR%	40%			

From Energy Standards Tables 140.3-B and 140.3-C

C. Overhang Factor

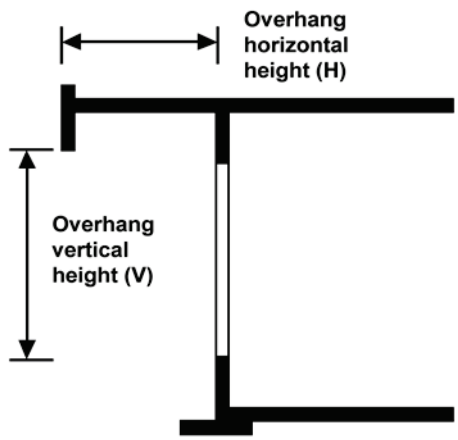
§140.3(a)5C

Relative solar heat gain (RSHGC) is essentially the same as SHGC, except for the external shading correction. It is calculated by multiplying the SHGC of the fenestration product by an overhang factor. If an overhang does not exist, then the overhang factor is 1.0. Relative solar heat gain is applicable only when using the prescriptive compliance approach.

Tables 140.3-B and 140.3-C of the Energy Standards (Table 3-17 above) specify the maximum area-weighted average RSHGC, excluding the effects of interior shading.

Overhang factors may either be calculated or taken from Table 3-18 below and depend upon the ratio of the overhang horizontal length (H) and the overhang vertical height (V). These dimensions are measured from the vertical and horizontal planes passing through the bottom edge of the window glazing, as shown in Figure 3-14. An overhang factor may be used if the overhang extends beyond both sides of the window jamb a distance equal to the overhang projection (§140.3(a)5Cii). The overhang projection is equal to the overhang length (H), as shown in Figure 3-14. If the overhang is continuous along the side of a building, this restriction will usually be met. If there are overhangs for individual windows, each must be shown to extend far enough from each side of the window.

Figure 3-14: Overhang Dimensions



Equation 3-1 – Relative Solar Heat Gain Coefficient

$RSHGC = SHGC_{win} \times OHF$

Where:

RSHGC = Relative solar heat gain Coefficient

$SHGC_{win}$ = Solar heat gain coefficient of the window

Equation 3-2 – Overhang Factor

$$OHF = OverhangFactor = 1 + \frac{aH}{V} + b\left(\frac{H}{V}\right)^2$$

Where:

H = Horizontal projection of the overhang from the surface of the window in ft, but no greater than V

V = Vertical distance from the windowsill to the bottom of the overhang, in ft.

a = -0.41 for north-facing windows, -1.22 for south-facing windows, and -0.92 for east- and west-facing windows

b =0.20 for north-facing windows, 0.66 for south-facing windows, and 0.35 for east- and west-facing windows

Table 3-18: Overhang Factors

H/V	North	South	East/West
0.00	1.00	1.00	1.00
0.10	0.96	0.88	0.91
0.20	0.93	0.78	0.83
0.30	0.90	0.69	0.76
0.40	0.87	0.62	0.69
0.50	0.85	0.56	0.63
0.60	0.83	0.51	0.57
0.70	0.81	0.47	0.53
0.80	0.80	0.45	0.49
0.90	0.79	0.44	0.46
1.00 or greater	0.79	0.44	0.43

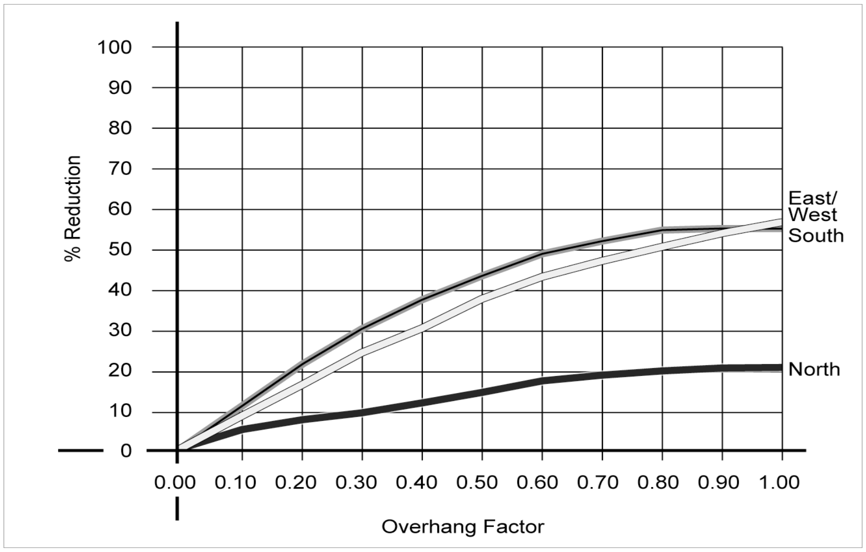
To use Table 3-18:

1. Measure the horizontal projection of the overhang (H) and the vertical height from the bottom of the glazing to the shading cutoff point of the overhang (V).
2. Calculate H/V.
3. Enter the table at that point.
4. Choose the next higher value to the calculated H/V value if the calculated H/V falls between two values in the table
5. Move across to the column that corresponds to the orientation of the window and find the overhang factor.

Any value of H/V greater than 1 has the same overhang factor (for a given orientation) shown in the last row of the table.

Figure 3-15 graphs the overhang factors of the various orientations as a function of H/V. It shows that overhangs have only a minor effect on the north. (Maximum reduction in SHGC is only about 20 percent.) East, west, and south overhangs can achieve reductions of 55–60 percent. The benefits of the overhang level off as the overhang becomes larger. (This graph is presented only to illustrate the benefits of overhangs.)

Figure 3-15: Graph of Overhang Factors



Example 3-13

Question:

An east-facing window has glass with a solar heat gain coefficient of 0.71. It has a fixed overhanging eave that extends 3 ft out from the plane of the glass (H = 3) and is 6 ft above the bottom of the glass (V = 6). The overhang extends more than 3 ft beyond each side of the glass, and the top of the window is less than 2 ft vertically below the overhang. What is the RSHGC for this window?

Answer:

First, calculate H/V. This value is 3 / 6 = 0.50. Next, find the overhang factor from Table 3-18. For east-facing windows, this value is 0.63. Finally, multiply it by the solar heat gain coefficient to obtain the RSHGC: 0.63 x 0.71 = 0.45.

D. Visible Light Transmittance (VT)

§140.3(a)5D

The prescriptive requirements of Tables 140.3-B and 140.3-C (Table 3-17) of the Energy Standards prescribe specific VT values for all climate zones and glass types. The visible light transmittance is used in the performance method in the calculation of the interior illumination levels and lighting energy savings due to daylight controls. This is discussed in more detail in Chapter 5 of this manual.

Fenestration must meet the climate zone-specific prescriptive requirement of having an area-weighted average VT of 0.42 or greater for fixed windows, 0.32 or greater for operable windows, 0.46 or greater for curtain walls and 0.17 or greater for glazed doors. Products with spectrally selective “low-e” coatings (also known as single, double or triple silver low-e) are available to meet this requirement.

A combination of high VT glazing in the upper part of a window (clerestory) and lower VT glazing at the lower part of the window (view window) can be used, as long as the area-weighted average meets the prescriptive requirement. This allows daylight to enter the space through the high VT glazing making a better daylighting design.

The Energy Standards also allow a slight variance if the window-to-wall ratio (WWR) is greater than 40 percent. For this case, assume 0.40 for the WWR in the equation below, or if the glazing can comply with the prescriptive requirements if the area-weighted average VT meets the following minimum requirement:

Equation 3-3 – Visible Light Transmittance

$$VT \geq 0.11 / WWR$$

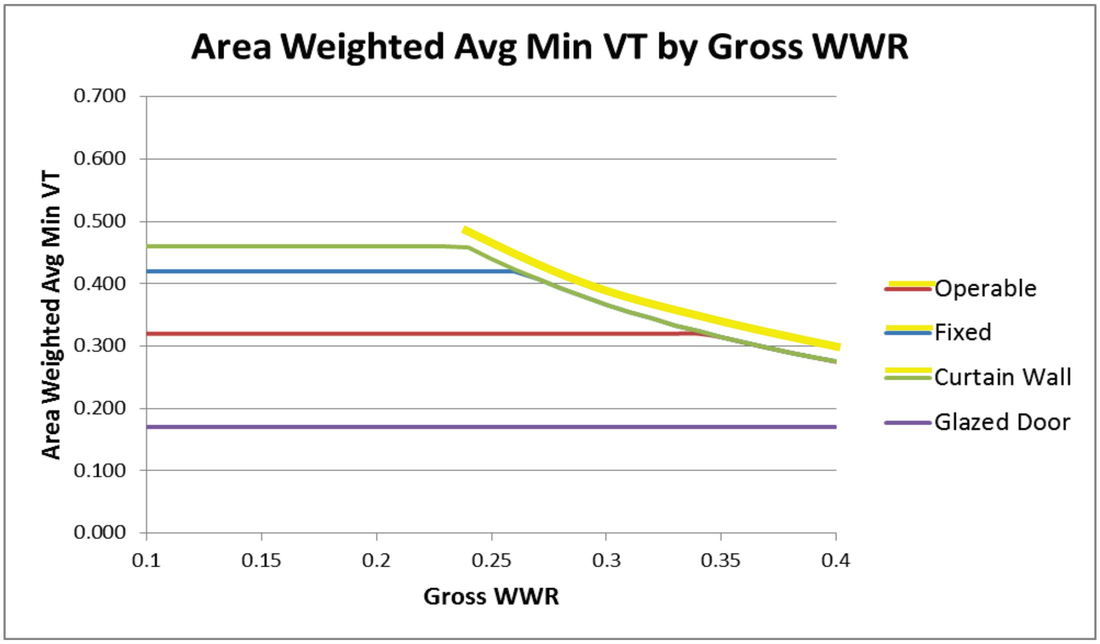
Where:

VT = the visible transmittance of the framed window

WWR = the gross window-to-wall ratio

The graph below shows the allowed area weighted average minimum VT's by gross WWR for four types of windows

Figure 3-16: Area Weighted Average Minimum VT by Gross Window-to-Wall Ratio

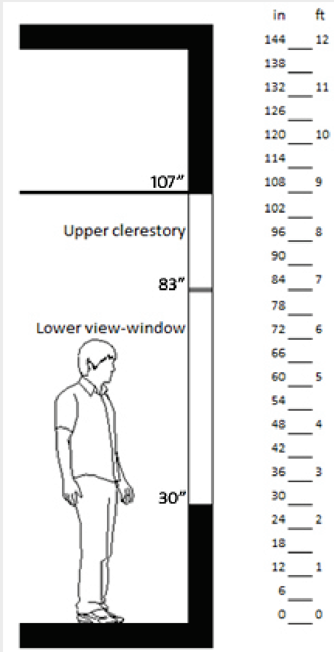


The average VT requirements apply separately to chromatic (dynamic or color changing) glazing and nonchromatic glazing. For chromatic glazing, higher ranges of VT can be used to meet the prescriptive requirements. However, all glazing that is not chromatic must separately meet the area-weighted VT prescriptive requirements.

Example 3-14

Question:

A space has a gross window-to-wall ratio of 30 percent and has a fixed window with a sill height of 2'6" (30") and a head height of 8'11" (107"), which runs 10' wide (120"). The window has a break at 6'11" (83") such that the upper portion or clerestory portion of the window is 2' (24") tall and can have a glazing different from that in the lower portion (view window). Can a designer use 0.30 VT glazing in the view window?



Answer:

Using the formula VT ≥ 0.11 / WWR, staff determines the minimum area weighted average VT for this space,

VT ≥ 0.11 / 0.3 = 0.367

So the area weighted minimum VT we need for this window is 0.367.

I.e. (View window Area x View window VT) + (Clerestory Area x Clerestory VT) / Total Window Area = 0.367

In this case:

Clerestory area = 24” height x 120” width = 2,880 sq.in

View window area = (83” - 30”) height x 120” width = 6,360 sq.in.

If the designer wants to use a 0.30 VT glazing in the view window then View window VT = 0.30

Total window area = (107” - 30”) height x 120” width = 9,240 sq.in.

Solving the above equation for Clerestory VT, staff gets:

Clerestory VT = 0.515

(6360 x 0.367) + (2880 x VT_{CL})/9240

So, to use a 0.3 VT glazing in the view window, the designer must use a 0.515 VT window in the clerestory.

3.3.2.3. Compliance Options

A. Dynamic Glazing − Chromatic Glazing

Chromatic-type fenestration has the ability to change performance properties (U-factor, SHGC, and VT). The occupant can manually or automatically control his or her environment by tinting or darkening a window with the flip of a switch or by raising/lowering a shade positioned between panes of glass. Some windows and doors change the performance automatically in response to a control or environmental signal.

These “smart windows” provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss. While still a relatively new technology, high-performance windows are expected to grow substantially in the coming years.

Look for the NFRC Dynamic Glazing Label to compare and contrast the energy performance for these new products. See the example of a Dynamic Glazing NFRC label in Figure 3-17 below. The unique rating identifiers help consumers understand the “dynamics” of the product and allow comparison with other similar fenestration products.

If the product can operate at intermediate states, a dual directional arrow, **(↔),** with the word “variable” underneath will appear on the label. Some dynamic glazing is able to adjust to intermediate states, allowing for a performance level between the endpoints. The low value rating is displayed to the left (in the closed position), and the high value rating is displayed to the right (in the open position). This lets the consumer know at a glance the best and worst case performance of the product and what the default or de-energized performance level will be.

Figure 3-17: Dynamic Glazing NFRC Label

The label references the following information:

1. **U-factor** measures the rate of heat loss through a product. Therefore, the lower the U-factor, the lower the amount of heat loss. In cold climates where heating bills are a concern, choosing products with lower U-factors will reduce the amount of heat that escapes from inside the house.
2. The **solar heat gain coefficient (SHGC)** measures the rate of heat gain from solar energy passing through a product. Therefore, the lower the SHGC, the less amount of solar heat gain. In hot climates where air conditioning bills are a concern, choosing products with a lower SHGC will reduce the amount of heat that comes in from the outside.

3. **Visible transmittance (VT)** measures the amount of light that comes through a product. The higher the VT rating, the more light is allowed through a window or door.
4. **Air Leakage (AL)** is a measurement of heat loss and gain by infiltration through cracks in the window assembly which affects occupant comfort. The lower the AL, the less air will pass through cracks in the window assembly.

To receive chromatic glazing credit, the following must be met:

1. Optional prescriptive − default to Table 140.3-B and 140.3-C, U-factor and SHGC
2. Performance approach compliance − maximum credit allowance for best rating
3. Automatic controls to receive best rating values or
4. NFRC Dynamic Glazing Compliance Label is required; otherwise, default to Table 110.6-A and 110.6-B values.

B. Window Films

Developed in the early 1950s, window films are made of mostly polyester substrate that is durable, tough, and highly flexible. It absorbs little moisture and has both high and low temperature resistances. Polyester film offers crystal clarity and can be pretreated to accept different types of coatings for energy control and long-term performance. Window films are made with a special scratch-resistant coating on one side and with a mounting adhesive layer on the other side. The adhesive is normally applied to the interior surface (room side) of the glass, unless a film is specifically designed to go on the exterior window surface.

Polyester film can be metalized and easily laminated to other layers of polyester film.

There are three basic categories of window films:

1. Clear (nonreflective) films are used as safety or security films and to reduce ultraviolet (UV) light, which contributes to fading of finished surfaces and furnishings. However, they are not normally used for solar control or energy savings.
2. Tinted or dyed (nonreflective) films reduce both heat and light transmission, mostly through increased absorptance and can be used in applications where the primary benefit desired is glare control with energy savings as secondary benefit.
3. Metalized (reflective) films can be metalized though vacuum coating, sputtering, or reactive deposition and may be clear or colored. Metalized (reflective) films are the preferred window films in most energy-saving applications, since they reduce transmission primarily through reflectance and are manufactured to selectively reflect heat more than visible light through various combinations of metals.

Look for the NFRC–certified attachment ratings energy-performance label, which helps consumers understand the contrast in energy performance of window films. An example of a window film energy performance label is shown on Figure 3-18 given below.

Window Film Compliance

To receive window film credit the, following must be met:

1. The performance approach must be used.
2. Use only the alteration to existing building compliance method.
   a. The NFRC window film energy performance label is required for each film; otherwise, use the Default Table 110.6-A and 110.6-B values.
   b. Window films shall have a 10-year or longer warranty.

Figure 3-18: Window Film Energy Performance Label

National Fenestration Rating Council® CERTIFIED

NFRC ATTACHMENT RATINGS

XYZ Applied Film Company • Deluxe Green Film
CPD#000-X-1 (Interior)
This rating uses reference product energy performance - actual product performance may vary.

ENERGY PERFORMANCE RATINGS

Reference Product		U-Factor		Solar Heat Gain Coefficient		Visible Transmittance	
Type	Glazing	W/O Film	With Film	W/O Film	With Film	W/O Film	With Film
Residential	Single Glazed Clear	1.09	1.01	0.71	0.40	0.74	0.57
	Double Glazed Clear	0.66	0.67	0.63	0.44	0.67	0.52
Non-Residential	Single Glazed Clear	1.02	0.93	0.72	0.43	0.78	0.60
	Single Glazed Gray	1.02	0.93	0.51	0.35	0.39	0.31
	Double Glazed Clear	0.60	0.53	0.62	0.47	0.69	0.54
	Double Glazed Gray	0.60	0.53	0.41	0.32	0.35	0.27

Manufacturer stipulates that these ratings conform to applicable NFRC procedures for determining whole product performance. NFRC ratings are determined for a fixed set of environmental conditions and a specific product size. NFRC does not recommend any product and does not warrant the suitability of any product for any specific use. Consult manufacturer's literature for other product performance information.
www.nfrc.org

3.3.3 Skylights

There are two ways that skylights can be mounted into a roof system, either flush-mounted or curb-mounted. To ensure water flows around them, skylights are often mounted on "curbs" set above the roof plane. These curbs, rising 6 to 12 inches above the roof, create additional heat loss surfaces.

When skylights are specified, the designer must show the skylit daylight zones on the building plans. Automatic daylighting controls are required when the installed power in the daylit zones of a room is greater than 120W. See Chapter 5 of this manual for a detailed discussion of the daylight zones.

3.3.3.1. **Skylight Mandatory Measures**

There are no mandatory measures for skylights, so the prescriptive or performance approach must be used. However, there are mandatory requirements for lighting controls related to daylighting, as discussed below.

A. Controls

§130.1(d)

Electric lighting in skylight daylit zones shall meet the mandatory control requirements in §130.1(d). Chapter 5 contains information about lighting control requirements and daylighting control requirements. As described above, obstructions are ignored for evaluating the architectural area served by skylights. However, for controlling lighting, one must consider the area shaded that is behind permanent obstructions that are greater than half the ceiling height. As a result, those luminaires behind tall obstructions are not part of the skylit daylit area and, therefore, not controlled by automatic daylighting controls.

3.3.3.2. **Skylight Prescriptive Requirements**

140.3(a)6

As with windows, there are four aspects of the prescriptive envelope approach for skylights:

1. Maximum total area.
2. Maximum U-factor.
3. Maximum solar heat gain coefficient (SHGC).
4. Minimum visible transmittance (VT).

Table 3-19: Skylight Requirements (Area-Weighted Performance Rating)

		All Climate Zones		
		Glass, Curb Mounted	Glass, Deck-Mounted	Plastic, Curb-Mounted
Nonresidential	U-factor	0.58	0.46	0.88
	SHGC	0.25	0.25	NR
	VT	0.49	0.49	0.64
	Maximum SRR%	5%		
High-Rise Residential	U-factor	0.58	0.46	0.88
	SHGC	0.25	0.25	NR
	VT	0.49	0.49	0.64
	Maximum SRR%	5%		

Excerpt from Energy Standards Tables 140.3-B and 140.3-C, Skylight Roof Ratio, SRR

A. Skylight Area

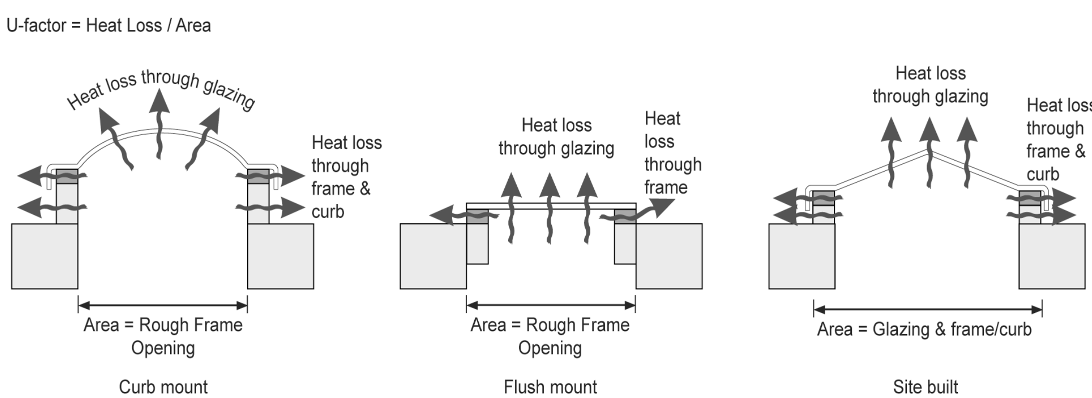
§140.3(a)6A

Skylight area is defined in JA1 as the area of the rough opening of a skylight. The area limit for skylights is 5 percent of the gross exterior roof area, sometimes called the skylight roof ratio (SRR). The limit increases to 10 percent for buildings with an atrium more than 55 ft high. .) The 55-ft height is also the threshold at which the California Building Code requires a mechanical smoke-control system for atriums (CBC Sec. 909). In practice, this means that the 10 percent SRR is not allowed for atriums unless they also meet this smoke control requirement.

Site-built monumental or architectural skylights equipped with integral built-in or site-built curbs (that is not part of the roof construction) are often used for atrium roofs, malls, and other applications that need large skylights. These are treated differently within the Energy Standards: in these cases the skylight area is the surface area of the glazing and frame/curb, *not the area of the rough-framed opening*. This is regardless of the geometry of the skylight, that is, it could be flat pyramid, bubble, barrel vault, or other three-dimensional shape – what matters is the anticipated heat exchanged through the glazing, which is a function of its area. Also, for special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5 of this manual.

§140.3(c)4 also requires that the skylight area be at least 3 percent of the floor area (not accounting for obstructions), or that the product of the skylight area and the area-weighted average visible transmittance of the skylights be at least 1.5 percent of the floor area (not accounting for obstructions). This assures that enough light reaches the skylighted spaces. The visual transmittance option acknowledges that more skylight area is not needed for buildings with highly transmitting skylights. For example, if plastic skylights are installed with the prescriptive minimum transmittance of 0.64, the maximum ratio of skylight area to floor area within 0.7 times the ceiling height of skylights is 2.3 percent.

Figure 3-19: Skylight Area



B. Skylight U-Factor

§140.3(a)6B

The U-factor for skylights is an inclusive measurement of its heat losses, and includes heat losses through the glazing, the frame, and the integral curb (when one exists). If an NFRC rating does not exist, such as for projecting plastic skylights, the designer can make use of default fenestration U-factors found in Table 110.6-A of the Energy Standards.

For skylights, the U-factor criteria depend on whether the skylight glazing material is plastic or glass, and whether the skylight is curb-mounted, noting that plastic skylights are assumed to be mounted on a curb. These criteria are shown in Tables 140.3-B, C, and D.

C. Skylight SHGC

§140.3(a)6C

Skylights are regulated for SHGC rather than RSHGC because skylights cannot have overhangs. The SHGC criteria vary with the SRR, and the criteria can be found in Tables 140.3-B, C, and D (Table 3-19). The designer can make use of default SHGC values in Table 110.6-B of the Energy Standards, or can use the Nonresidential Reference Appendix NA6 if all site-built fenestration (skylights and vertical fenestration) is less than 1,000 ft².

D. Visible Transmittance (VT)

§140.3(a)6D

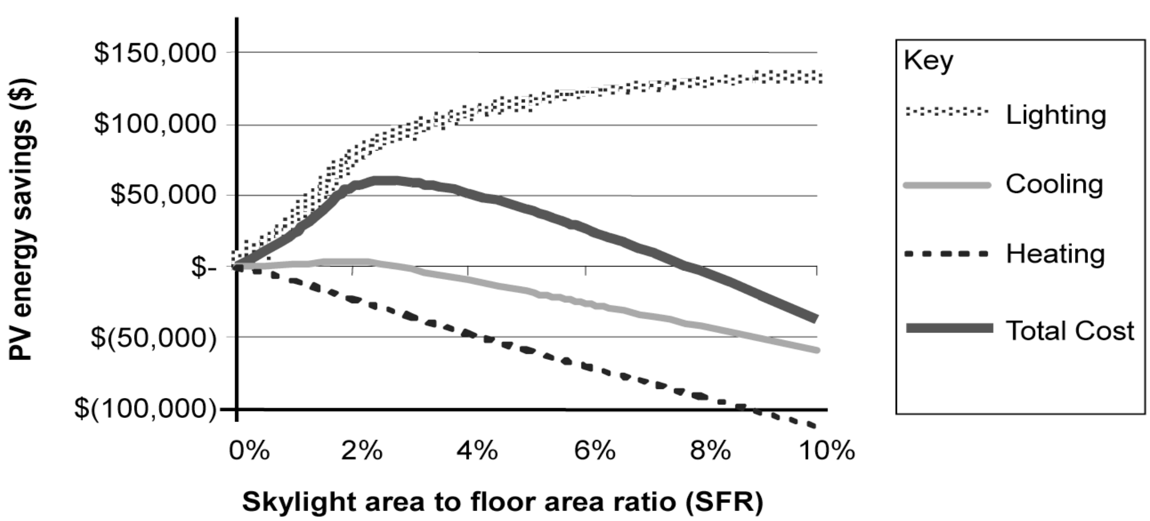
Skylights shall have an area-weighted average visible transmittance (VT) of no less than the value required by §140.3(a)6D.

E. Minimum Daylighting Prescriptive Requirements in Large Enclosed Spaces

§140.3(c)

Appropriately sized skylight systems can dramatically reduce the lighting energy consumption of a building when combined with appropriate daylighting controls. Daylighting control requirements under skylights are discussed in Chapter 5 of this manual. Sizing is important: with too little skylight area, insufficient light is available to turn off electric lighting; with too much skylight area, solar gains and heat losses through skylights negate the lighting savings by adding heating and cooling loads.

Figure 3-20: Present Value Savings of Skylight 50,000 ft² Warehouse in Sacramento



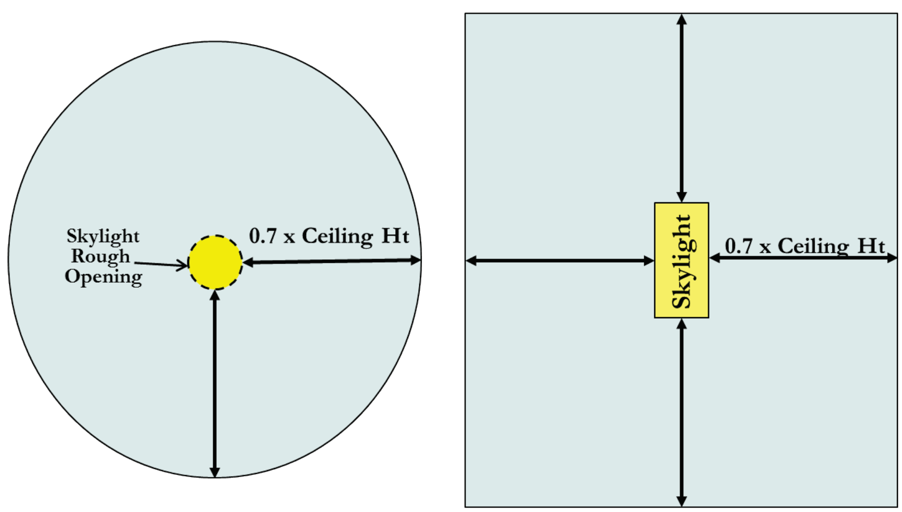
Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms) that:

- Are larger than 5,000 ft².
- Are directly under a roof.
- Have ceiling heights greater than 15 ft.
- Have lighting power densities greater than 0.3 W/ft².

The Energy Standards require that at least 75 percent of the floor area be within one or more of the following:

1. A skylit daylit zone, meaning an area in plan view that is directly under a skylight or within 0.7 times the average ceiling height in each direction from the edges of the rough opening of the skylight (see Figure 3-21), or
2. A primary sidelit daylit zone, meaning an area in plan view that is directly adjacent to vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window based on §130.1(d).

Figure 3-21: Area Within 0.7 Times Ceiling Height of Rough Opening of Circular Skylight and Rectangular Skylight

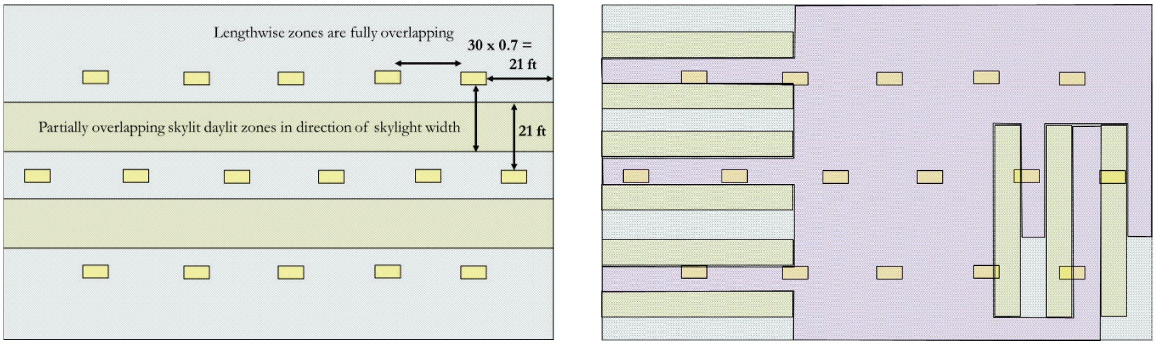


The shape of the skylit daylit zone will be similar in shape to the rough opening of the skylight, as shown in Figure 3-21.

Examples: If the skylight is circular, the area that is within a horizontal distance 0.7 times the average ceiling height from the edge of the rough opening, is also a circle, with the radius of the circle being the radius of the skylight + 0.7 x the ceiling height.

If the skylight is rectangular, the zone is rectangular, with the edges increased in each direction by 0.7 times the ceiling height.

Figure 3-22: Comparison of Skylit Area for Calculating Minimum Skylit Area and the Skylit Daylit Zone for Controlling Luminaires in §130.1(d)



a) Entire space is within 0.7 x ceiling height of skylights for meeting minimum daylit area (§140.3(c))

b)Skylit daylit zone (§130.1(d)) for controlling luminaires is limited by racks blocking daylight

The specifications for daylighting controls in §130.1(d) describe which luminaires must be controlled, and consider the daylight obstructing effects of tall racks, shelves, and partitions taller than one-half the distance from the floor to the bottom of the skylight when determining if daylight will reach a given space. As shown in Figure 3-22, it is considerably easier to calculate.

(a) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights.

Versus

(b) The total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of rough opening of skylights, minus any area on a plan beyond a permanent obstruction that is taller than the following: A permanent obstruction that is taller than one-half the distance from the floor to the bottom of the skylight.

(a) is required to be calculated to comply with minimum skylight area requirements of §140.3(c), and (b), is required to comply with the automatic daylighting control requirements of §130.1(d) (essentially, to ensure that daylighting controls are not installed where they would not be effective).

In §130.1(d), the skylit daylit areas are required to be drawn on the plans, and any general lighting luminaires that are in the daylit zones must be separately controlled by automatic daylighting controls. (See the daylighting requirements in Chapter 5 Lighting).

Two exemptions from §140.3(c) include:

1. *Auditoriums, churches, museums and movie theaters due to the demanding lighting control needs.*
2. *Refrigerated warehouses to minimize heat gains.*

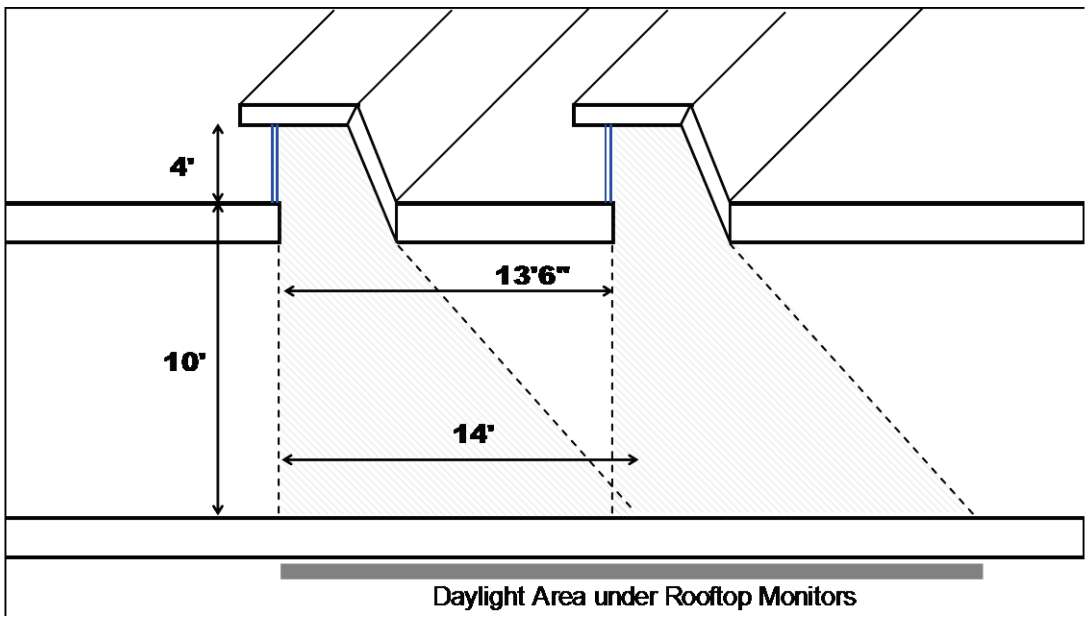
Since skylights paired with daylighting controls can significantly reduce energy demands from lighting, they are mandatory on all nonresidential occupancies that meet the above criteria *whether the space is conditioned or unconditioned*. Further information can be found in Section 3.3.3.1.

For large buildings with high ceilings, skylighting 75 percent of the floor area can be achieved by evenly spacing skylights across the roof of the building. As a general rule, a space can be fully skylighted by having skylights spaced so that the edges of the skylights are not further than 1.4 times the ceiling height apart. For example, in a space having a ceiling height of 20 feet, the space can be fully skylighted if the edges of skylights are no more than 28 feet apart.

F. Rooftop Monitors

Rooftop monitors are considered vertical fenestration, and the daylight area next to them is the same as the daylit area next to other vertical fenestration. The daylit area is from the inward facing plane of the fenestration one window head height and in the direction parallel to the fenestration 0.5 window head heights on either side.

Figure 3-23: Daylight Area Under Rooftop Monitors (Primary Sidelit Daylit Zone)



G. Exceptions for Shading

Occasionally there is not a solar resource available for skylighting. This situation occurs, for example, if a short building is shadowed by surrounding taller buildings. To account for this, minimum daylighting requirements are exempted for spaces where permanent architectural features of the building, existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m. This can be documented to the local building official using a variety of tools including equipment that superimposes the sun path diagram on a photograph of the sky taken at the site[4], hand calculation tools such as the sun path calculator[5], and computer-aided design software tools that automate this calculation.

4 Resource noted for information only, not intended as an endorsement: http://www.solarpathfinder.com/

5 Resource noted for information only, not intended to be an endorsement https://www.pilkington.com/resources/pilkingtonsunanglecalculatormanual.pdf

3.3.3.3. Ignoring Partitions and Shelves

The rationale for ignoring the presence of partitions for specifying minimum skylight area and spacing is that the design of the envelope may be developed before there is any knowledge of the location of the partial height partitions or shelves, as is often the case for core and shell buildings. Thus, the architectural daylit zone requirement of 75 percent of the space area indicates the possibility of the architectural space being mostly daylit. By not accounting for partial ceiling height partitions and racks, the Energy Standards are consistent in addressing architectural daylit areas, regardless of whether the design is core and the shell or a complete design development, including interior design. This approach does not require the addition of extra skylights or windows if racks and partial height partitions are added later.

Example 3-15

Question:

What is the maximum spacing and recommended range for skylights in a 40,000 ft^2 warehouse with 30-foot-tall ceiling and a roof deck?

Answer:

From the definition of *Skylit Daylit Zone* in Section 130.1(d), the maximum spacing of skylights that will result in the space being fully skylit is:

Maximum skylight spacing = 1.4 x Ceiling Height + Skylight width

Spacing skylights closer together results in more lighting uniformity and thus better lighting quality, – but costs more as more skylights are needed. However as a first approximation, one can space the skylights 1.4 times the ceiling height. For this example, skylights can be spaced 1.4 x 30 = 42 feet. In general the design will also be dictated by the size of roof decking materials (such as 4' by 8' plywood decking) and the spacing of roof purlins so the edge of the skylights line up with roof purlins. For this example, staff assumes that roof deck material is 4' by 8' and skylights are spaced on 40-foot centers.

Each skylight is serving a 40-foot by 40-foot area of 1,600 sf. A standard skylight size for warehouses is often 4' by 8' (so it displaces one piece of roof decking). The ratio of skylight area to daylit area is 2 percent (32/1600 = 0.02). Assuming this is a plastic skylight and it has a minimally compliant visible light transmittance of 0.64, the product of skylight transmittance and skylight area to daylit area ratio is

(0.64)(32/1,600) = 0.013 = 1.3%

This is a little less than the 2 percent rule of thumb described earlier for the product of skylight transmittance and skylight area to daylit area ratio. If one installed an 8 ft by 8 ft skylight (two 4 ft by 8 ft skylights) on a 40 foot spacing, it would yield a 2.6 percent product of skylight transmittance and skylight area to daylit area ratio and provide sufficient daylight. With 64 square feet of skylight area for each 1,600 square feet of roof area, the skylight-to-roof area ratio (SRR) is 4 percent, which is less than the maximum SRR of 5 percent allowed by Section 140.3(a) and thus complies with the maximum skylight requirement.

An alternate (and improved) approach would be to space 4 ft x 8 ft skylights closer together, which would provide more uniform daylight distribution in the space and could more closely approach the desired minimum VT skylight area product. A 32-foot center-to-center spacing of skylights results in (32 x 32) = 1,024 square feet of daylit area per skylight. By taking the product of the skylight VT and the skylight area and dividing by 0.02 (the desired ratio), it yields the approximate area the skylight should serve. In this case, with a VT of 0.65 and a skylight area of 32 square feet, each skylight should serve around:

(0.64 x 32 /0.02) = 1,024 sf.

For a minimally compliant 4 ft by 8 ft plastic skylight with a visible light transmittance of 0.65, the product of skylight transmittance and skylight area to daylit area ratio is:

(0.64)(32/1,024) = 0.020 = 2.0%

Energy savings can be improved than this rule of thumb approach by using a whole-building energy performance analysis tool that enhances the trade-offs among daylight, heat losses and gains, and electric lighting energy consumption.

3.3.3.4. **Glazing Material and Diffusers**

§140.3(a)6E

Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003 (notwithstanding its scope) or other test method approved by the Energy Commission.

For conditioned spaces the Energy Standards require the use of double-glazed skylights. When the skylights are above unconditioned spaces, there is no limitation placed on the maximum skylight area or the U-factor or SHGC.

Regardless of whether the space is conditioned, the code requires that the skylights diffuse and bring in enough sunlight so that, when the electric lights are turned off, the occupants have relatively uniform daylight in the space. If the space is unconditioned, single-glazed skylights will comply with the code requirements as long as they are sufficiently diffusing (that is, the glazing or diffuser material has a haze rating greater 90 percent) and the visible transmittance is above the VT requirements in Table 140.3-B or C of the Energy Standards. Products that have such a rating include prismatic diffusers, laminated glass with diffusing interlayers, pigmented plastics, and so forth. This requirement assures that light is diffused over all sun angles. Any unconditioned space that later becomes conditioned must meet the new construction envelope requirements. Therefore, if the space may become conditioned in the future, it is recommended that the envelope meet the conditioned envelope thermal requirements.

Other methods of diffusion that result in sufficient diffusion of light over the entire year would also be acceptable in lieu of using diffusing glazing. Acceptable alternatives are baffles or reflecting surfaces that ensure direct beam light is reflected off a diffuse surface before entering the space over all sun angles encountered during a year. This alternative method of diffusion would have to be documented by the designer and approved by the code authority in your jurisdiction.

Figure 3-24: Daylit Area Under Skylights

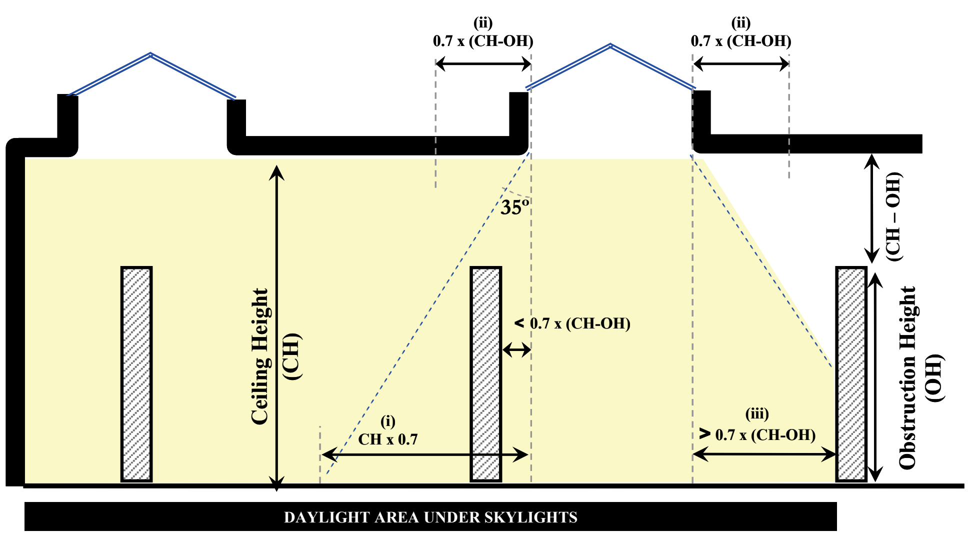
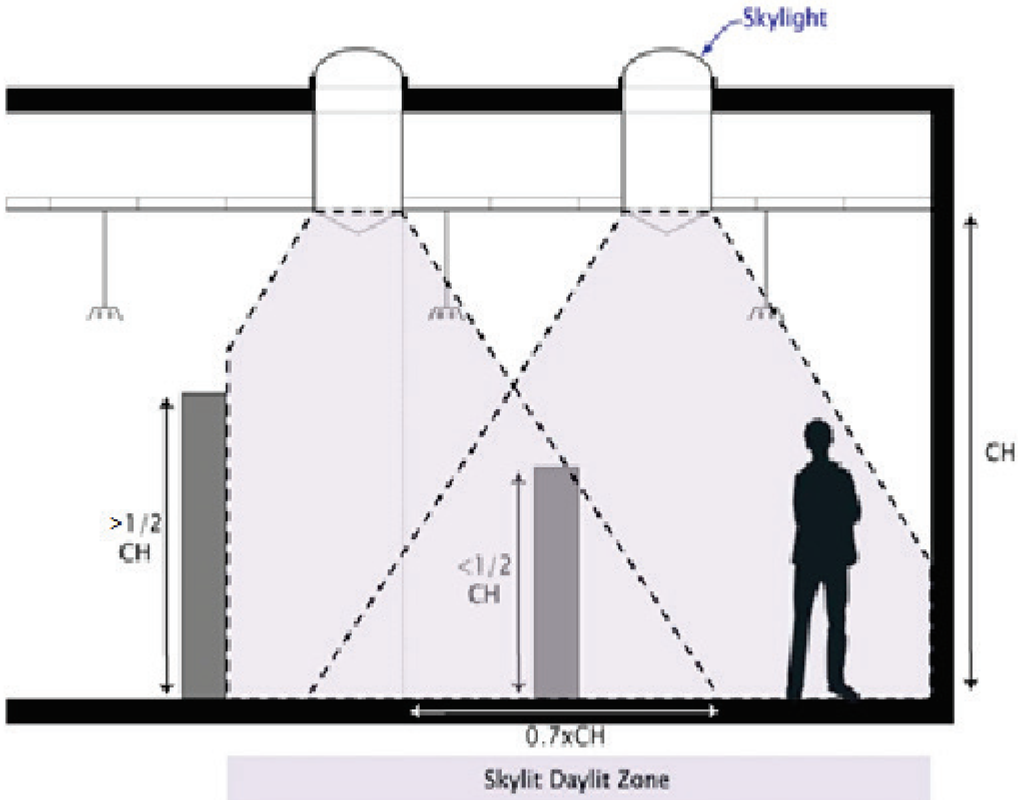


Figure 3-25: Daylit Area Tradeoff Between Skylights



Example 3-16

Question:

A designer is using a U-factor of 0.57 for compliance with a curtain wall system. The glazing system uses two lites of 1/4 in (6mm) glass with a low-e= 0.1 coating on the second surface. The air gap is 1/2 in (12 mm). A standard metal frame is proposed for the curtain wall system. Is 0.57 a reasonable U-factor for compliance, and can it reasonably be achieved by the glazing contractor through the NFRC process for site-built fenestration?

Answer:

The default U-factor for this glazing combination from Reference Nonresidential Appendix NA6 is 0.59. If no NFRC rating information is available, a U-factor of 0.59 must be used. The design U-factor of 0.57 cannot be used.

3.4 Relocatable Public School Buildings

Table 140.3-D of the Energy Standards
Reference Nonresidential Appendix NA4

Public school building design is defined by these prescriptive requirements:

- Table 140.3-B covers prescriptive requirements for climate-specific relocatable public school buildings.
- Table 140.3-D covers prescriptive requirements for relocatable public school buildings that can be installed in any climate zone.

- Building envelopes must meet the prescriptive requirements in §140.3. For additional design requirements, refer to §140.3 and Reference Nonresidential Appendix NA4.

Manufacturers must certify compliance and provide documentation according to the chosen method of compliance. Performance compliance calculations must be performed for multiple orientations, with each model using the same proposed design energy features rotated through the different orientations (north, east, south and west) and the 12 climate zones (Reference Nonresidential Appendix NA4). Also see §140.3(a)8 and §141.0(b)2.

When the manufacturer/builder certifies a relocatable public school building for use in any climate zone, the building must be designed and built to meet the energy budget for the most severe climate zones (as specified in the Reference Nonresidential Appendix NA4), assuming the prescriptive envelope criteria in Table 140.3-D of the Energy Standards.

However, when the relocatable building is manufactured for use in specific climate zones and cannot be lawfully used in other climate zones, the energy budget must be met for each climate zone that the manufacturer/building certifies, using prescriptive envelope criteria in Table 140.3-B. The energy budget and the energy use of the proposed building must be determined using the multiple orientation approach specified in the Reference Nonresidential Appendix NA4. The manufacturer/builder shall meet the requirements for identification labels specified in §140.3(a)8.

3.5 Performance Approach

§140.1 Performance

Under the performance approach, energy use of the building is modeled by compliance software approved by the Energy Commission. The compliance software simulates the time-dependent value (TDV) energy use of the proposed building, including a detailed accounting of envelope heat transfers using the assemblies and fenestration input, and the precise geometry of any exterior overhangs or side fins. The most accurate tradeoffs between different envelope components – and among the envelope, the space-conditioning system, and the installed lighting design – are accounted for and compared with the standard design version of the building. The proposed design has to have TDV energy less than or equal to the standard design.

This section presents some basic details on the modeling of building envelope components. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program. All compliance software, however, are required to have the same basic modeling capabilities. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 9.

The following modeling capabilities are required by all approved nonresidential compliance software. These modeling features affect the thermal loads seen by the HVAC system model. More information may be found in the *ACM Reference Manual* and the CBECC-Com User Guide.

3.5.1 Opaque Surface Mass Characteristics

Heat absorption, retention, and thermal transfer characteristics associated with the heat capacity of exterior opaque mass surfaces such as walls, roofs and floors are modeled.

Typical inputs are:

- Spacing

- Thickness
- Standard U-factor
- Reference Appendix JA4 table
- Framed cavity R-value
- Proposed assembly U-factor.

The heat capacity of concrete masonry unit walls and solid concrete walls is provided in Tables 4.3.5 and 4.3.6 of Reference Appendix JA4. Effective R-values for interior and exterior insulation are provided in Table 4.3.13 of Reference Appendix JA4.

3.5.2 Opaque Surface

Heat gains and heat losses are modeled through opaque surfaces of the building envelope. The following inputs or acceptable alternative inputs are used by this modeling capability:

1. Surface areas by opaque surface type.
2. Surface orientation and slope.
3. Thermal conductance of the surface. The construction assembly U-factor is developed by specifying a construction as a series of layers of building materials, each of which may be insulation, framing, homogenous construction material, or a combination of framing and cavity insulation.
4. Surface absorptance = 1– solar reflectance. Surface absorptance is a restricted input (except for roofs).

Note for roofs: Surface absorptance and emittance are variable inputs in the proposed design for roofs to provide design flexibility where a cool roof is not specified. The roof reference design is set with a cool roof surface absorptance for nonresidential buildings in all climate zones. The difference in surface absorptance creates a credit that can be used with the whole-building performance method. For more information on cool roofs, see Section 3.2.2.1.

To model the proposed design as a cool roof, the roofing product must be listed in the directory of the CRRC. If the roof is not rated, a default aged reflectance of 0.08 is used for asphalt or composition shingles and 0.10 for other roofing products. If the proposed design does not have a cool roof, the performance method may be used to trade off with other measures, such as increased insulation or HVAC equipment efficiency, so that the TDV energy of the proposed design does not exceed that of the standard design.

3.5.3 Fenestration Heat Transfer

Heat transfer through all fenestration surfaces of the building envelope are modeled using the following inputs:

1. Fenestration areas. The glazing width and height dimensions are those of the rough-out opening for the window or fenestration product. Window area of the standard design is limited to the prescriptive limit of 40 percent of the gross exterior wall area (that is adjacent to conditioned space) or six times the display perimeter, whichever is greater. If the proposed design window area exceeds this limit, a trade-off may be made with measures such as increased envelope insulation or increased equipment efficiency to offset the penalty from fenestration.
2. Fenestration orientation and slope. Vertical windows installed in a building located in any of the four cardinal orientations, north, south west, and east. Skylights are

considered less than 60° from the horizontal, and all windows and skylights provide solar gain that can affect the overall energy of the building unless they are insulated glass.

3. Fenestration thermal conductance (U-factor). The overall U-factor shall be taken from NFRC rating information, default values in Table 110.6-A of the Energy Standards, or from Reference Nonresidential Appendix NA6 if less than 1,000 ft².
4. Fenestration solar heat gain coefficient (SHGC). The SHGC shall be taken from NFRC rating information default values in Table 110.6-B of the Energy Standards or from Reference Nonresidential Appendix NA6 if less than 1,000 ft². The baseline building uses a SHGC equal to the value from Tables 140.3-B, 140.3-C, or 140.3-D. The baseline building has no overhangs, but overhangs can be modeled in the baseline building, as described below.

3.5.4 Overhangs and Vertical Shading Fins

Approved compliance software programs are able to model overhangs and vertical fins. Typical inputs for overhangs are:

- Overhang projection.
- Height above window.
- Window height.
- Overhang horizontal extension past the edge of the window.
  - If the overhang horizontal extension (past the window jambs) is not an input, then the program assumes that the extension is zero (that is, overhang width is equal to window width), which results in fewer benefits from the overhang.

Vertical fins are modeled with inputs of horizontal and vertical position relative to the window, the vertical height of the fin and the fin depth (projection outward perpendicular to the wall).

3.5.5 Slab-on-Grade Floors and Basement Floors

Heat transfer through slab-on-grade floors and basement floors is modeled by calculating perimeter heat losses and interior slab heat losses. The heat losses from the perimeter and the interior are modeled by the use of an F-factor that accounts for the rate of heat transfer from the slab to the soil. Reference Appendix JA4 contains F-factors for common insulation conditions (vertical insulation outside or a combination of the two). The insulation depth and insulation R-value affect heat loss through basement floors.

3.6 Additions and Alterations

The Energy Standards offer prescriptive approaches and a performance approach to additions and alterations, but they do not apply to repairs. Relevant definitions from §100.1(b) are provided below:

A. Addition is a change to an existing building that increases conditioned floor area and volume. See §141.0(a) and §100.1(b) for a detailed definition.

When an unconditioned building or unconditioned part of a building adds heating or cooling so that it becomes conditioned, this area is treated as an addition.

B. Alteration is a change to an existing building that is not an addition. An alteration could include a new HVAC system, lighting system, or change to the building envelope, such as a new window. See §141.0(b) and §100.1(b). Roof replacements (reroofing) and reconstructions and renewal of the roof are considered alterations and are subject to all applicable Energy Standards requirements. For alterations, the compliance procedure includes:

1. The prescriptive envelope component approach.
2. The addition alone approach.
3. The existing-plus-alteration performance approach.
4. The existing-plus-addition-plus alteration performance approach.

C. Repair is the reconstruction or renewal of any part of an existing building for maintenance. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration. See §141.0(b) and §100.1(b).

For example, a repair could include the replacement of a pane of glass in an existing multilite window without replacing the entire window.

Additions and alterations to the building envelope must meet the prescriptive insulation requirements in §141.0 or comply with the performance compliance approach.

3.6.1 Mandatory Requirements

3.6.1.1. Additions

All additions must meet the applicable mandatory measures from the following Energy Standards sections:

- §110.6 − Mandatory Requirements for Fenestration Products and Exterior Doors
- §110.7 − Mandatory Requirements for Joints and Other Openings
- §110.8 − Mandatory Requirements for Insulation and Roofing Products (Cool Roofs)
- §120.7− Mandatory Requirements for Insulation.

3.6.1.2. Alterations

§141.0(b)1

All alterations must meet the mandatory requirements stated above for additions, with the exception of the insulation requirement of §120.7 for opaque envelope components (roofs, ceilings, walls, and floors).

A. Wall Insulation

Insulation for walls that separate conditioned space from either unconditioned space or the exterior shall comply with the mandatory requirements of §141.0(b)1B. This section provides two options for wall insulation compliance: either a minimum insulation R-value or a maximum assembly U-factor. The mandatory requirements are determined by the wall type:

- Light mass and heavy mass walls do not have mandatory requirements for minimum R-value and maximum U-factor.

- Metal buildings - A minimum of R-13 insulation between framing members or an area-weighted average U-factor no greater than 0.113 is required.
- Metal-framed walls - A minimum of R-13 insulation between framing members or an area-weighted average U-factor no greater than 0.217 is required.
- Wood-framed walls and other wall types - A minimum of R-11 insulation between framing members, or an area-weighted average U-factor no greater than 0.110 is required.
- Spandrel panels and glass curtain walls - A minimum of R-4 insulation or an area-weighted average U-factor no greater than 0.280 is required.

B. Floor Insulation

Insulation for floors that separate conditioned space from either unconditioned space or the exterior shall comply with the mandatory requirements of §141.0(b)1C. This section provides two options for compliance with the mandatory requirements: either a minimum insulation R-value or a maximum assembly U-factor. For floors, the mandatory requirements are determined by both building type and floor type.

- Raised framed floors - A minimum of R-11 insulation between framing members or the weighted average U-factor no greater than 0.071 is required.
- Raised mass floors in high-rise residential and hotel/motel guest rooms - A minimum of R-6 insulation or an area-weighted average U-factor no greater than 0.111 is required.
- Raised mass floors in all other occupancies - No minimum U-factor is required.

3.6.2 Prescriptive Requirements

3.6.2.1 Additions

§141.0(a)1

Prescriptive compliance for the building envelope of additions is addressed in §141.0(a)1 and §140.3. §140.3(a) provides prescriptive compliance alternatives for the building envelope, including tradeoffs between roofing insulation and the solar reflectance of roofing products (cool roofs) in Table 140.3-A. Tradeoffs between other envelope components are not allowed in the prescriptive method. The performance method may be used for tradeoff for both new construction and alterations.

All additions must also comply with §140.3(c), Minimum Skylight Area, for large enclosed spaces in buildings with three or fewer stories.

For more details on the prescriptive requirements for additions, see Section 3.2 for envelope requirements and Section 3.3 for fenestration requirements.

Alternatively, the addition may meet compliance by using the performance compliance approach of §140.1, which compares the TDV energy (space conditioning, lighting, and water heating) of the proposed building addition to a TDV energy budget that complies with prescriptive requirements.

3.6.2.2 Alterations

§141.0(b)2

In general, any alteration to an existing building that involves changes to a portion of the building envelope triggers the Energy Standards. The prescriptive requirements for alterations to building envelopes are in §141.0(b)2A and B of the Energy Standards.

The altered components of the envelope shall meet the applicable mandatory requirements of §110.6 and §110.8.

A. Fenestration

When fenestration is altered that does not increase the fenestration area, it shall meet the requirements of Table 141.0-A of the Energy Standards (Table 3-20 below) based on climate zone.

When new fenestration area is added to an alteration, it shall meet the requirements of §140.3(a) and Tables 140.3-B, C or D of the Energy Standards. Compliance with §140.3(a) is not required when the fenestration is temporarily removed and then reinstalled.

In cases where small amounts of fenestration area are changed, several options exist.

- If less than 150 ft² of fenestration area is replaced throughout the entire building, then the Energy Standards require that only the U-factor requirements in Tables 140.3-B, C, or D are met. The SHGC, RSHGC, or VT requirements need not be met.
- The same requirements and exceptions apply if 50 ft² or less of fenestration (or skylight) area is added. A typical example of this may be changing a door from a solid door to a glass door.

Table 3-20: Altered Window Maximum U-Factor and Minimum RSHGC and VT

Climate Zone	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
U-factor	0.47	0.47	0.58	0.47	0.58	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
RSHGC	0.41	0.31	0.41	0.31	0.41	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.41

		Fixed Window	Operable Window	Curtain Wall/ Storefront	Glazed Doors
VT	Vertical	0.42	0.32	0.46	0.17
		Glass, Curb-Mounted	Glass, Deck-Mounted	Plastic, Curb-Mounted	
	Skylights	0.49	0.49	0.64	

Energy Standards Table 141.0-A

Example 3-17

Question:

The envelope and space conditioning system of an office building with 120,000 ft² of conditioned floor area is being altered. The building has 24,000 ft² of vertical fenestration. Which of the following scenarios does the NFRC label certificate requirement apply to?

1. Existing glazing remains in place during the alteration.

2. Existing glazing is removed, stored during the alteration period, and then reinstalled (glazing is not altered in any way).

3. Existing glazing is removed and replaced with new site-built glazing with the same dimensions and performance specifications.

4. Existing glazing on the north façade (total area 800 ft²) is removed and replaced with site-built fenestration.

Answer:

NFRC label certificate or California Energy Commission default values requirements do not apply to Scenarios 1 and 2 but do apply to Scenario 3.

1. Requirement does not apply because the glazing remains unchanged and in place.

2. *Exception* to §110.6(a)1 applies in this case. (This exception applies to fenestration products removed and reinstalled as part of a building alteration or addition.)

3. Use either NFRC label certificate or use Table 110.6-A default values; applies in this case as 24,000 ft² (more than the threshold value of 1,000 ft²) of new fenestration is being installed.

4. Since the site-built fenestration area is less than 1,000 ft², use either the NFRC label certificate, the applicable default U-factor or SHGC set forth in Reference Nonresidential Appendix NA6, or California Energy Commission default values.

B. Walls and Floors

All nonresidential building alterations involving exterior walls, demising walls, external floors, or soffits must either comply as a component with the requirements in Tables 140.3-B, C, or D in the Energy Standards, or by approved compliance software following the rules of the *ACM Reference Manual* that demonstrates that the overall TDV energy use of the altered building complies with the Energy Standards.

C. Roofs

Existing roofs being replaced, recovered, or recoated for nonresidential, high-rise residential and hotels/motels buildings shall meet the requirements of §110.8(i). When the alteration is being made to either 50 percent of the existing roof area or when more than 2,000 ft^2 of the roof is being altered, the requirements of this section apply. Thus, when a small repair is made, these requirements do not apply. For example, the requirements of regarding roof insulation would not be "triggered" if the existing roof surface were overlaid instead of replaced.

These requirements do apply to roofs over conditioned, nonprocess spaces even if the building has a portion that is a process space. These roof areas can be delineated by the fire separation walls between process areas and conditioned, nonprocess areas.

The California Building Code and local amendments place limitations on the number of new roof covering layers that are allowed to overlay an existing roof covering in accordance with CBC 1510. When this limit is reached, the existing roof covering must be removed down to the roof deck or to the insulation recover boards.

When a roof is exposed to the roof deck or to the roof recover boards, and alteration complies with the prescriptive requirements for roofing products, the exposed roof area shall be insulated to the levels specified in Table 141.0-C of the Energy Standards (Table 3-21 below).

The amount of insulation required varies by climate zone and building type. The requirements are given in terms of a continuous layer of insulation (usually installed on top of the roof deck) or an overall roof U-factor based on the default tables and calculation method in Reference Appendix JA4. The U-factor method provides the most flexibility, as insulation can be added continuously on top of the roof deck, below the roof deck between roof joists, or a combination of insulation above and below the roof deck.

Table 3-21: Insulation Requirements for Roof Alterations

	Nonresidential		High-Rise Residential and Guest Rooms of Hotel/Motel Buildings	
Climate Zone	Continuous Insulation R-value	U-Factor	Continuous Insulation R-Value	U-Factor
1	R-8	0.082	R-14	0.055
2	R-14	0.055	R-14	0.055
3-9	R-8	0.082	R-14	0.055
10-16	R-14	0.055	R-14	0.055

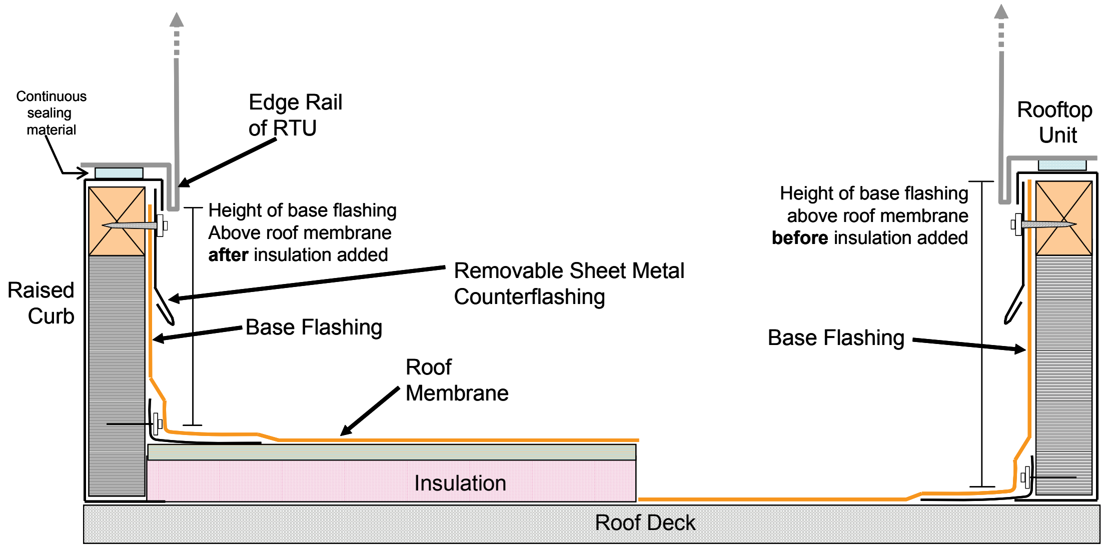
Energy Standards Table 141.0-C

For reroofing, when roofs are exposed to the roof deck and meet the roofing products requirements in §141.0(b)2Bi or ii, the exposed area must be insulated to levels specified in the Energy Standards Table 141.0-C. For nonresidential buildings, this level is R-8 continuous insulation in Climate Zones 1 and 3 through 9 and R-14 continuous insulation in Climate Zones 2 and 10 through 16. Several exceptions are provided:

1. No additional insulation is required if the roof is already insulated to a minimum level of R-7.
2. When insulation is added on top of a roof, the elevation of the roof membrane is increased. As shown in Figure 3-26, when insulation is added to a roof and the curb height (or reglet or counterflashing for walls) is unchanged, the height of the base flashing above the roof membrane will be reduced. In some cases when the overhanging edge of the space-conditioning equipment is very close to the side of the curb, this may also limit how far up the curb the base flashing may be inserted. Many manufacturers and the National Roofing Contractors Association (NRCA) recommend maintaining a minimum base flashing height of 8 inches above the roofing membrane.

Thus, when adding insulation on top of a formerly uninsulated or underinsulated roof, one must consider the effects on base flashing height. It may be desirable to increase curb heights or counterflashing heights to maintain the same or higher base flashing heights above the roof membrane. In other cases, where leak risk is low, one can ask the roofing manufacturer for a variance on installation requirements for a roofing warranty; this may require additional waterproofing measures to obtain the manufacturer's warranty. Installing insulation under the roof deck when access is feasible doesn't change the base flashing height and, in some cases, may be the least expensive way to insulate the roof.

Figure 3-26: Base Flashing on Rooftop Unit Curb Detail



In some circumstances it is costly or difficult to increase the curb or counterflashing height for maintaining the base flashing at a suitable height above the roof membrane. In the following situations, added insulation is limited to the thickness that will still maintain a base flashing height of 8 inches (20 cm) above the surface of the roof membrane.

If there is any space-conditioning equipment on the roof that is not disconnected and lifted during reroofing, the condition of this “undisturbed” equipment will determine how much, if any, insulation must be added to the entire roof. That is, if the equipment that is not disconnected and lifted is situated on a curb that is 9 inches above the roof membrane, only 1 inch of insulation must be added to the roof. If the undisturbed equipment is situated on a curb that is 8 inches (20 cm) or less above the roof membrane, no additional insulation is required.

If adding the required insulation will reduce the base flashing height to less than 8 inches at penthouse or parapet walls, the insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches from the roof membrane surface to the top of the base flashing. For the above exemption to apply, the following conditions must be met:

1. The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material.
2. The penthouse or parapet walls have exterior cladding material that must be removed to install the new roof covering membrane to maintain a base flashing height of 8 inches.
3. For nonresidential buildings, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for Climate Zones 2 and 10 through 16, and less than 100 square feet per linear foot for Climate Zones 1 and 3 through 9.
4. For high-rise residential buildings, hotels, or motels, the ratio of the replaced roof area to the linear dimension of affected penthouse or parapet walls shall be less than 25 square feet per linear foot for all climate zones.

5. Increasing the elevation of the roof membrane by adding insulation may also affect roof drainage. The Energy Standards allow tapered insulation to be used that has a thermal resistance less than that prescribed in Table 141.0-C at the drains and other low points, provided that the thickness of insulation is increased at the high points of the roof so that the average thermal resistance equals or exceeds the value that is specified in Table 141.0-C.

For more details on the prescriptive requirements for alterations, see Section 3.2 for the opaque envelope assembly requirements and Section 3.3.2.2 for the requirements for fenestration.

1. *Thermal Emittance and Solar Reflectance Prescriptive Requirements*

§141.0(b)2B

For nonresidential buildings, the prescriptive requirements for roofing products are based on roof slope and climate zone:

- Low-sloped roofs in Climate Zones 1 through 16 have a required minimum aged solar reflectance of 0.63 and a minimum thermal emittance of 0.75, or a minimum SRI of 75.
- Steep-sloped roofs in Climate Zones 1 through 16 have a minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

For high-rise residential buildings and hotels and motels, the prescriptive requirements for roofing products are based on roof slope and climate zone:

- Low-sloped roofs in Climate Zones 10, 11, 13, 14 and 15 have a required minimum aged solar reflectance of 0.55 and a minimum thermal emittance of 0.75, or a minimum SRI of 64.
- Steep-sloped roofs in Climate Zones 2 through 15 have a required minimum aged solar reflectance of 0.20 and a minimum thermal emittance of 0.75, or a minimum SRI of 16.

There are three exceptions to the prescriptive requirements:

Nonresidential buildings:

1. *An aged solar reflectance less than 0.63 is allowed, provided that additional insulation is installed.*

High-rise residential buildings and hotels and motels:

1. *For roof area covered by building integrated photovoltaic panels and building integrated solar thermal panels, roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.*
2. *For roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² roofing products are not required to meet the minimum requirements for solar reflectance, thermal emittance, or SRI.*

Table 141.0-B (Table 3-22 below) has been added to the Energy Standards to simplify the process of making insulation/aged solar reflectance trade-off. The table expresses the trade-off requirements in terms of overall roof U-factors, rather than in terms of continuous insulation R-value.

Table 3-22: Roof/Ceiling Insulation Trade-Off for Aged Solar Reflectance

Aged Solar Reflectance	Climate Zone 1, 3-9 U-factor	Climate Zone 2, 10-16 U-factor
0.62 - 0.60	0.075	0.052
0.59 - 0.55	0.066	0.048
0.54 - 0.50	0.060	0.044
0.49 - 0.45	0.055	0.041
0.44 - 0.40	0.051	0.039
0.39 - 0.35	0.047	0.037
0.34 - 0.30	0.044	0.035
0.29 - 0.25	0.042	0.034

Energy Standards Table 141.0-B

U-factors measure the thermal performance of the entire roof assembly, both above and below the roof deck. Utilizing U-factors provides flexibility. Trade-offs can be made by installing additional insulation continuously above the roof deck, between the joists below the roof deck, or a combination of both approaches.

Simplified trade-off process:

- Locate in Table 141.0-B of the Energy Standards the maximum roof/ceiling U-factor that applies to the aged solar reflectance of the roofing products to be installed.
- Locate the climate zone of the building.
- Consult the U-factor tables in Reference Appendix JA4 and then determine what configurations of above and/or below-deck insulation satisfy the trade-off.
    - Reference Appendix JA4 contains U-factor tables for many common roof constructions (wood-framed, metal-framed, span deck, and concrete roofs, and others).

See the examples at the end of this section for illustrations of insulation/reflectance trade-offs.

Table 141.0-B of the Energy Standards not only takes account of the amount of insulation necessary to compensate for using a noncompliant roofing product, it also accounts for the minimum insulation requirements that apply to roof alterations generally.

Example 3-18

Question:

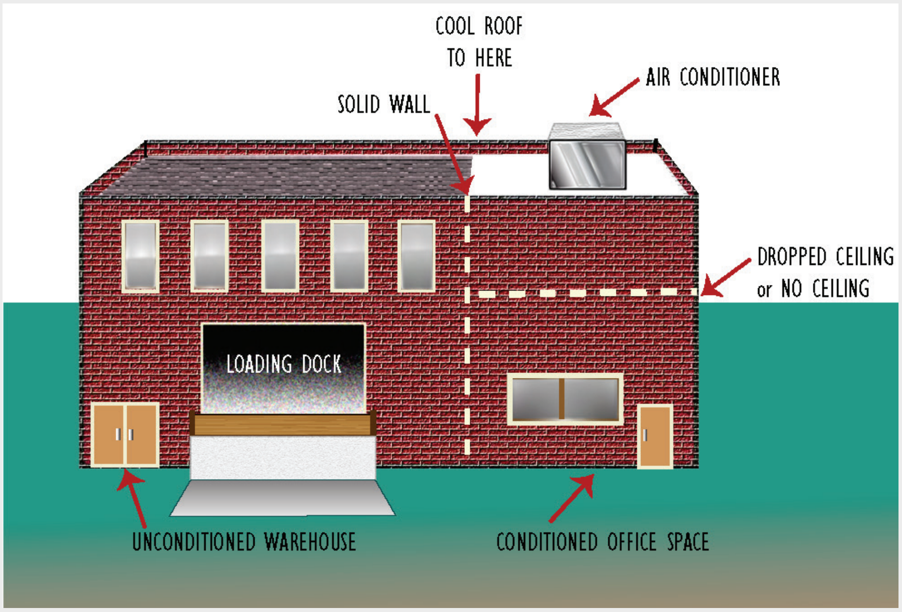
What are the Energy Standards requirements for cool roofs when reroofing an unconditioned warehouse containing conditioned office space? The warehouse has a low-sloped roof.

Answer:

Scenario 1.

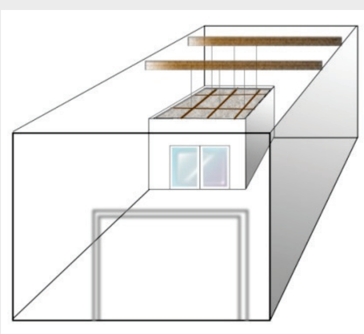
In this situation (see picture below), there is either directly or indirectly conditioned space under the roof. The cool roof requirements apply to just the portion(s) of the warehouse roof over the conditioned space(s). The rest of the roof (over unconditioned warehouse space) is not required to be a cool roof.

The walls of the conditioned space go all the way up to the underside of the warehouse.



Scenario 2.

The walls of the conditioned space do not reach all the way to the warehouse roof. (See picture below.) In this case, the roof requirements do not apply because the space directly below the roof is unconditioned and communicates with the rest of the unconditioned portion of the warehouse.



Example 3-14

Question:

I have a barrel roof on nonresidential conditioned building that needs to be reroofed. Must I follow the Energy Standards roofing product requirement?

Answer:

Yes, the roof would need to meet the aged solar reflectance and thermal emittance for a steep-sloped roof. The reason is that a barrel roof, although it has both low-sloped and steep-sloped roofing areas, has a continuous gradual slope change that would allow the steep-sloped section of the roof to be seen from ground level. This was the reason to allow barrel roofs to only meet the steep-sloped requirement for the entire roof area.

Example 3-20

Question:

40 percent of the low-sloped roof on a 500 ft by 100 ft retail building in Concord, California (CZ12,) is being reroofed. The roofing is removed down to the roof deck, and there is no insulation. The building has a stucco-clad parapet roof, and the current base flashing is 9 inches above the level of the roof. Must insulation be added before reroofing?

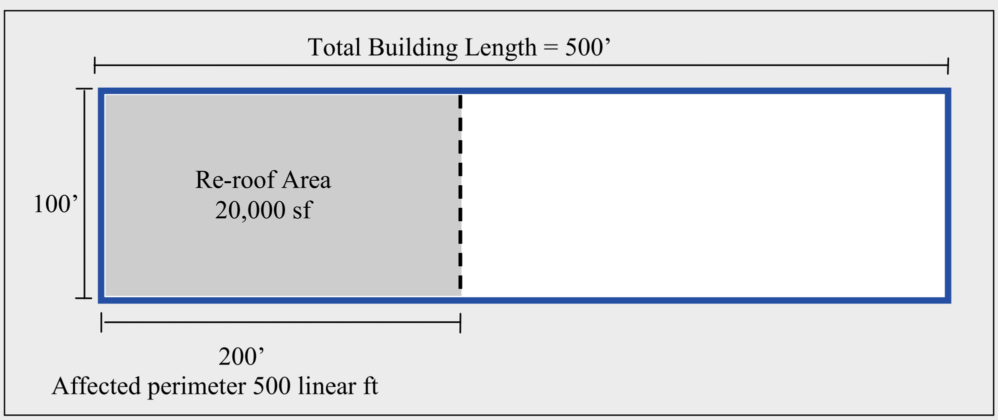


Figure 3-27: Plan View of Partial Building Re-roofing Project

Answer:

Yes, §141.0(b)2B requires when either 50 percent (or more) of the roof area or 2,000 ft² (whichever is less) is reroofed down to the roof deck or recover boards, that insulation be installed if the roof has less than R-7 insulation. Though the reroofing covers only 40 percent of the roof area, the requirements still apply because the 20,000 ft² of replacement roof area is greater than the threshold area of 2,000 ft². As stated in the question, the roof does not have any insulation and, therefore, is required to add insulation.

Concord, California, is in Climate Zone 12[6]. As per Energy Standards Table 141.0-C "Insulation Requirements for Roof Alterations," for nonresidential buildings in Climate Zone 12, the requirement for insulation is either R-14 continuous insulation or an effective roof U-factor of 0.055 Btu/h•ft²•°F. If the ratio of replaced roof area to affected clad wall length is less than 25 ft² of roof per linear ft of wall, then the insulation thickness is allowed to be limited to the maximum thickness that will maintain a base flashing height of no less than 8 inches above the roof membrane.

The ratio of the replaced roof to the affected wall area is 20,000 ft² / 500 linear ft = 40:1. Since this ratio is greater than 25:1, the full required insulation must be installed regardless of the existing base flashing height. This may require changing the height of the base flashing, removing some of the parapet wall cladding and moving the counterflashing (or reglet) higher up on the wall. Alternatively, the installer may ask for the roofing manufacturer to provide a variance in the warrantee to accept a slightly lower base flashing height above the roof surface. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. When access to the underside of the roof deck is available, an alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Energy Standards Table 141.0-C.

Example 3-21

Question:

If the building in the question above was located in San Francisco, would the insulation requirements be different on the building?

Answer:

Yes. San Francisco (as shown in Reference Appendix JA2) is in Climate Zone 3. In Energy Standards Table 141.0-C from §141.0(b)2B, the insulation requirement for roof alterations for nonresidential buildings in Climate Zone 3 is R-8 or a U-factor of 0.081.

The criteria for limiting the insulation thickness based on the existing base flashing height are different for Climate Zone 3 than for Climate Zone 12. For nonresidential buildings in Climate Zone 3, if the ratio of replaced roof area to affected clad wall length is less than 100 ft² of roof per linear foot of wall, then the insulation thickness is limited to the thickness that will maintain a base flashing height of no less than 8 inches above the roof membrane. The ratio of the replaced roof to the affected wall area is 20,000 ft² / 500 linear ft = 40:1. Since this ratio is less than 100:1, only the amount of insulation (and recover board) that will still maintain a base flashing height of 8 inches above the roofing membrane is required. Thus, one could still add 1 inch of insulation board.

Example 3-22

Question:

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement the roof deck will be exposed. This building has a rooftop air conditioner that is sitting on an 8-inch-high curb above the roof membrane level. The roof is uninsulated. If the rooftop air-conditioner unit is not disconnected and not lifted off the curb during reroofing, is adding insulation required?

6 A listing of climate zones by city is found in Reference Appendix JA2.

Answer:

No, the exception to §141.0(b)2Biii, specifically exempts reroofing projects when space-conditioning equipment is not disconnected and lifted. In this case, the requirements for adding insulation are limited to the thicknesses that result in the base flashing height to be no less than 8 inches above the roofing membrane surface, Adding insulation increases the height of the membrane surface and thus for a given curb would reduce the base flashing height above the roof membrane. Since the base flashing height is already 8 inches above the roof membrane, no added insulation is required.

Example 3-23

Question:

What if the rooftop air conditioner from Example 3-22 is lifted temporarily during reroofing to remove and replace the roofing membrane? Is added insulation required?

Answer:

Yes, insulation is required.

The exception to §141.0(b)2Biii specifically applies when the space-conditioning equipment is not disconnected and lifted. Since the roof membrane level will be higher after the addition of insulation, the base flashing height will no longer be 8 inches above the roof membrane. When the rooftop unit is lifted as part of the reroofing project, the incremental cost of replacing the curb or adding a curb extension is reduced.

Thus to maintain the 8-inch base flashing height, one can replace the curb or add a curb extension before reinstalling the roof top unit. Alternatively, one can ask for a roofing manufacturer’s variance to the warranty from the typical minimum required 8 Inches base flashing height above the roof membrane to the reduced amount after the roof insulation is installed. The specific risk of roof leakage at a given site has to be considered carefully before reducing the base flashing height. An alternative method of compliance that does not affect base flashing heights is to add insulation below the roof deck to the overall U-factor levels given in Table 141.0-C of §141.0(b)2B.

Example 3-24

Question:

A nonresidential building is having 5,000 ft² of roofing replaced. During roofing replacement, the roof deck will be exposed. This building has several unit skylights that are sitting on an 8–inch-high (20 cm) curb above the roof membrane level. The roof is uninsulated. Is added insulation required?

Answer:

Yes, insulation is required. The exception to §141.0(b)2Biii specifically applies when space-conditioning equipment is not lifted. Unit skylights are not space-conditioning equipment; thus, the exception does not apply. Removing a unit skylight and increasing its curb height is substantially less effort than that for space-conditioning equipment.

Example 3-25

The rooftop unit with the 9-inch base flashing is disconnected and lifted during reroofing. However, the rooftop unit on the curb with the 14-inch (36 cm) base flashing is not lifted. In this situation, is the insulation added limited to the amount of insulation that will result in an 8-inch base flashing on the unit with the lower curb?

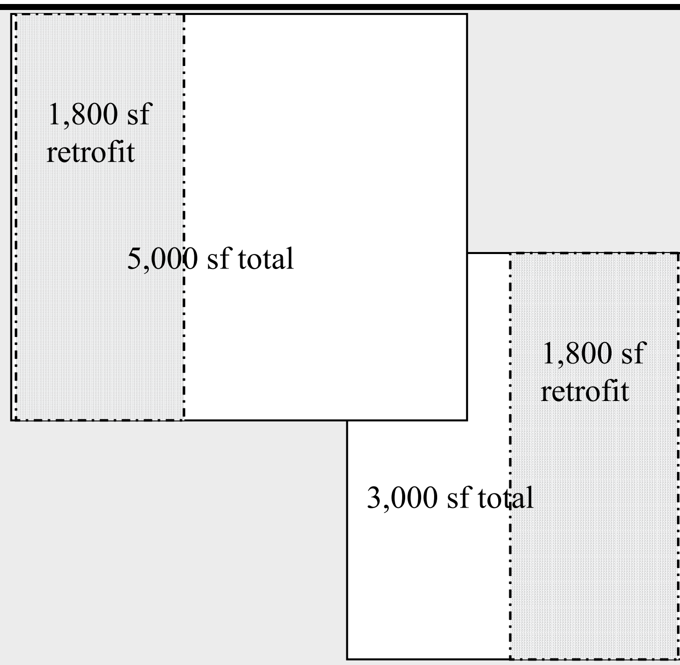


Figure 3-28: Building with Two Roof Configurations

Scenario 1:

A building has low-sloped roofs at two elevations (Figure 3-28). One roof is 18 feet above grade and has a total area of 5,000 ft²; the other roof is 15 feet above grade and has a total area of 3,000 ft². Both roofs are uninsulated and are above conditioned space. If 1,800 ft² of the 3,000 ft² roof is being reroofed and the roof deck is exposed, is that portion of the roof required to be insulated and be a “cool roof” (high reflectance and emittance)?

Answer:

Yes, the reroofed section of the roof must be insulated and have a “cool roof”. Section 141.0(b)2B requires insulation and cool roofs for low-sloped roof alterations if the alteration is greater than 2,000 ft² or greater than 50 percent of the roof area. Since 1,800 ft² is 60 percent of 3,000 ft², the cool roof and insulation requirements apply.

Scenario 2:

If the 1,800 ft² of roofing being replaced was on the 5,000 ft² uninsulated roof, would the portion of the roof replaced be required to have “cool roof” radiative properties and have insulation installed?

Answer:

No. The 1,800 ft² retrofit is 36 percent of the 5,000 ft² roof. Thus, the 1,800 ft² retrofit is less than 50 percent of the roof area and it is less than 2,000 ft²; thus, it is not required to comply with the insulation and cool roof requirements in §141.0(b)2B.

Example 3-26

A 10,000 ft² building in Climate Zone 10 with an uninsulated roof above conditioned space is having roofing removed so that the roof deck is exposed. There are two rooftop units on this section of the roof that is being altered. One rooftop unit has a curb with a 9-inch base flashing, and the other has a modern curb with a 14-inch base flashing. Consider the following three scenarios:

Scenario 1:

Answer:

No. The unit with the 9 inches base flashing was disconnected and lifted and thus it does not qualify for the exception to §141.0(b)2Biii:

"Not be disconnected and lifted as part of the roof replacement." One could add as much as 6 inches or more of insulation before the base flashing height would be reduced below 8 inches on the unlifted rooftop unit with a 14-inch curb. The Climate Zone 10 roof insulation requirement is R-14. The thickness of rigid insulation that provides this amount of R-value is substantially thinner than 6 inches. Thus, the full R-14 insulation would be required.

Scenario 2:

The rooftop unit with the 9-inch base flashing is not disconnected and lifted during reroofing. In this situation, is the insulation that must be added limited to the amount of insulation that will result in an 8-inch base flashing on the unit with the lower curb?

Answer:

Yes. The unit with the 9-inch (23 cm) base flashing was not disconnected and lifted, and thus it qualifies for the exception to §141.0(b)2Biiia. One could add only 1 inch (2.5 cm) of insulation before the base flashing height would be reduced below 8 inches (20 cm) on the unlifted rooftop unit with a - inch (23 cm) base flashing. The insulation requirement is R-14, but the thickness of rigid insulation that provides this amount of R-value is greater than 1 inch (2.5 cm). Therefore, only 1 inch (2.5cm) of additional insulation is required because adding any more insulation would reduce the base flashing height below 8 inches (20 cm) on the unlifted rooftop unit with a 9-inch (23 cm) base flashing.

Scenario 3:

In Scenario 2 above, does this reduced amount of required insulation apply only to the area immediately surrounding the unlifted unit or to the entire roof?

Answer:

The added insulation for the entire roof would be limited to 1 inch (2.5 cm) so that the base flashing of the unlifted unit is not reduced to less than 8 inches (20 cm). However, if a building has multiple roofs, the limitation would apply only to any roof with a rooftop unit that was not disconnected and lifted and that has a low curb.

Example 3-15

Question:

In reroofing, is existing roofing that is a rock or gravel surface equivalent to a gravel roof over an existing cap sheet, and therefore qualify for the exception discussed in the previous question?

Answer:

No, the two roofs are not equivalent (rock or gravel roofs do not perform the same as gravel roofs over an existing cap sheet), and, therefore, the gravel roof over existing cap sheet may not qualify for the exception.

Example 3-16

Question:

If I am doing a reroof, would Exceptions 1 through 4 to §140.3(a)1Ai apply to reroofing and roof alterations?

Answer:

Yes, these exceptions apply to reroofing and alterations, and the roofs that meet one or more of these exceptions are exempt from the cool roof requirements.

Example 3-17

Question:

What happens if I have a low-sloped roof on most of the building but steep-sloped on another portion of the roof? Do I have to meet two sets of rules in §141.0(b)2Bi and ii?

Answer:

Yes, the low-sloped portion of the roof must comply with the requirements for low-sloped roofs, while the steep-sloped portion of the roof must comply with the requirements for steep-sloped roofs. These requirements are climate zone-based and vary based on the density of the outer roofing layer.

Example 3-18

Question:

A low-sloped nonresidential building in Santa Rosa needs to be reroofed. It has a wood-framed rafter roof. The rafters are 2 x 4's spaced 16 inches on center. The owner wants to install a roofing product with an aged reflectance of 0.60, which is less than the prescriptive standard of 0.63. Can I install additional insulation to make up for the shortfall in reflectance?

Answer:

Yes. There are two ways to make an insulation/reflectance trade-off when reroofing a low-sloped nonresidential building.

Scenario1:

The Simplified Performance Tradeoff Approach has been modified for the *2013 Standards*. It is a software tool that allows users to make roof insulation/reflectance trade-offs through a simplified process. The user enters a limited number of inputs, such as building type, building vintage, roof insulation, and reflectance details. The software analyzes the inputs and generates for the user a range of compliant design options. The software does all the work. There is no need for the user to consult reference appendices or make manual calculations. The software tool can be accessed on the Energy Commission's website at *http://www.energy.ca.gov/title24/2013standards*

Scenario 2:

Another way to make an insulation/reflectance trade-off is to use Table 141.0-B. First, look up in the table the maximum roof/ceiling insulation U-factor for the aged solar reflectance of the roofing product and the climate zone in which the building is located. In this case, the roofing product has an aged reflectance of 0.60, and Santa Rosa is in Climate Zone 2, so the appropriate U-factor is found in row 1, column 2 of the table. It is 0.052.

Next, consult Section 4.2 (Roofs and Ceilings) of Reference Appendix JA4 to find the U-factor table for the type of roof in question. Reference Appendix JA4 can be accessed on the Commission's website at http://www.energy.ca.gov/title24/2016standards/

The appropriate table in this case is Table 4.2.2, U-factors of Wood Framed Rafter Roofs. Locate the section of the table that pertains to 2 x 4 rafters spaced 16 inches on center. There are several U-factors in this area of the table that are equal to or less than 0.052. A combination of R-11 cavity insulation and R-8 continuous insulation, for example, has a U-factor of 0.050. Similarly, a combination of R-13 cavity insulation and R-6 continuous insulation has a U-factor of 0.052. Any U-factor that is equal to or less than 0.052 represents a combination of above- and below-deck insulation that complies with the requirements for the proposed trade-off.

Example 3-19

Question:

There several exceptions to the minimum insulation requirements for roof alterations. Can these be used to limit the insulation required to make a trade-off under Table 141.0-B?

Answer:

No. The exceptions to §141.0(b)2Biii do not apply to trade-off situations. They apply only when a compliant roofing product is being installed and no trade-off is involved.

3.6.3 Performance Requirements

A. Additions

The envelope and indoor lighting in the conditioned space of the addition, and any newly installed space-conditioning system or water-heating system serving the addition, shall meet the applicable requirements of §110.0 through §130.5; and either 1 or 2 below:

1. The addition alone shall comply with §141.0(a).
2. Existing plus addition plus alteration. The standard design building is the reference building against which the altered building is compared. The standard design building uses equivalent building envelope, lighting, and HVAC components when those components are not altered. For components that are altered or added, the standard design uses either the prescriptive requirements for new construction or the envelope baseline specified in §141.0. The proposed design energy use is the combination of the unaltered components of the existing building to remain and the altered component's energy features, plus the proposed energy features of the addition.

   EXCEPTION to Additions - Performance Approach: Additions that increase the area of the roof by 2,000 square feet or less are exempt from the requirements of §110.10.

B. Alterations

The envelope and indoor lighting in the conditioned space of the alteration shall meet the applicable requirements of §110.0 through §130.5 and either A or B below:

1. The altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of §110.0 through §110.9, §120.0 through §120.6, and §120.8 through §130.5.

   EXCEPTION to §141.0(b)3A: Window Films. Applied window films installed as part of an alteration complies with the U-factor, RSHGC and VT requirements of Table 141.0-D (Table 3-23 below).

2. The standard design for an altered component shall be the higher efficiency of existing conditions or the requirements stated in Table 141.0-D. For components not being altered, the standard design shall be based on the existing conditions. The proposed design shall be based on the actual values of the altered components.

Notes to Alterations – Performance Approach:

1. *If an existing component must be replaced with a new component, that component is considered an altered component for determining the energy budget and must meet the requirements of §141.0(b)3.*
2. *The standard design shall assume the same geometry and orientation as the proposed design.*

Table 3-23: The Standard Design for an Altered Component

Altered Component	Standard Design Without Third-Party Verification of Existing Conditions Shall be Based On	Standard Design With Third-Party Verification of Existing Conditions Shall be Based On
Roof/Ceiling Insulation, Wall Insulation, and Floor/Soffit Insulation	The requirements of §141.0(b)2.	
Fenestration. The allowed glass area shall be the smaller of the a. or b. below: a. The proposed glass area: or b. The larger of: 1.The existing glass area that remains; or 2.The area allowed in §140.3(a)5A.	The U-factor and RSHGC requirements of TABLE 141.0-A.	The existing U-factor and RSHGC levels
Window Film	The U-factor, RSHGC and VT shall be based on TABLE 140.1-A. The existing fenestration in the alteration shall be based on TABLE 110.6-A and Table 110.6-B. Third Party verification not required.	
Roofing Products	The requirements of §141.0(b)2B.	
All Other Measures	The proposed efficiency levels.	

Energy Standards Table 141.0-D

3.6.4 Historical Buildings

§100.0(a), Exception 1, states that qualified historic buildings, as defined in the California Historical Building Code (Title 24, Part 8 or California Building Code, Title 24, Part 2, Volume I, Chapter 34, Division II) are not covered by the Energy Standards. However, nonhistorical components of the buildings, such as new or replaced space-conditioning, plumbing, and electrical (including lighting) equipment, additions and alterations to historic buildings, and new appliances in historic buildings must comply with the Energy Standards and *Appliance Efficiency Regulations*, as well as other codes. Additions and alterations to historical buildings must also meet applicable requirements of the Energy Standards. For more information about energy compliance requirements for historical buildings, see Section 1.7.1, Building Types Covered.

Table of Contents

4. Mechanical Systems

4.1 Overview

The objective of the Building Energy Efficiency Standards (Energy Standards) requirements for mechanical systems is to reduce energy consumption while maintaining occupant comfort. These goals are achieved by:

1. Maximizing equipment efficiency, both at design conditions and during part load operation
2. Minimizing distribution losses of heating and cooling energy
3. Optimizing system control to minimize unnecessary operation and simultaneous use of heating and cooling energy

The Energy Standards also recognize the importance of indoor air quality for occupant comfort and health. To this end, the Energy Standards incorporate requirements for outdoor air ventilation that must be met during all operating conditions.

This chapter summarizes the requirements for space conditioning, ventilating, and service water heating systems for non-process loads in nonresidential buildings. Chapter 10 covers process loads in nonresidential buildings and spaces.

This chapter is organized as follows:

Section 4.1 provides an overview of the chapter and the scope of the mechanical systems requirement in the Energy Standards.

Section 4.2 addresses the requirements for Heating, Ventilation, and Air Conditioning (HVAC) and service water heating equipment efficiency and equipment mounted controls.

Section 4.3 includes mechanical ventilation, natural ventilation, and demand controlled ventilation.

Section 4.4 covers construction and insulation of ducts and pipes and duct sealing to reduce leakage.

Section 4.5 covers control requirements for HVAC systems including zone controls and controls to limit reheating and recooling.

Section 4.6 covers the remaining requirements for HVAC systems, including sizing and equipment selection, load calculations, economizers, electric resistance heating limitation, limitation on air-cooled chillers, fan power consumption, and fan and pump flow controls.

Section 4.7 covers the remaining requirements for service water heating.

Section 4.8 covers the performance method of compliance.

Section 4.9 covers compliance requirements for additions and alterations.

Section 4.10 covers the glossary, reference, and definitions.

Section 4.11 describes the mechanical plan check documents, which includes information that must be included in the building plans and specifications to show compliance with the Energy Standards, including the mechanical compliance documents.

Acceptance requirements apply at all times to the systems covered regardless of whether the prescriptive or performance compliance approach is used.

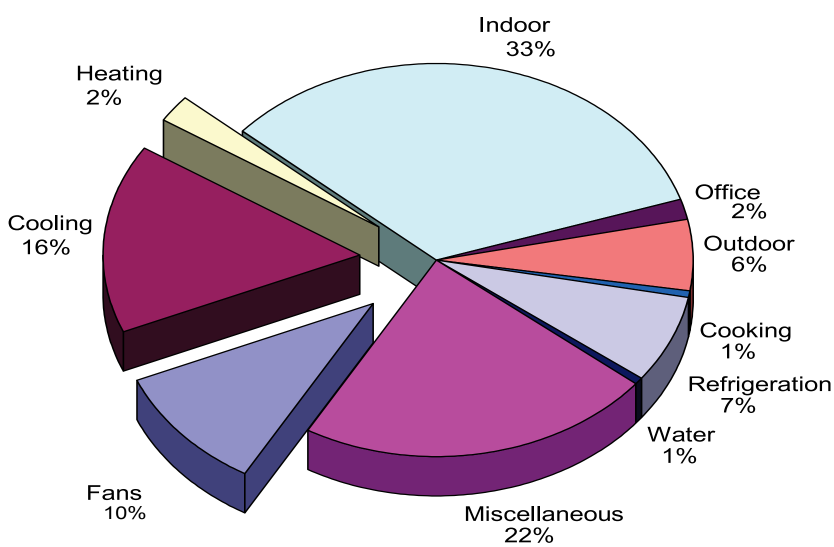
Chapter 12 describes mandated acceptance test requirements, which are summarized at the end of each section.

The full acceptance requirements are in §120.5 of the Energy Standards and in the 2016 Reference Appendix NA7.

4.1.1 HVAC Energy Use

Mechanical and lighting systems are the largest consumers of energy in nonresidential buildings. The amount of energy consumed by various mechanical components varies according to system design and climate. For most buildings in lower elevation California climates, fans and cooling equipment are the largest components of energy consumed for HVAC purposes. Energy consumed for heating is usually less than fans and cooling, followed by service water heating.

Figure 4-1: Typical Nonresidential Building Electricity Use



Heating, cooling and ventilation account for about 28% of commercial building electricity use in California.
Source IEQ RFP, December 2002, California Energy Commission No. 500-02-501.

4.1.2 Mandatory Measures

Mandatory measures, covered in §110.0-110.5 and §120.0-120.9, apply to all nonresidential buildings, whether the designer chooses the prescriptive or performance approach for compliance and include:

1. Equipment certification and equipment efficiency - §110.1 and §110.2.
2. Service water heating systems and equipment - §110.3.
3. Spa and pool heating systems and equipment - §110.4.
4. Restrictions on pilot lights for natural gas appliances and equipment - §110.5.
5. Ventilation requirements - §120.1.
6. Control requirements - §120.2.

7. Pipe insulation - §120.3.
8. Duct construction and insulation - §120.4.
9. Acceptance tests in §120.5 and the 2016 Reference Appendices NA7.
10. Commissioning - §120.8.
11. Commercial Boilers - §120.9.

4.1.3 Prescriptive and Performance Compliance Approaches

The Energy Standards allow mechanical system compliance to be demonstrated by meeting the mandatory requirements and the requirements of either the prescriptive or performance compliance approaches.

4.1.3.1 **Prescriptive Compliance Approach**

The measures in the prescriptive compliance approach, §140.4, cover specific requirements for individual components and systems that directly comply with the Energy Standards, including:

1. Load calculations, sizing, system type and equipment selection - §140.4(a) and (b).
2. Fan power consumption - §140.4(c).
3. Controls to reduce reheating, recooling and mixing of conditioned air streams - §140.4(d).
4. Economizers - §140.4(e).
5. Supply temperature reset - §140.4(f).
6. Restrictions on electric-resistance heating - §140.4(g).
7. Fan speed controls for heat rejection equipment - §140.4(h).
8. Limitation on centrifugal fan cooling towers - §140.4(h).
9. Minimum chiller efficiency - §140.4(i).
10. Limitation on air-cooled chillers - §140.4(j).
11. Hydronic system design - §140.4(k).
12. Duct sealing - §140.4(l).
13. Supply fan control - §140.4(m).
14. Mechanical System Shut-off control - §140.4(n).

4.1.3.2 **Performance Compliance Approach**

The performance compliance approach, §140.1, allows the designer to trade off energy use in different building systems. This approach provides greater design flexibility, but requires extra effort and a computer simulation of the building. The design must still meet all of the mandatory requirements.

Performance approach trade-offs can be applied to the following disciplines: mechanical, lighting, envelope, and covered processes. The performance approach requires creating two models using Energy Commission-certified compliance software:

1. Base-case building energy model which meets all of the mandatory and prescriptive requirements.
2. Proposed building energy model that reflects the proposed building design.

The proposed model complies if it has a lower TDV value than the base-case model.

The performance approach may only be used to model the performance of mechanical systems that are covered under the building permit application (see Section 4.8 and Chapter 11 for more detail).

4.2 Equipment Requirements

With the exception of chillers, all of the equipment efficiency requirements are mandatory measures.

The mandatory requirements for mechanical equipment must be included in the system design, whether compliance is shown by the prescriptive or the performance approach. These features have been shown to be cost effective over a wide range of building types and mechanical systems.

It is worth noting that most mandatory features for equipment efficiency are requirements for the manufacturer. It is the responsibility of the designer, however, to specify products in the building design that meet these requirements. Manufacturers of central air conditioners and heat pumps, room A/C, package terminal A/C, package terminal heat pumps, spot air conditioners, computer room air conditioners, central fan-type furnaces, gas space heaters, boilers, pool heaters and water heaters are regulated through the Title 20 Appliance Efficiency Regulations. Manufacturers must certify to the Energy Commission that their equipment meets or exceeds minimum standards. The Energy Commission maintains a database which lists the certified equipment and can be found at: www.energy.ca.gov/appliances/database

Additionally, manufacturers of low leakage air-handling units must certify to the Energy Commission that the air-handler unit meets the specifications in Reference Joint Appendix JA9.

4.2.1 Mandatory Requirements

Mechanical equipment must be certified by the manufacturer as complying with the mandatory requirements in the following Sections:

- §110.1 - Mandatory Requirements for Appliances.
- §110.2 - Mandatory Requirements for Space Conditioning Equipment
  - Efficiency
  - Gas- and Oil-Fired Furnace Standby Loss Controls
  - Low Leakage Air-Handling Units
- §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
  - Certification by Manufactures
  - Efficiency
- §110.4 - Mandatory Requirements for Pool and Spa Systems and Equipment
  - Certification by Manufactures

- §110.5 - Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited

Mechanical equipment must be specified and installed in accordance with Sections:

- §110.2 - Mandatory Requirements for Space Conditioning Equipment
  - Controls for Heat Pumps with Supplementary Electric Resistance Heaters
  - Thermostats
  - Open and Closed Circuit Cooling Towers (blowdown control)
- §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
- §120.1 - Requirements for Ventilation
- §120.2 - Required Controls for Space Conditioning Systems including
  - Occupant Controlled Smart Thermostats (OCST)
  - Direct Digital Controls (DDC)
  - Optimum start/stop controls
- §120.3 - Requirements for Pipe Insulation
- §120.4 - Requirements for Air Distribution Ducts and Plenums
- §120.5 - Required Nonresidential Mechanical System Acceptance

4.2.2 Equipment Efficiency

§110.2(a)

All space conditioning equipment installed in a nonresidential building subject to these regulations must be certified as meeting certain minimum efficiency and control requirements. These requirements are contained in §110.2. Minimum efficiencies vary based on the type and capacity of the equipment. The following tables, which are duplicates of Tables 110.2A-110.2K of the Energy Standards, list the minimum equipment efficiency requirements.

Table 4-1: Unitary Air Conditioners and Condensing Units

Equipment Type	Size Category	Efficiency [a,b]		Test Procedure[c]
		Before 1/1/2016	After 1/1/2016	
Air conditioners, air cooled both split and single packaged	≥65,000 Btu/h and < 135,000 Btu/h	11.2 EER 11.4 IEER	11.2 EER 12.9 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	11.0 EER 11.2 IEER	11.0 EER 12.4 IEER	
	≥240,000 Btu/h and < 760,000 Btu/h	10.0 EER 10.1 IEER	10.0 EER 11.6 IEER	
	≥760,000 Btu/h	9.7 EER 9.8 IEER	9.7 EER 11.2 IEER	
Air conditioners, water cooled	≥65,000 Btu/h and < 135,000 Btu/h	12.1 EER 12.3 IEER	12.1 EER 13.9 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	12.5 EER 12.5 IEER	12.5 EER 13.9 IEER	ANSI/AHRI 340/360
	≥240,000 Btu/h and < 760,000 Btu/h	12.4 EER 12.6 IEER	12.4 EER 13.6 IEER	ANSI/AHRI 340/360
	≥760,000 Btu/h	12.2 EER 12.4 IEER	12.2 EER 13.5 IEER	ANSI/AHRI 340/360
Air conditioners, evaporatively cooled	≥65,000 Btu/h and < 135,000 Btu/h	12.1 EER[b] 12.3 IEER[b]		ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	12.0 EER[b] 12.2 IEER[b]		ANSI/AHRI 340/360
	≥240,000 Btu/h and < 760,000 Btu/h	11.9 EER[b] 12.1 IEER[b]		ANSI/AHRI 340/360
	≥760,000 Btu/h	11.7 EER[b] 11.9 IEER[b]		ANSI/AHRI 340/360
Condensing units, air cooled	≥ 135,000 Btu/h	10.5 EER 11.8 IEER		ASNI/AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h	13.5 EER 14.0 IEER		ASNI/AHRI 365
Condensing units, evaporatively cooled	≥ 135,000 Btu/h	13.5 EER 14.0 IEER		

[a] IEERs are only applicable to equipment with capacity control as specified by ANSI/AHRI 340/360 test procedures
[b] Deduct 0.2 from the required EERs and IEERs for units with a heating section other than electric resistance heat
[c] Applicable test procedure and reference year are provided under the definitions

Energy Standards Table 110.2-A

Table 4-2: Unitary and Applied Heat Pumps

Equipment Type	Size Category	Efficiency[a,b]		Test Procedure[c]
		Before 1/1/2016	**After 1/1/2016**	
Air Cooled (cooling mode), both split system and single package	≥65,000 Btu/h and < 135,000 Btu/h	11.0 EER 11.2 IEER	11.0 EER 12.2 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	10.6 EER 10.7 IEER	10.6 EER 11.6 IEER	
	≥240,000 Btu/h	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
Water source (cooling mode)	≥65,000 Btu/h and < 135,000 Btu/h	86^{0}F entering water	13.0 EER	ISO-13256-1
Groundwater source (cooling mode)	< 135,000 Btu/h	59^{0}F entering water	18.0 EER	ISO-13256-1
Ground source (cooling mode)	< 135,000 Btu/h	77^{0}F entering water	14.1 EER	ISO-13256-1
Water source water-to-water (cooling)	< 135,000 Btu/h	86^{0}F entering water	10.6 EER	ISO-13256-2
Groundwater source water-to-water	< 135,000 Btu/h	59^{0}F entering water	16.3 EER	ISO-13256-1
Ground source brint-to-water (cooling mode)	< 135,000 Btu/h	77^{0}F entering water	12.1 EER	ISO-13256-2
Air Cooled (Heating Mode) Split system and single package	≥65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	47^{0}F db/43^{0}F wb outdoor air	3.3 COP	ANSI/AHRI 340/360
		17^{0}F db/15^{0}F wb outdoor air	2.25 COP	
	≥135,000 Btu/h (cooling capacity)	47^{0}F db/43^{0}F wb outdoor air	3.2 COP	
		17^{0}F db/15^{0}F wb outdoor air	2.05 COP	

(Cont.) Table 4-2: Unitary and Applied Heat Pumps

Equipment Type	Size Category	Subcategory or Rating Condition	Efficiency[a]	Test Procedure[c]
Water source (heating mode)	< 135,000 Btu/h (cooling capacity)	68^0F entering water	4.3 COP	ISO-13256-1
	≥135,000 Btu/h and < 240,000 Btu/h (cooling capacity)	68^0F entering water	2.9 COP	
Groundwater source (heating mode)	< 135,000 Btu/h (cooling capacity)	50^0F entering water	3.7 COP	ISO-13256-1
Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)	32^0F entering water	3.2 COP	ISO-13256-1
Water source water-to-water (heating mode)	< 135,000 Btu/h (cooling capacity)	68^0F entering water	3.7 COP	ISO-13256-2
Groundwater source water-to-water (heating mode)	< 135,000 Btu/h (cooling capacity)	50^0F entering water	3.1 COP	ISO-13256-2
Ground source brine-to-water (heating mode)	< 135,000 Btu/h (cooling capacity)	32^0F entering water	2.5 COP	ISO-13256-2

[a] IEERs are applicable to equipment with capacity control as specified by ANSI/AHRI 340/360 test procedures.
[b] Deduct 0.2 from the required EERs and IEERs for units with a heating section other than electric resistance heat
[c] Applicable test procedure and reference year are provided under the definitions

Energy Standards Table 110.2-B

Table 4-3: Air Cooled Gas Engine Heat Pumps

Equipment Type	Size Category	Subcategory or Rating Condition	Efficiency	Test Procedure[a]
Air-cooled gas-engine heat pump (cooling mode)	All Capacities	95^0F db Outdoor air	0.60 COP	ANSI Z21.40.4A
Air-cooled gas-engine heat pump (heating mode)	All Capacities	47^0F db/43°F wb Outdoor air	0.72 COP	ANSI Z21.40.4A

[a] Applicable test procedure and reference year are provided under the definitions

Energy Standards Table 110.2-C

Table 4-4: Water Chilling Packages Minimum Efficiency

Equipment Type	Size Category	Path A Efficiency [a,b]	Path B Efficiency [a,b]	Test Procedure
Air Cooled, With Condenser Electrically Operated	< 150 tons	≥ 10.1 EER ≥ 13.7 IPLV	≥ 9.7 EER ≥ 15.8 IPLV	AHRI 550/590
	≥ 150 tons	≥ 10.1 EER ≥ 14.0 IPLV	≥ 9.7 EER ≥ 16.1 IPLV	
Air Cooled, without condenser Electrically Operated	All Capacities	Air-cooled chillers without condensers must be rated with matching condensers and comply with the air-cooled chiller efficiency requirements.		
Water Cooled, Electrically Operated, (Reciprocating)	All Capacities	Reciprocating units must comply with the water-cooled positive displacement efficiency requirements.		AHRI 550/590
Water Cooled, Electrically Operated Positive Displacement	< 75 tons	≤ 0.750 kW/ton ≤ 0.600 IPLV	≤ 0.780 kW/ton ≤ 0.500 IPLV	AHRI 550/590
	≥ 75 tons and < 150 tons	≤ 0.720-kW/ton ≤ 0.560 IPLV	≤ 0.750 kW/ton ≤ 0.490 IPLV	
	≥ 150 tons and < 300 tons	≤ 0.660 kW/ton ≤ 0.540 IPLV	≤ 0.680 kW/ton ≤ 0.440 IPLV	
	≥ 300 tons and < 600 tons	≤ 0.610 kW/ton ≤ 0.520 IPLV	≤ 0.625 kW/ton ≤ 0.410 IPLV	
	> 600 tons	≤ 0.560 kW/ton ≤ 0.500 IPLV	≤ 0.585 kW/ton ≤ 0.380 IPLV	
Water Cooled, Electrically Operated, Centrifugal	< 150 tons	≤ 0.610 kW/ton ≤ 0.550 IPLV	≤ 0.695 kW/ton ≤ 0.440 IPLV	
	≥ 150 tons and < 300 tons	≤ 0.610 kW/ton ≤ 0.550 IPLV	≤ 0.635 kW/ton ≤ 0.400 IPLV	
	≥ 300 tons and < 400 tons	≤ 0.560 kW/ton ≤ 0.520 IPLV	≤ 0.595 kW/ton ≤ 0.390 IPLV	
	≥ 400 tons and < 600 tons	≤ 0.560 kW/ton ≤ 0.500 IPLV	≤ 0.585 kW/ton ≤ 0.380 IPLV	
	≥ 600 tons	≤ 0.560 kW/ton ≤ 0.500 IPLV	≤ 0.585 kW/ton ≤ 0.380 IPLV	

(Cont.) Table 4-4: Water Chilling Packages Minimum Efficiency

Equipment Type	Size Category	Path A Efficiency [a,b]	Path B Efficiency [a,b]	Test Procedure[c]
Air Cooled Absorption, Single Effect	All Capacities	≥ 0.600 COP	NA[d]	ANSI/AHRI 560
Water Cooled Absorption, Single Effect	All Capacities	≥ 0.700 COP	NA[d]	
Absorption Double Effect, Indirect-Fired	All Capacities	≥ 1.000 COP ≥ 1.050 IPLV	NA[d]	
Absorption Double Effect, Direct-Fired	All Capacities	≥ 1.000 COP ≥ 1.000 IPLV	NA[d]	
Water Cooled Gas Engine Driven Chiller	All Capacities	≥ 1.2 COP ≥ 2.0 IPLV	NA[d]	ANSI Z21.40.4A

[a] No requirements for:

- Centrifugal chillers with design leaving evaporator temperature < 36^{0}F; or
- Positive displacement chillers with designed leaving fluid temperatures ≤ 32^{0}F; or
- Absorption chillers with design leaving fluid temperature < 40^{0}F

[b] Must meet the minimum requirements of Path A or Path B. However, both the full load (COP) and IPLV must be met to fulfill the requirements of the applicable Path.

[c] See §100.1 for definitions

[d] NA means not applicable

Energy Standards Table 110.2-D

Table 4-5: Packaged Terminal Air Conditioners and Heat Pumps

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Efficiency	Test Procedure[c]
PTAC (cooling mode) newly constructed or newly conditioned or additions	All Capacities	95^0F db Outdoor air	14.0-(0.300 x Cap/1000) [a] EER	ANSI/AHRI/CSA 310/380
PTAC (cooling mode) Replacements[b]	All Capacities	95^0F db Outdoor air	10.9-(0.213 x Cap/1000) [a] EER	
PTHP (cooling mode) Newly constructed or newly conditioned or additions	All Capacities	95^0F db Outdoor air	14.0-(0.300 x Cap/1000) [a] EER	
PTHP (Cooling mode) Replacements[b]	All Capacities	95^0F db Outdoor air	10.8-(0.213 x Cap/1000) [a] EER	
PTHP (Heating mode) Newly constructed or newly conditioned or additions	All Capacities		3.7-(0.052 x Cap/1000) [a] COP	
PTHP (Heating mode) Replacements[b]	All Capacities		2.9-(0.026 x Cap/1000) [a] COP	
SPVAC (Cooling mode)	< 65,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0 EER	ANSI/AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0 EER	
SPVAC (Cooling Mode) nonweatherized space constrained	≤ 30,000 Btu/h	95^0F db/75^0F wb Outdoor air	9.20 EER	
	> 30,000 Btu/h and ≤36,000 Btu/h	95^0F db/75^0F wb Outdoor air	9.00 EER	
SPVHP (Cooling mode)	< 65,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95^0F db/75^0F wb Outdoor air	10.0 EER	
SPVHP (Cooling mode) nonweatherized space constrained	≤ 30,000 Btu/h	95^0F db/75^0F wb Outdoor air	9.20 EER	
	> 30,000 Btu/h and ≤36,000 Btu/h	95^0F db/75^0F wb Outdoor air	9.00 EER	
SPVHP (Heating mode)	< 65,000 Btu/h	47^0F db/43^0F wb Outdoor air	3.0 COP	
	≥ 65,000 Btu/h and < 135,000 Btu/h	47^0F db/43^0F wb Outdoor air	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47^0F db/43^0F wb Outdoor air	3.0 COP	

SPVHP (Heating mode)	≤ 30,000 Btu/h	47^0F db/43^0F wb Outdoor air	3.00 COP	
nonweatherized space constrained	> 30,000 Btu/h and ≤36,000 Btu/h	47^0F db/43^0F wb Outdoor air	3.00 COP	

[a] cap means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.
[b] Replacement units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEWLY CONSTRUCTED BUILDINGS." Replacement efficiencies apply only to units with existing sleeves less than 16 inches high or less than 42 inch wide and having a cross-sectional area less than 670 square inches.
[c] Applicable test procedure and reference year are provided under the definitions

Energy Standards Table 110.2-E

Table 4-6: Heat Transfer Equipment

Equipment Type	Subcategory	Minimum Efficiency [a]	Test Procedure [b]
Liquid-to-liquid heat exchangers	Plate type	NR	ANSI/AHRI 400

[a] NR = no requirement
[b] Applicable test procedure and reference year are provided under the definitions

Energy Standards Table 110.2-F

Table 4-7: Performance Requirements for Heat Rejection Equipment

Equipment Type	Total System Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required, [a, b, c, d]	Test Procedure[e]
Propeller or axial fan open-circuit cooling towers	All	95^0F entering water 85^0F leaving water 75^0F entering air wb	≥ 42.1 gpm/hp	CTI ATC-105 and CTI STD-201
Centrifugal fan open-circuit cooling towers	All	95^0F entering water 85^0F leaving water 75^0F entering air wb	≥ 20.0 gpm/hp	
Propeller or axial fan closed-circuit cooling towers	All	102^0F entering water 90^0F leaving water 75^0F entering air wb	≥ 14.0 gpm/hp	
Centrifugal fan closed-circuit cooling towers	All	102^0F entering water 90^0F leaving water 75^0F entering air wb	≥ 7.0 gpm/hp	

(Cont.) Table 4-7: Performance Requirements for Heat Rejection Equipment

Propeller or axial fan evaporative condensers	All	R-507A test fluid 165^{0}F entering gas temp 105^{0}F condensing temp 75^{0}F entering air wb	≥ 157,000 Btu/h x hp	CTI ATC-106
	All	Ammonia test fluid 140^{0}F entering gas temp 96.3^{0}F condensing temp 75^{0}F entering air wb	≥ 134,000 Btu/h x hp	
Centrifugal fan evaporative condensers	All	R-507A test fluid 165^{0}F entering gas temp 105^{0}F condensing temp 75^{0}F entering air wb	≥ 135,000 Btu/h x hp	
	All	Ammonia test fluid 140^{0}F entering gas temp 96.3^{0}F condensing temp 75^{0}F entering air wb	≥ 110,000 Btu/h x hp	
Air cooled condensers	All	125^{0}F condensing temperature R22 test fluid 190^{0}F entering gas temperature 15^{0}F subcooling 95^{0}F entering db	≥ 176,000 Btu/h x hp	ANSI/AHRI 460

a Open-circuit cooling tower performance is defined as the water flow rating of the tower at the given rated conditions divided by the fan motor nameplate power.

b Closed-circuit cooling tower performance is defined as the process water flow rating of the tower at the given rated conditions divided by the sum of the fan motor nameplate rated power and the integral spray pump motor nameplate power.

c Air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan motor nameplate power.

d Open cooling towers shall be tested using the test procedures in CTI ATC-105. Performance of factory assembled open cooling towers shall be either certified as base models as specified in CTI STD-201 or verified by testing in the field by a CTI approved testing agency. Open factory assembled cooling towers with custom options added to a CTI certified base model for the purpose of safe maintenance or to reduce environmental or noise impact shall be rated at 90 percent of the CTI certified performance of the associated base model or at the manufacturer's stated performance, whichever is less. Base models of open factory assembled cooling towers are open cooling towers configured in exact accordance with the Data of Record submitted to CTI as specified by CTI STD-201. There are no certification requirements for field erected cooling towers.

e Applicable test procedure and reference year are provided under the definitions.

For refrigerated warehouses or commercial refrigeration applications, condensers shall comply with requirements specified by §120.6(a) or §120.6(b)

Energy Standards Table 110.2-G

Table 4-8: Electrically Operated Variable Refrigerant Flow Air Conditioners

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency	Test Procedure[a]
Variable Refrigerant Flow (VRF) Air Conditioners, Air Cooled	< 65,000 Btu/h	All	VRF Multi-Split System	13.0 SEER	ANSI/AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.2 EER 13.1 IEER[b]	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.0 EER 12.9 IEER[b]	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	10.0 EER 11.6 IEER[b]	

a Applicable test procedure and reference year are provided under the definitions.
b IEERs are only applicable to equipment with capacity control as specified by ASNI/AHRI 1230 test procedures.

Energy Standards Table 110.2-H

Table 4-9: Electrically Operated VRF Air to Air and Applied Heat Pumps

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency	Test Procedure[b]
VRF Air Cooled, (cooling mode)	< 65,000 Btu/h	All	VRF multi-split System[a]	13 SEER	AHRI 1230
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or none)	VRF multi-split System[a]	11.0 EER 12.9 IEER[c]	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF multi-split System[a]	10.6 EER 12.3 IEER[c]	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF multi-split System[a]	9.5 EER 11.0 IEER[c]	
VRF Water source (cooling mode)	< 65,000 Btu/h	All	VRF multi-split System[a] 86^{0}F entering water	12.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	VRF multi-split System[a] 86^{0}F entering water	12.0 EER	
	≥ 135,000 Btu/h	All	VRF multi-split system[a] 86^{0}F entering water	10.0 EER	
VRF Groundwater source (cooling mode)	< 135,000 Btu/h	All	VRF multi-split system[a] 59^{0}F entering water	16.2 EER	

(Cont.) Table 4-9: Electrically Operated VRF Air to Air and Applied Heat Pumps

VRF Groundwater source (cooling mode)	≥ 135,000 Btu/h	All	VRF multi-split system[a] 59^{0}F entering water	13.8 EER	AHRI 1230
VRF Ground source (cooling mode)	< 135,000 Btu/h	All	VRF multi-split system[a] 77^{0}F entering water	13.4 EER	
	≥ 135,000 Btu/h	All	VRF multi-split system[a] 77^{0}F entering water	11.0 EER	
VRF Air cooled (heating mode)	< 65,000 Btu/h (cooling capacity)		VRF multi-split system	7.7 HSPF	
	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)		VRF multi-split system 47^{0}F db/ 43^{0}F wb outdoor air	3.3 COP	
			VRF multi-split system 17^{0}F db/ 15^{0}F wb outdoor air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)		VRF multi-split system 47^{0}F db/ 43^{0}F wb outdoor air	3.2 COP	
			VRF multi-split system 17^{0}F db/ 15^{0}F wb outdoor air	2.05 COP	
VRF Water source (heating mode)	< 135,000 Btu/h (cooling capacity)		VRF multi-split system 68^{0}F entering water	4.2 COP	
	≥ 135,000 Btu/h (cooling capacity)		VRF multi-split system 68^{0}F entering water	3.9 COP	
VRF Groundwater source (heating mode)	< 135,000 Btu/h (cooling capacity)		VRF multi-split system 50^{0}F entering water	3.6 COP	
	≥ 135,000 Btu/h (cooling capacity)		VRF multi-split system 50^{0}F entering water	3.3 COP	
VRF Ground source (heating mode)	< 135,000 Btu/h (cooling capacity)		VRF multi-split system 32^{0}F entering water	3.1 COP	
	≥ 135,000 Btu/h (cooling capacity)		VRF multi-split system 32^{0}F entering water	2.8 COP	

[a] Deduct 0.2 from the required EERs and IEERs for VRF multi-split system units with a heating recovery section.
[b] Applicable test procedure and reference year are provided under the definitions.
[c] IEERs are only applicable to equipment with capacity control as specified by ANSI/AHRI 1230 test procedures.

Energy Standards Table 110.2-I

Table 4-10: Warm-Air Furnaces and Combination Warm-Air Furnaces/Air-Conditioning Units, Warm-Air Duct Furnaces, and Unit Heaters

Equipment Type	Size Category (Input)	Subcategory or Rating Condition[b]	Minimum Efficiency	Test Procedure[a]
Warm-Air Furnace, Gas-Fired	< 225,000 Btu/h	Maximum Capacity[b]	78% AFUE or 80% E_t	DOE 10 CFR Part 430 or Section 2.39, Thermal Efficiency, ANSI Z21.47
	≥ 225,00 Btu/h	Maximum Capacity[b]	80% E_t	Section 2.39, Thermal Efficiency, ANSI Z21.47
Warm-Air Furnace, Oil-Fired	< 225,000 Btu/h	Maximum Capacity[b]	78% AFUE or 80% E_t	DOE 10 CFR Part 430 or Section 42, Combustion, UL 727
	≥ 225,000 Btu/h	Maximum Capacity[b]	81% E_t	Section 42, Combustion, UL 727
Warm-Air Duct Furnaces, Gas-Fired	All Capacities	Maximum Capacity[b]	80% E_c	Section 2.10, Efficiency, ANSI Z83.8
Warm-Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity[b]	80% E_c	Section 2.10, Efficiency, ANSI Z83.8
Warm-Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity[b]	81% E_c	Section 40, Combustion, UL 731

[a] Applicable test procedure and reference year are provided under the definitions.
[b] Compliance of multiple firing rate units shall be at maximum firing rate.
E_t = thermal efficiency, units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75 percent of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
E_c = combustion efficiency (100% less flue losses). See test procedure for detailed discussion.

As of August 8, 2008, according to the Energy Policy Act of 2005, units must also include interrupted or intermittent ignition device (IID) and have either power venting or an automatic flue damper.
Combustion units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.

Energy Standards Table 110.2-J

Table 4-11: Gas and Oil Fired Boilers

Equipment Type	Sub Category	Size Category (Input)	Minimum Efficiency[b,c]		Test Procedure[a]
			Before 3/2/2020	After 3/2/2020	
Boiler, hot water	Gas Fired	< 300,000 Btu/h	82% AFUE	82% AFUE	DOE 10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[d]	80% E_t	80% E_t	DOE 10 CFR Part 431
		> 2,500,000 Btu/h[e]	82% E_c	82% E_c	
	Oil Fired	< 300,000 Btu/h	84% AFUE	84% AFUE	DOE 10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[d]	82% E_t	82% E_t	DOE 10 CFR Part 431
		> 2,500,000 Btu/h[e]	84% E_c	84% E_c	
Boiler, steam	Gas Fired	< 300,000 Btu/h	80% AFUE	80% AFUE	DOE 10 CFR Part 430
	Gas Fired – all, except natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[d]	79% E_t	79% E_t	DOE 10 CFR Part 431
		> 2,500,000 Btu/h[e]	79% E_t	79% E_t	DOE 10 CFR Part 431
	Gas Fired, natural draft	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[d]	77% E_t	79% E_t	DOE 10 CFR Part 431
		> 2,500,000 Btu/h[e]	77% E_t	79% E_t	DOE 10 CFR Part 431
	Oil-Fired	< 300,000 Btu/h	82% AFUE	82% AFUE	DOE 10 CFR Part 430
		≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h[d]	81% E_t	81% E_t	DOE 10 CFR Part 431
		> 2,500,000 Btu/h[e]	81% E_t	81% E_t	DOE 10 CFR Part 431

[a] Applicable test procedure and reference year are provided under the definitions.
[b] E_c = combustion efficiency (100% less flue losses). See reference document for detail information
[c] E_t = thermal efficiency. See test procedure for detailed information.
[d] Maximum capacity – minimum and maximum ratings as provided for and allowed by the unit's controls.
[e] Included oil-fired (residual).

Energy Standards Table 110.2-K

In the above tables, where more than one efficiency standard or test method is listed, the requirements of both shall apply. For example, unitary air-cooled air conditioners have an EER requirement for full-load operation and an IEER for part-load operation. The air conditioner must have both a rated EER and IEER equal to or higher than that specified in the Energy Standards at the specified Air-Conditioning, Heating, and Refrigeration Institute (AHRI) standard rating conditions. Similarly, where equipment serves more than one function, it must comply with the efficiency standards applicable to each function.

When a requirement is for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the capacity shall be as provided for and allowed by the controls during steady state operation. For example, a boiler with high/low firing must meet the efficiency requirements when operating at both its maximum capacity and minimum capacity.

Exceptions exist to the listed minimum efficiency for specific equipment. The first exception applies to water-cooled centrifugal water-chilling packages, which are not designed for operation at ANSI/AHRI Standard 550/590 test conditions, which are:

1. 44°F leaving chilled water temperature.
2. 85°F entering condenser water temperature.
3. 3 gallons per minute per ton condenser water flow.

Packages not designed to operate at these conditions must have maximum adjusted Full Load and NPLV ratings. These ratings can be calculated, in kW/ton, using Equation 4-1 and Equation 4-2.

Equation 4-1

$$Full\ Load\ Rating_{max,\ adj} = \frac{(Full\ Load\ Rating)}{K_{adj}}$$

Equation 4-2

$$NPLV\ Rating_{max,\ adj} = \frac{(IPLV\ Rating)}{K_{adj}}$$

The values for the Full Load and IPLV Ratings are found in Table 4-4. K_{adj} is the product of A and B, as in Equation 4-3. A is calculated by entering the value for $LIFT$ determined using Equation 4-5 into the fourth level polynomial in Equation 4-4. B is found using Equation 4-6.

Equation 4-3

$$K_{adj} = A \times B$$

Equation 4-4

$$A = (1.4592 \times 10^{-7})\left(LIFT^{4}\right) - (3.46496 \times 10^{-5})(LIFT^{3}) + (3.14196 \times 10^{-3})(LIFT^{2}) - (0.147199)(LIFT) + 3.9302$$

Equation 4-5

$$LIFT = LvgCond - LvgEvap$$

Where:

LvgCond = Full-load leaving condenser fluid temperature (°F)

LvgEvap = Full-load leaving evaporator fluid temperature (°F)

Equation 4-6

$$B = (0.0015)(LvgEvap) + 0.934$$

Where:

LvgEvap = Full-load leaving evaporator fluid temperature (°F)

The adjusted maximum adjusted Full Load and NPLV rating values are only applicable for centrifugal chillers meeting all of the following full-load design ranges:

1. Minimum Leaving Evaporator Fluid Temperature: 36°F
2. Maximum Leaving Condenser Fluid Temperature: 115°F
3. LIFT ≥ 20°F and ≤ 80°F

Centrifugal chillers designed to operate outside of these ranges are not covered by this exception and therefore have no minimum efficiency requirements.

Exception 2 is for positive displacement (air- and water-cooled) chillers, with a leaving evaporator fluid temperature higher than 32°F, which shall show compliance with Table 4-4 when tested or certified with water at standard rating conditions, per the referenced test procedure.

Exception 3 is for equipment primarily serving refrigerated warehouses or commercial refrigeration systems. These systems must comply with the efficiency requirements of Energy Standards §120.6(a) or (b). For more information see Chapter 10.

4.2.3 Equipment Not Covered by the Appliance Efficiency Regulations

§110.2 and §110.3.

To comply, equipment specified in the plans and specifications must meet the minimum standards mandated in that section. Manufacturers of equipment not regulated by the Appliance Efficiency Regulations are not required to certify their equipment to the Energy Commission; it is the responsibility of the designer and contractor to specify and install equipment that complies.

To verify certification, use one of the following options:

1. The Energy Commission's website includes listings of energy efficient appliances for several appliance types. The website address is http://www.energy.ca.gov/appliances/. The Energy Commission's Hotline staff can provide further assistance, at 1-800-772-3300 or (916) 654-5106, if appliance information is not found on the website.
2. The complete appliance database can be downloaded. This requires spreadsheet programs compatible with Microsoft Excel. To use the data, a user must download the database file (or files), download a brand file and a manufacturer file, and then decompress the files. Next, the user will need to download a description file that provides details on what is contained in each of the data fields. With these files, and using database software, the data can be sorted and manipulated.
3. The Air Conditioning, Heating and Refrigeration Institute (AHRI) Directory of Certified Products can be used to verify certification of air-conditioning equipment. This information is available on their website at www.ahrinet.org.

4.2.4 Controls for Heat Pumps with Supplementary Electric Resistance Heaters

§110.2(b)

The Energy Standards discourage use of electric resistance heating when an alternative method of heating is available. In the case of a heat pump, these systems may contain electric resistance heat strips which act as a supplemental heating source. If this system is used, then controls must be put in place that prevents use of the electric resistance supplementary heating when the heating load can be satisfied with the heat pump alone.

This includes the requirement that the thermostat must be able to provide step up controls that will incrementally adjust the indoor temperature setting so that the heat pump can gradually raise the temperature until the final desired indoor temperature is reached. Also, the controls must set a “cut-on” temperature for compressor heating which is higher than the “cut-on” temperature for electric resistance heating, and the “cut-off temperature for compression heating is higher than the “cut-off” temperature for electric resistance heating.

Exceptions exist for this requirement:

1. If the electric resistance heating is for defrost, and during transient periods such as start-ups and following room thermostat set points (or another control mechanism designed to preclude the unnecessary operation).
2. If the heat pump is a room air-conditioner heat pump.

4.2.5 Thermostats

§110.2(c) and §120.2(b)4

When a central energy management control system (EMCS) is not included in the design of the HVAC system, then a thermostat with setback capabilities must be installed. The requirement is for all unitary heating or cooling systems to have a thermostat that is capable of at least 4 set points in a 24 hour period. In the case of a heat pump, the control requirements of Section 4.2.4 must also be met. In addition, per §120.2(b)4, the thermostats on all unitary single zone, air conditioners, heat pumps must comply with the requirements of Reference Joint Appendix JA5, also known as the Occupant Controlled Smart Thermostats, which are capable of receiving demand response signals in the event of grid congestion and shortages during high electrical demand periods.

There are two exceptions to §120.2(b)4 Occupant Controlled Smart Thermostats:

1. Systems serving zones that must have constant temperatures to protect a process or product (e.g. a laser laboratory or a museum).
2. The following HVAC systems do not need to comply with the setback or Occupant Controlled Smart Thermostat requirement:
   a. Gravity gas wall heaters
   b. Gravity floor heaters
   c. Gravity room heaters
   d. Non-central electric heaters
   e. Fireplaces or decorative gas appliance
   f. Wood stoves
   g. Room air conditioners
   h. Room heat pumps
   i. Packaged terminal air conditioners
   j. Packaged terminal heat pumps

4.2.6 Furnace Standby Loss Controls

§110.2(d)

Forced air gas- and oil-fired furnaces with input ratings ≥ 225,000 Btu/h are required to have controls and designs that limit their standby losses:

1. They must have either an intermittent ignition or interrupted device (IID). Standing pilot lights are not allowed.
2. They must have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the conditioned space.

Any furnace with an input rating ≥225,000 Btu/h that is not located within the conditioned space must have jacket losses not exceeding 0.75 percent of the input rating. This includes electric furnaces as well as fuel-fired units.

4.2.7 Open and Closed Circuit Cooling Towers

§110.2 (e)

All open and closed circuit cooling towers with rated capacity of 150 tons or greater must have a control system that maximizes the cycles of concentration based on the water quality conditions based on either conductivity or flow. If the controls system is conductivity based, then the system must automate bleed and chemical feed based on conductivity. The installation criteria for the conductivity controllers must be in accordance with the manufacturer’s specifications in order to maximize accuracy. If the control system is flow based, then the system must be automated in proportion to metered makeup volume, metered bleed volume, recirculating pump run time or bleed time.

The makeup water line must be equipped with an analog flow meter that is either wired or wireless and an overflow alarm to prevent overflow of the sump in the event of water valve failure. The alarm system may send an audible signal or an alert through an EMCS.

Drift eliminators are of a louvered or comb like design that is installed at the top of the cooling tower to capture water particles that become entrained in the air stream. These drift eliminators are now required to achieve drift reduction to 0.002 percent of the circulated water volume for counter-flow towers and 0.005 percent for cross-flow towers.

Additionally, maximum achievable cycles of concentration must be documented based on local water supply (which is reported annually by the local utility) and Langelier Saturation Index (LSI) of 2.5 or less. A calculator that is approved by the Energy Commission must be used in this process and the compliance document must be reviewed and approved by the Professional Engineer (P.E.) of record. The Energy Commission’s website includes an approved LSI calculator in the form of an excel file. The website address is http://www.energy.ca.gov/title24/2013standards/documents/maximum_cycles_calculator.xls

4.2.8 Pilot Lights

§110.5

Pilot lights are prohibited in:

1. Fan type central furnaces. This includes all space-conditioning equipment that distributes gas-heated air through duct work §110.5(a). This prohibition does not apply to radiant heaters, unit heaters, boilers or other equipment that does not use a fan to distribute heated air.

2. Household cooking appliances unless the appliance does not have an electrical connection, and the pilot consumes less than 150 Btu/h §110.5(b).
3. Pool and spa heaters §110.5(c) and §110.5(d) respectively.

Example 4-1

Question

If a 15 ton (180kBtuh) air-cooled packaged AC unit with a gas furnace rated at 260,000 Btu/h maximum heating capacity has an EER of 10.9, an IEER of 11.2, and a heating thermal efficiency of 78 percent, does it comply?

Answer

No. The cooling side complies because both the EER and IEER exceed the requirements of Table 4-1(11.0-0.2=10.8 EER and 11.2-0.2=11.0 IEER for a 15 ton unit). The EER and IEER in this table are for units with electric heat. Footnote b reduces the required EER and IEER by 0.2 for units with heating sections other than electric resistance heat. With gas heat, an EER of 10.9 (>10.8) and an IEER of 11.2 (>11.0), this unit complies. Note that the 0.2 deduction provided in Table 4-1and Table 4-2compensate for the higher fan power required to move air over the heat exchangers for fuel-fired heaters.

From Table 4-10, the heating efficiency must be at least 80 percent thermal efficiency. This unit has a 78percent thermal efficiency (<80%); therefore the unit does not comply.

Example 4-2

Question

A 500,000 Btu/h gas-fired boiler with high/low firing has a full load combustion efficiency of 82 percent, 78 percent thermal efficiency and a low-fire combustion efficiency of 80 percent. Does the unit comply?

Answer

No. Per Table 4-11, the thermal efficiency must be greater than 80 percent. This boiler's thermal efficiency is 78percent (<80%) so it doesn't comply.

Example 4-3

Question

A 300 ton centrifugal chiller is designed to operate at 44°F chilled water supply, 90°F condenser water return and 3 gpm/ton condenser water flow. What is the maximum allowable full load kW/ton and NPLV?

Answer

As the chiller is centrifugal and is designed to operate at a condition different from AHRI Standard 550/590 standard rating conditions, the appropriate efficiencies can be calculated using the Kadj equations.

From Table 4-4 (Equipment Type: Water Cooled, Electrically Operated, Centrifugal; Size Category: ≥ 300 tons and < 600 tons), this chiller at AHRI rating conditions has a maximum full load efficiency of 0.576 kW/ton and a maximum IPLV of 0.549 kW/ton for Path A and a maximum full load efficiency of 0.600 kW/ton and a maximum IPLV of 0.400 kW/ton for Path B.

The Kadj is calculated as follows:

LIFT = LvgCond – LvgEvap = 90F-44F = 46F

$A = (0.00000014592 \times (46)^4) – (0.0000346496 \times (46)^3)+ (0.00314196 \times (46)^2) – (0.147199 \times *(46)) + 3.9302=1.08813$

$B = (0.0015 \times 44) + 0.934 = 1.000$

$Kadj=A \times B=1.08813$

For compliance with Path A, the maximum Full load kW/ton = 0.576 / 1.08813 = 0.529 kW/ton and the maximum NPLV= 0.549 / 1.08813 = 0.505 kW/ton

For compliance with Path B the maximum Full load kW/ton = 0.600 / 1.08813 = 0.551 kW/ton and the maximum NPLV= 0.400 / 1.08813 = 0.388 kW/ton

To meet the mandatory measures of 4.2.2 (Energy Standards §110.2) the chiller can comply with either the Path A or Path B requirement (footnote b in Table 4-4). To meet the prescriptive requirement of 4.6.2.8 (Energy Standards §140.4(i)) the chiller would have to meet or exceed the Path B requirement.

Example 4-4

Question

A 300 ton water cooled chiller with a screw compressor that serves a thermal energy storage system is designed to operate at 34°F chilled water supply, 82°F condenser water supply and 94°F condenser water return, does it have a minimum efficiency requirement and if so, what is the maximum full load kW/ton and NPLV?

Answer

As the chiller is positive displacement (screw and scroll compressors are positive displacement) and is designed to operate at a chilled water temperature above 32°F it does have a minimum efficiency requirement per 4.2.2 (Exception 2 to §110.2(a)). From Table 4-4(Equipment Type: Water Cooled, Electrically Operated, Positive Displacement; Size Category: ≥ 300 tons) this chiller at AHRI rating conditions has a maximum full load efficiency of 0.620 kW/ton and a maximum IPLV of 0.540 kW/ton for Path A and a maximum full load efficiency of 0.639 kW/ton and a maximum IPLV of 0.490 kW/ton for Path B.

The Kadj is calculated as follows:

LIFT = LvgCond – LvgEvap = 94F-34F = 60F
A = (0.00000014592 x (60)4) – (0.0000346496 x (60)3)+ (0.00314196 x (60)2) – (0.147199 x *(60)) + 3.9302=0.81613
B = (0.0015 x 34) + 0.934 = 0.98500
Kadj=A x B=0.80388

For compliance with Path A, the maximum Full load kW/ton = 0.620 / 0.80388 = 0.771 kW/ton and the maximum NPLV= 0.540 / 0.80388 = 0.672 kW/ton. For compliance with Path B the maximum Full load kW/ton = 0.639 / 0.80388 = 0.795 kW/ton and the maximum NPLV= 0.490 / 0.80388 = 0.610 kW/ton. To meet the mandatory measures of 4.2.2 (Energy Standards §110.2) the chiller can comply with either the Path A or Path B requirement (footnote b in Table 4-4). To meet the prescriptive requirement of 4.6.2.8 (Energy Standards §140.4(i)) the chiller would have to meet or exceed the Path B requirement.

Example 4-5

Question

Are all cooling towers required to be certified by CTI?

Answer

No. Per footnote d in Table 4-7, field-erected cooling towers are not required to be certified. Factory-assembled towers must either be CTI-certified or have their performance verified in a field test (using ATC 105) by a CTI-approved testing agency. Furthermore only base models need to be tested; options in the air-stream, like access platforms or sound traps, will derate the tower capacity by 90 percent of the capacity of the base model or the manufacturer’s stated performance, whichever is less.

Example 4-6

Question

Are there any mandatory requirements for a water-to-water plate-and-frame heat exchanger?

Answer

Yes, Table 4-6 requires that it be rated per ANSI/AHRI 400. This standard ensures the accuracy of the ratings provided by the manufacturer.

4.2.9 Commercial Boilers

§120.9

A commercial boiler is a type of boiler with a capacity (rated maximum input) of 300,000 Btu per hour (Btu/h) or more and serving a space heating or water heating load in a commercial building.

A. Combustion air positive shut-off shall be provided on all newly installed commercial boilers as follows:

1. All boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a non-positive vent static pressure. This is sometimes referred to as natural draft or atmospheric boilers. Forced draft boilers, which rely on a fan to provide the appropriate amount of air into the combustion chamber, are exempt from this requirement.
2. All boilers where one stack serves two or more boilers with a total combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h). This requirement applies to natural draft and forced draft boilers.

Combustion air positive shut-off is a means of restricting air flow through a boiler combustion chamber during standby periods, used to reduce standby heat loss. A flue damper and a vent damper are two examples of combustion air positive shut-off devices.

Installed dampers can be interlocked with the gas valve so that the damper closes and inhibits air flow through the heat transfer surfaces when the burner has cycled off, thus reducing standby losses. Natural draft boilers receive the most benefit from draft dampers because they have less resistance to airflow than forced draft boilers. Forced draft boilers rely on the driving force of the fan to push the combustion gases through an air path that has relatively higher resistance to flow than in a natural draft boiler. Positive shut-off on a forced draft boiler is most important on systems with a tall stack height or multiple boiler systems sharing a common stack.

B. Boiler combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

1. The fan motor shall be driven by a variable speed drive, or
2. The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume.

Electricity savings result from run time at part-load conditions. As the boiler firing rate decreases, the combustion air fan speed can be decreased.

C. Newly installed boilers with an input capacity of 5 MMBtu/h (5,000,000 Btu/h) and greater shall maintain excess (stack-gas) oxygen concentrations at less than or equal to 5.0 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to firing rate or measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

Boilers with steady state full-load thermal efficiency 85 percent or higher are exempt from this requirement.

One way to meet this requirement is with parallel position control. Boilers mix air with fuel (usually natural gas although sometimes diesel or oil) to supply oxygen during combustion. Stoichiometric combustion is the ideal air/fuel ratio where the mixing proportion is correct, the fuel is completely burned, and the oxygen is entirely consumed. Boilers operate most efficiently when the combustion air flow rate is slightly higher than the stoichiometric air-fuel ratio. However, common practice almost always relies on excess air to ensure complete combustion, avoid unburned fuel and potential explosion, and prevent soot and smoke in the exhaust. Excess air has a penalty, which is increased stack heat loss and reduced combustion efficiency.

Parallel positioning controls optimize the combustion excess air to improve the combustion efficiency of the boiler. It includes individual servo motors allowing the fuel supply valve and the combustion air damper to operate independently of each other. This system relies on preset fuel mapping (i.e., a pre-programmed combustion curve) to establish proper air damper positions (as a function of the fuel valve position) throughout the full range of burner fire rate. Developing the combustion curve is a manual process, performed in the field with a flue-gas analyzer in the exhaust stack, determining the air damper positions as a function of the firing rate/fuel valve position. Depending on type of burner, a more consistent level of excess oxygen can be achieved with parallel position compared to single-point positioning control, since the combustion curve is developed at multiple points (firing rates), typically 10 to 25 points. Parallel positioning controls allow excess air to remain relatively low throughout a burner's firing range. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while still maintaining a safe margin of excess air to insure complete combustion.

4.3 Ventilation Requirements

§120.1

All of the ventilation requirements are mandatory measures. Some measures require acceptance testing, which is addressed in Section 4.3.11.

Within a building, all enclosed spaces that are normally used by humans must be continuously ventilated during occupied hours with outdoor air, using either natural or mechanical ventilation An exception is provided for refrigerated warehouses or other buildings or spaces that are not normally used for human occupancy or work.

The Energy Standards allow for ventilation to use transfer air as long as it doesn't have any "unusual sources of indoor air contaminants" and "the outdoor air that is supplied to all spaces combined, is sufficient to meet the requirements for each space individually. Good practice dictates that sources of contaminants be isolated and controlled with local exhaust. The designation and treatment of such spaces is subject to the designer's discretion. Spaces needing special consideration include:

- Commercial and coin-operated dry cleaners.
- Bars and cocktail lounges.
- Smoking lounges and other designated smoking areas.
- Beauty and barbershops.

- Auto repair workshops.
- Print shops, graphic arts studios and other spaces where solvents are used in a process.
- Copy rooms, laser printer rooms or other rooms where it is expected that equipment may generate heavy concentrations of ozone or other contaminants.
- Blueprint machines.

"Spaces normally used by humans" refers to spaces where people can be reasonably expected to remain for an extended period of time. Spaces where occupancy will be brief and intermittent, and that do not have any unusual sources of air contaminants, do not need to be directly ventilated. For example:

- A closet does not need to be ventilated, provided it is not normally occupied.
- A storeroom that is only infrequently or briefly occupied does not require ventilation. However, a storeroom that can be expected to be occupied for extended periods for clean-up or inventory must be ventilated, preferably with systems controlled by a local switch so that the ventilation system operates only when the space is occupied.

"Continuously ventilated during occupied hours" implies that the design ventilation must be provided throughout the entire occupied period. This means that VAV systems must provide the code-required ventilation over their full range of operating supply airflow. Some means of dynamically controlling the minimum ventilation air must be provided.

4.3.1 Natural Ventilation

§120.1(b)1

Natural outdoor ventilation may be provided for spaces where all normally occupied areas of the space are within a specific distance from an operable wall or roof opening through which outdoor air can flow. This distance is 20 ft. for most spaces and 25 ft. for hotel/motel guestrooms and high-rise residential spaces. The sum of the operable open areas must total at least 5 percent of the floor area of each space that is naturally ventilated. The openings must also be readily accessible to the occupants of the space at all times.

Airflow through the openings must come directly from the outdoors; air may not flow through any intermediate spaces such as other occupied spaces, unconditioned spaces, corridors, or atriums. Also, high windows, operable skylights, and other operable openings need to have a control mechanism accessible from the floor.

Example 4-7

Question

What is the window area required to ventilate a 30 ft. x 32 ft. classroom?

Answer

In order for all points to be within 20 ft. of an opening, windows must be distributed and run at least along two of the opposite walls. The area of the openings must be:

(32 ft. x 30 ft.) x 5 percent = 48 ft²

The actual window area must be at least 96 ft² if only half the window can be open at a time.

Calculations must be based on free area, taking into account framing and bug screens; the actual window area is approximately 100 ft² without bug screens and 110 ft² with bug screens.

Example 4-8

Question

Naturally ventilated classrooms are located on either side of a doubly-loaded corridor and transoms are provided between the classrooms and corridor. Can the corridor be naturally ventilated through the classrooms?

Answer

No. The corridor cannot be naturally ventilated through the classrooms and transom openings. The Energy Standards require that naturally ventilated spaces have direct access to properly-sized openings to the outdoors. The corridor would require mechanical ventilation using either supply or exhaust fans.

4.3.2 Mechanical Ventilation

§120.1(b)2 and (d)

Mechanical outdoor ventilation must be provided for all spaces normally occupied that are not naturally ventilated. The Energy Standards require that a space conditioning system provide outdoor air equal to or exceeding the ventilation rates required for each of the spaces that it serves. At the space, the required ventilation can be provided either directly through supply air or indirectly through transfer of air from the plenum or an adjacent space. The required minimum ventilation airflow at the space can be provided by an equal quantity of supply or transfer air. At the air-handling unit, the minimum outside air must be the sum of the ventilation requirements of each of the spaces that it serves. The designer may specify higher outside air ventilation rates based on the owner’s preference or specific ventilation needs associated with the space. However, specifying more ventilation air than the minimum allowable ventilation rates increases energy consumption and electrical peak demand and increases the costs of operating the HVAC equipment. Thus the designer should have a compelling reason to specify higher design minimum outside air rates than the calculated minimum outside air requirements in the Energy Standards.

The minimum OSA provided is required to be within 10 percent of the calculated minimum for both VAV and constant volume units.

In summary:

1. Ventilation compliance at the space is satisfied by providing supply and/or transfer air.
2. Ventilation compliance at the unit is satisfied by providing, at minimum, the outdoor air that represents the sum of the ventilation requirements at each space that it serves.

For each space requiring mechanical ventilation the ventilation rates must be the greater of either:

1. The conditioned floor area of the space, multiplied by the applicable minimum ventilation rate from Table 4-12. This provides dilution for the building-borne contaminants like off-gassing of paints and carpets, or
2. 15 cfm per person, multiplied by the expected number of occupants. For spaces with fixed seating (such as a theater or auditorium), the expected number of occupants is the number of fixed seats. For spaces without fixed seating, the expected number of occupants is assumed to be no less than one-half that determined for egress purposes in the California Building Code (CBC). The Energy Standards specify the minimum outdoor ventilation rate to which the system must be designed. If desired, the designer may, with documentation, elect to provide more ventilation air. For example, the design outdoor ventilation rate may be determined using the procedures described in

ASHRAE 62, provided the resulting outdoor air quantities are no less than required by the Energy Standards.

Table 4-12: Minimum Ventilation Rates

Type of Use	CFM per ft² of Conditioned Floor Area
Auto repair workshop	1.50
Barber shop	0.40
Bars, cocktail lounges, and casinos	0.20
Beauty shop	0.40
Coin-operated dry cleaning	0.30
Commercial dry cleaning	0.45
High-rise residential	Ventilation Rates Specified by the CBC and CMC
Hotel guest room (less than 500 ft²)	30 cfm/guest room
Hotel guest room (500 ft² or greater)	0.15
Retail store	0.20
All Others	0.15

Energy Standards Table 120.1-A

Table 4-13 shows the typical maximum occupant loads for various building uses (upon which minimum ventilation calculations are based). This provides dilution for the occupant-borne contaminants (or bioeffluents) like body odor and germs.

Table 4-14 summarizes the combination of these two rates for typical spaces.

As previously stated, each space-conditioning system must provide outdoor ventilation air as follows.

1. For a space-conditioning system serving a single space, the required system outdoor airflow is equal to the design outdoor ventilation rate of the space.
2. For a space-conditioning system serving multiple spaces, the required outdoor air quantity delivered by the space-conditioning system must not be less than the sum of the required outdoor ventilation rate to each space. The Energy Standards do not require that each space actually receive its calculated outdoor air quantity. Instead, the actual supply to any given space may be any combination of recirculated air, outdoor air, or air transferred directly from other spaces, provided:
   a. The total amount of outdoor air delivered by the space-conditioning system(s) to all spaces is at least as large as the sum of the space design quantities.
   b. Each space always receives supply airflow, including recirculated air and/or transfer air, no less than the calculated outdoor ventilation rate.
   c. When using transfer air, none of the spaces from which air is transferred has any unusual sources of contaminants.

Table 4-13: CBC Maximum Floor Area Allowances Per Occupant

Function of Space	Occupant Load Factor
Accessory storage areas, mechanical equipment room	300 gross
Agricultural building	300 gross
Aircraft hangers	500 gross
Airport terminal	
Baggage claim	20 gross
Baggage handling	300 gross
Concourse	100 gross
Waiting areas	15 gross
Assembly	
Gaming floors (keno, slots, etc.)	11 gross
Exhibit Gallery and Museum	30 net
Assembly with fixed seats	See Section 1004.4
Assembly without fixed seats	
Concentrated (chairs only – not fixed)	7 net
Standing space	5 net
Non-concentrated (tables and chairs)	15 net
Bowling centers and all other spaces	7 net
Bowling lanes (including 15 feet of approach)	5 person per lane
Business areas	100 gross
Courtrooms – other than fixed seating areas	40 net
Day care	35 net
Dormitories	50 gross
Educational	
Classroom area	20 net
Shops and other vocational room areas	50 net
Exercise rooms	50 gross
H-5 Fabrication and manufacturing areas	200 gross
Industrial areas	100 gross
Institutional areas	
Inpatient treatment areas	240 gross
Outpatient areas	100 gross
Sleeping areas	120 gross
Kitchens, commercial	200 gross
Library	
Reading rooms	50 net
Stack area	100 gross
Locker Rooms	50 gross
Mercantile	
Area on other floors	60 gross
Basement and grade floor areas	30 gross
Storage, stock, shipping areas	300 gross
Parking garages	200 gross
Residential	200 gross
Skating rinks, swimming pools	
Rink and pool	50 gross
Decks	15 gross
Stages and platforms	15 net
Warehouses	500 gross

Source: Table 1004.1.2 of the California Building Code

Where:

Floor Area, Gross - The floor area within the inside perimeter of the exterior walls of the building under consideration, exclusive of vent shafts and courts, without deduction for corridors, stairways, closets, the thickness of interior walls, columns or other features. The floor area of a building, or portion thereof, not provided with surrounding exterior walls shall be the usable area under the horizontal projection of the roof or floor above. The gross floor area shall not include shafts with no openings or interior courts.

Floor Area, Net - The actual occupied area not including unoccupied accessory areas such as corridors, stairways, toilet rooms, mechanical rooms and closets.

Table 4-14: Required Minimum Ventilation Rate per Occupancy

	Occupancy	Use	CBC Occupancy Load (ft²/occc)	CBC Occupancy Load (occ/1000 ft²)[A]	CBC Based Ventilation (cfm/ft²)[B]	Ventilation from Table 120.1-A (cfm/ft²)	Required Ventilation (larger of CBC or Table 120.1-A) (cfm/ft²)
1)	Aircraft Hangars		500	2	0.02	0.15	0.15
2)	Auction Rooms		See Section 1004.4			0.15	n.a.
3)	Assembly Areas (Concentrated Use)						
		Auditoriums	See Section 1004.4			0.15	n.a.
		Bowling Lane	5 persons per lane			0.15	n.a.
		Bowling Center[5] (all other spaces)	7	142.86	1.07	0.15	1.07
		Churches & Chapels (Religious Worship)	7	142.86	1.07	0.15	1.07
		Dance Floors	5	200	1.50	0.15	1.50
		Lobbies	15	66.67	0.50	0.15	0.50
		Lodge Rooms	7	142.86	1.07	0.15	1.07
		Reviewing Stands	15	66.67	0.50	0.15	0.50
		Stadiums	See Section 1004.4			0.15	n.a.
		Theaters - All	See Section 1004.4			0.15	n.a.
		Waiting Areas	15	66.67	0.50	0.15	0.50
4)	Assembly Areas (Non-concentrated Use)						
		Conference & Meeting Rooms[1]	15	66.67	0.50	0.15	0.50
		Dining Rooms/Areas	15	66.67	0.50	0.15	0.50
		Drinking Establishments[2]	15	66.67	0.50	0.20	0.50
		Exhibit/Display Areas	15	66.67	0.50	0.15	0.50
		Gymnasiums/Sports Arenas	15	66.67	0.50	0.15	0.50
		Lounges	15	66.67	0.50	0.20	0.50
		Stages and Platform	15	66.67	0.50	0.15	0.50
		Gaming, Keno, Slot Machine and Live Games Areas	11	90.91	0.68	0.20	0.68
5)	Auto Repair Workshops		100	10	0.08	1.50	1.50
6)	Barber & Beauty Shops		100	10	0.08	0.40	0.40
7)	Children's Homes & Homes for Aged		120	8.33	0.06	0.15	0.15
8)	Classrooms		20	50	0.38	0.15	0.38
9)	Courtrooms		40	25	0.19	0.15	0.19
10)	Dormitories		50	20	0.15	0.15	0.15
11)	Dry Cleaning (Coin-Operated)		100	10	0.08	0.30	0.30
12)	Dry Cleaning (Commercial)		100	10	0.08	0.45	0.45
13)	Exercise Rooms		50	20	0.15	0.15	0.15
14)	Garage, Parking		200	5	0.04	0.15	0.15
15)	Healthcare Facilities:	Sleeping Rooms	120	8.33	0.06	0.15	0.15
		Treatment Rooms	240	4.17	0.03	0.15	0.15

(Cont) Table 4-14: Required Minimum Ventilation Rate per Occupancy

	Occupancy	Use	CBC Occupancy Load (ft²/occ)	CBC Occupancy Load (occ/1000 ft²)[A]	CBC Based Ventilation (cfm/ft²)[B]	Ventilation from Table 120.1-A (cfm/ft²)	Required Ventilation (larger of CBC or Table 120.1-A) (cfm/ft²)
16)	Hotels and Apartments						
		Hotel Function Area	7	142.86	1.07	0.15	1.07
		Hotel Lobby	100	10	0.08	0.15	0.15
		Hotel Guest Room (<500 ft²)[3]	200	5	0.04	n.a.[3]	n.a.[3]
		Hotel Guest Room (≥500 ft²)	200	5	0.04	0.15	0.15
		High-rise Residential[4]	200	5	0.04	n.a.[4]	n.a.[4]
17)	Kitchen (Commercial)		200	5	0.04	0.15	0.15
18)	Library:	Reading Rooms	50	20	0.15	0.15	0.15
		Stack Areas	100	10	0.08	0.15	0.15
19)	Locker Rooms		50	20	0.15	0.15	0.15
20)	Manufacturing		200	5	0.04	0.15	0.15
21)	Mechanical Equipment Room		300	3.33	0.03	0.15	0.15
22)	Nurseries for Children - Day Care		35	28.57	0.21	0.15	0.21
23)	Offices:	Office	100	10	0.08	0.15	0.15
		Bank/Financial Institution	100	10	0.08	0.15	0.15
		Medical & Clinical Care	100	10	0.08	0.15	0.15
24)	Retail:	Sales, Wholesale Showrooms	30	33.33	0.25	0.20	0.25
		Basement and Ground Floor	30	33.33	0.25	0.20	0.25
		Upper Floors	60	16.67	0.13	0.20	0.20
		Grocery	30	33.33	0.25	0.20	0.25
		Malls, Arcades, & Atria	30	33.33	0.25	0.20	0.25
25)	School Shops & Vocational Rooms		50	20	0.15	0.15	0.15
26)	Skating Rinks:	Skate Area	50	20	0.15	0.15	0.15
		On Deck	15	66.67	0.50	0.15	0.50
27)	Swimming Pools:	Pool Area	50	20	0.15	0.15	0.15
		On Deck	15	66.67	0.50	0.15	0.50
28)	Transportation Function Area		30	33.33	0.25	0.15	0.25
29)	Warehouses, Industrial & Commercial Storage/Stockrooms		500	2	0.02	0.15	0.15
30)	All Others -- Including Unknown, Corridors, Restrooms, & Support Areas Commercial & Industrial Work		100	10	0.08	0.15	0.15

Footnotes:

1. Includes Convention & Civic Meeting Areas.
2. Bars, Cocktail & Smoking Lounges, Casinos.
3. Guestrooms less than 500 ft² use 30 cfm/guestroom.
4. High-rise Residential - for habitable areas not ventilated with Natural Ventilation, cfm=(0.06 cfm/ft² + 5 cfm/occ). Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
5. Bowling centers, allow 5 persons for each lane including 15 feet of approach.

Equations:

A. CBC Occupancy Load Equation:

$$Number\ of\ occupants/1000ft^2 = \frac{1000}{ft^2/occupant}$$

B. CBC Based Ventilation Equation:

$$cfm/ft^2 = 15\ cfm \times \frac{\left(\frac{Occupants/1000\ ft^2}{2}\right)}{1000}$$

Example 4-9

Question

Ventilation for a two-room building:

Consider a building with two spaces, each having an area of 1,000 ft². One space is used for general administrative functions, and the other is used for classroom training. It is estimated that the office will contain 7 people, and the classroom will contain 50 (fixed seating). What are the required outdoor ventilation rates?

Answer

1. For the office area, the design outdoor ventilation air is the larger of:

   7 people x 15 cfm/person = 105 cfm; or

   1,000 ft² x 0.15 cfm/ft² = 150 cfm

   For this space, the design ventilation rate is 150 cfm.

2. For the classroom, the design outdoor ventilation air is the larger of:

   50 people x 15 cfm/person = 750 cfm; or

   1,000 ft² x 0.15 cfm/ft² = 150 cfm

   For this space the design ventilation rate is 750 cfm.

Assume the total supply air necessary to satisfy cooling loads is 1,000 cfm for the office and 1,500 cfm for the classroom. If each space is served by a separate system, then the required outdoor ventilation rate of each system is 150 cfm and 750 cfm, respectively. This corresponds to a 15 percent outside air (OA) fraction in the office HVAC unit, and 50 percent in the classroom unit.

If both spaces are served by a central system, then the total supply will be (1,000 + 1,500) cfm = 2500 cfm. The required outdoor ventilation rate is (150 + 750) = 900 cfm total. The actual outdoor air ventilation rate for each space is:

Office OA = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm

Classroom OA = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While this simplistic analysis suggests that the actual OA cfm to the classroom is less than design (540 cfm vs. 750 cfm), the analysis does not take credit for the dilution effect of the air recirculated from the office. The office is over-ventilated (360 cfm vs. 150 cfm) so the concentration of pollutants in the office return air is low enough that it can be used, along with the 540 cfm of outdoor air, to dilute pollutants in the classroom. The Energy Standards allow this design provided that the system always delivers at least 750 cfm to the classroom (including transfer or recirculated air), and that any transfer air is free of unusual contaminants.

4.3.3 Direct Air Transfer

The Energy Standards allow air to be directly transferred from other spaces in order to meet a part of the ventilation supply to a space, provided the total outdoor quantity required by all spaces served by the building's ventilation system is supplied by the mechanical systems. This method can be used for any space, but is particularly applicable to conference rooms, toilet rooms, and other rooms that have high ventilation requirements. Transfer air must be free from any unusual contaminants, and should not be taken directly from rooms where such sources of contaminants are anticipated. It is typically taken from the return plenum or directly from an adjacent space.

Air may be transferred using any method that ensures a positive airflow. Examples include: dedicated transfer fans, exhaust fans, and fan-powered VAV boxes. A system having a ducted return may be balanced so that air naturally transfers into the space. Exhaust fans serving the space may discharge directly outdoors, or into a return plenum. Transfer systems should be designed to minimize recirculation of transfer air back into the space; duct work should be arranged to separate the transfer air intake and return points.

When each space in a two-space building is served by a separate constant volume system, the calculation and application of ventilation rate is straightforward, and each space will always receive its design outdoor air quantity. However, a central system serving both spaces does not deliver the design outdoor air quantity to each space. Instead, one space receives more than its allotted share, and the other less. This is because the training room has a higher design outdoor ventilation rate and/or a lower cooling load relative to the other space.

4.3.4 Distribution of Outdoor Air to Zonal Units

§120.1(d)

When a return plenum is used to distribute outside air to a zonal heating or cooling unit, the outside air supply must be connected either:

1. Within 5 ft. of the unit; or
2. Within 15 ft. of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 ft. per minute.

Water source heat pumps and fan coils are the most common application of this configuration. The unit fans should be controlled to run continuously during occupancy in order for the ventilation air to be circulated to the occupied space.

A central space-conditioning system(s) augmented by a few zonal units for spot conditioning may use transfer air from spaces served by the central system. A direct source of outdoor air is not required for each zonal unit. Similarly, transfer air may be used in buildings having central interior space-conditioning systems with outdoor air, and zonal units on the perimeter (without outdoor air).

While not required, the Energy Standards recommend that sources of unusual contaminants be controlled through the use of containment systems that capture the contaminants and discharge them directly outdoors. Such systems may include exhaust hoods, fume hoods, small space exhausts and differential pressure control between spaces. The designer is advised to consult ASHRAE standards or other publications for guidance in this subject.

4.3.5 Ventilation System Operation and Controls

§120.1(c)

4.3.5.1 **Outdoor Ventilation Air and VAV Systems**

Except for systems employing Energy Commission-certified demand controlled ventilation (DCV) devices or space occupancy sensors, the Energy Standards require that the minimum rate of outdoor air calculated per §120.1(b)2 be provided to each space *at all times* when the space is normally occupied §120.1(c)1. For spaces served by variable air volume (VAV) systems, this means that the minimum supply setting of each VAV box should be no less than the design outdoor ventilation rate calculated for the space, unless transfer air is used. If transfer air is used, the minimum box position, plus the transfer air, must meet the minimum ventilation rate. If transfer air is not used, the box must be controlled so that the minimum required airflow is maintained at all times (unless demand controlled ventilation or occupant sensor are employed).

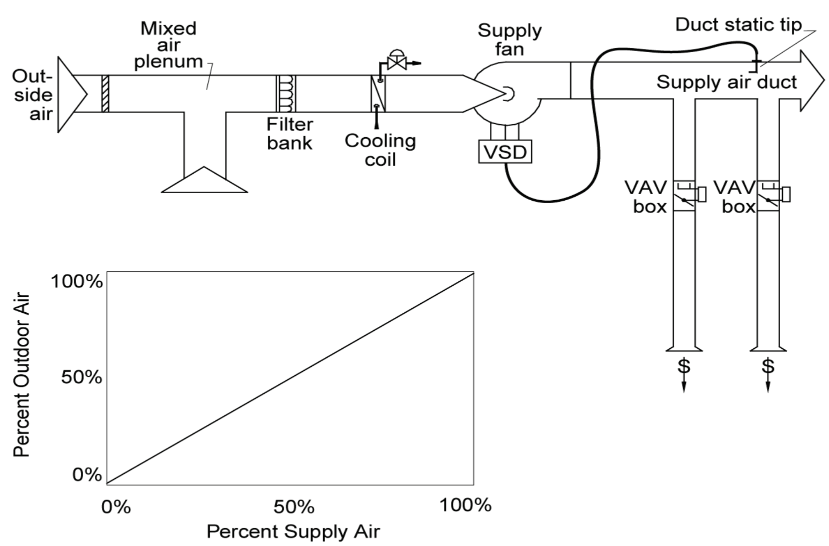
The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity §120.1(c)1. Section 4.3.11 describes mandated acceptance test requirements for outside air ventilation in VAV air handling systems. In these tests, the minimum outside air in VAV systems will be measured both at full flow and with all boxes at minimum position.

Figure 4-2 shows a typical VAV system. In standard practice, the testing and balancing (TAB) contractor sets the minimum position setting for the outdoor air damper during construction. It is set under the conditions of design airflow for the system, and remains in the same position throughout the full range of system operation. Does this meet code? The answer is no. As the system airflow drops, so will the pressure in the mixed air plenum. A fixed position on the minimum outdoor air damper will produce a varying outdoor airflow. As depicted in Figure 4-2, this effect will be approximately linear (in other words, outdoor air airflow will drop directly in proportion to the supply airflow).

The following paragraphs present several methods used to dynamically control the minimum outdoor air in VAV systems, which are described in detail below.

Regardless of how the minimum ventilation is controlled, care should be taken to reduce the amount of outdoor air provided when the system is operating during the weekend or after hours with only a fraction of the zones active. §120.2(g) requires provision of “isolation zones” of 25,000 ft² or less. This can be provided by having the VAV boxes return to fully closed when their associated zone is in unoccupied mode. When a space or group of spaces is returned to occupied mode (e.g. through off-hour scheduling or a janitor’s override), only the boxes serving those zones need to be active. During this partial occupancy, the ventilation air can be reduced to the requirements of those zones that are active. If all zones are of the same occupancy type (e.g. private offices), simply assign a floor area to each isolation zone and prorate the minimum ventilation area by the ratio of the sum of the floor areas presently active divided by the sum of all the floor areas served by the HVAC system.

Figure 4-2: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Setpoint



A. Fixed Minimum Damper Setpoint

This method does not comply with the Energy Standards; the airflow at a fixed minimum damper position will vary with the pressure in the mixed air plenum. It is explicitly prohibited in §120.1(e)2.

B. Dual Minimum Setpoint Design

This method complies with the Energy Standards. An inexpensive enhancement to the fixed damper setpoint design is the dual minimum setpoint design, commonly used on some packaged AC units. The minimum damper position is set proportionally based on fan speed or airflow between a setpoint determined when the fan is at full speed (or airflow) and minimum speed (or airflow). This method complies with the letter of the Energy Standards but is not accurate over the entire range of airflow rates and when there are wind or stack effect pressure fluctuations. But with DDC, this design has very low costs.

C. Energy Balance Method

The energy balance method uses temperature sensors in the outside, as well as return and mixed air plenums to determine the percentage of outdoor air in the supply air stream. The outdoor airflow is then calculated using the equations shown in Figure 4-3. This method requires an airflow monitoring station on the supply fan.

While technically feasible, it may be difficult to meet the outside air acceptance requirements with this approach because:

1. It is difficult to accurately measure the mixed air temperature, which is critical to the success of this strategy. Even with an averaging type bulb, most mixing plenums have some stratification or horizontal separation between the outside and mixed airstreams.[1]
2. Even with the best installation, high accuracy sensors, and field calibration of the sensors, the equation for percent outdoor air will become inaccurate as the return air temperature approaches the outdoor air temperature. When they are equal, this equation predicts an infinite percentage outdoor air.
3. The accuracy of the airflow monitoring station is likely to be low at low supply airflows.
4. The denominator of the calculation amplifies sensor inaccuracy as the return air temperature approaches the outdoor air temperature.

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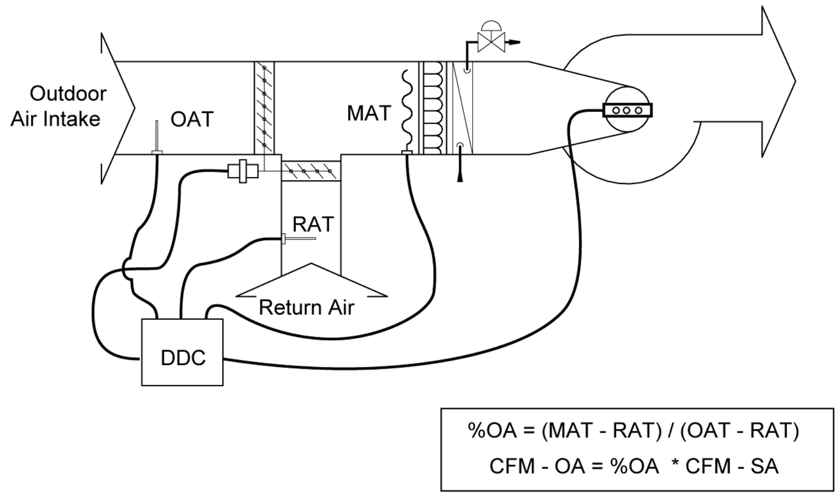
[1] This was the subject of ASHRAE Research Project 1045-RP, "Verifying Mixed Air Damper Temperature and Air Mixing Characteristics." Unless the return is over the outdoor air there are significant problems with stratification or airstream separation in mixing plenums.

Figure 4-3: Energy Balance Method of Controlling Minimum Outdoor Air



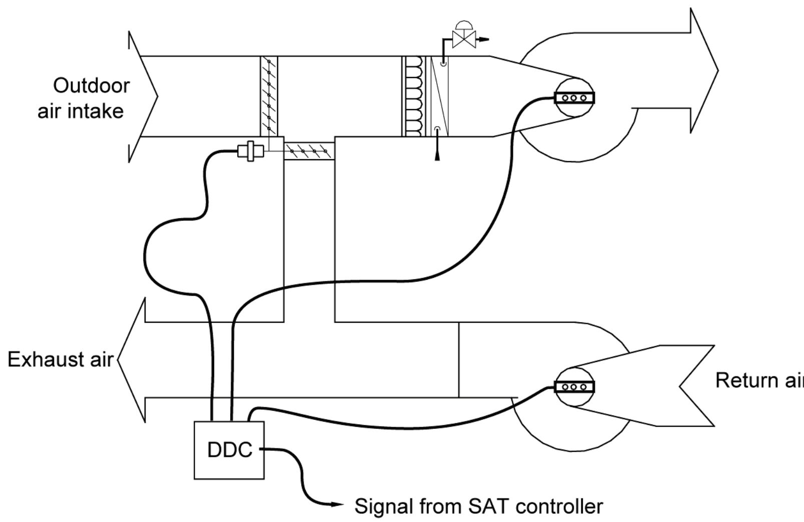
D. Return Fan Tracking

This method is also technically feasible, but will likely not meet the acceptance requirements because the cumulative error of the two airflow measurements can be large, particularly at low supply/return airflow rates. It only works theoretically when the minimum outdoor air rate equals the rate of air required to maintain building pressurization (the difference between supply air and return air rates). Return fan tracking (Figure 4-4) uses airflow monitoring stations on both the supply and return fans. The theory behind this is that the difference between the supply and return fans has to be made up by outdoor air, and controlling the flow of return air forces more ventilation into the building. Several problems occur with this method:

1. The relative accuracy of airflow monitoring stations is poor, particularly at low airflows;
2. The cost of airflow monitoring stations;
3. It will cause building pressurization problems unless the ventilation air is equal to the desired building exfiltration plus the building exhaust.

ASHRAE research has also demonstrated that in some cases this arrangement can cause outdoor air to be drawn into the system through the exhaust dampers due to negative pressures at the return fan discharge.

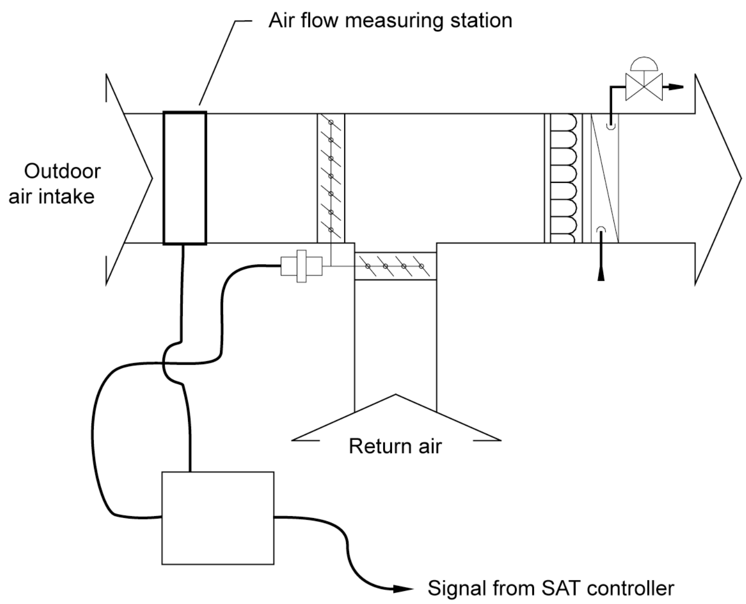
Figure 4-4: Return Fan Tracking



E. Airflow Measurement of the Entire Outdoor Air Inlet

This method is technically feasible but will likely not meet the acceptance requirements depending on the airflow measurement technology. Most airflow sensors will not be accurate to a 5-15 percent turndown (the normal commercial ventilation range). Controlling the outdoor air damper by direct measurement with an airflow monitoring station (Figure 4-5) can be an unreliable method. Its success relies on the turndown accuracy of the airflow monitoring station. Depending on the loads in a building, the ventilation airflow can be between 5 and 15 percent of the design airflow. If the outdoor airflow sensor is sized for the design flow for the airside economizer, this method has to have an airflow monitoring station that can turn down to the minimum ventilation flow (between 5 and 15 percent). Of the different types available, only a hot-wire anemometer array is likely to have this low-flow accuracy while traditional pilot arrays will not. One advantage of this approach is that it provides outdoor airflow readings under all operating conditions, not just when on minimum outdoor air. For highest accuracy, provide a damper and outdoor air sensor for the minimum ventilation air that is separate from the economizer outdoor air intake.

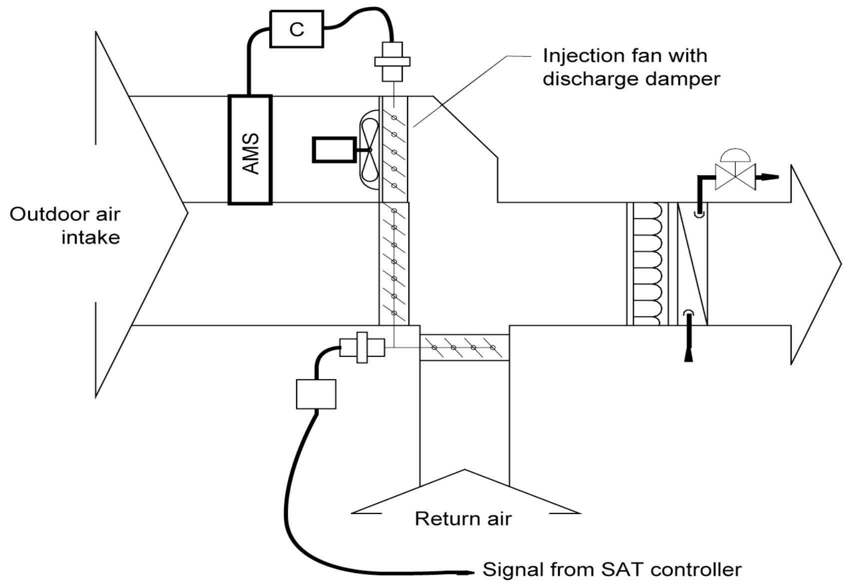
Figure 4-5: Airflow Measurement of 100% Outdoor Air



F. Injection Fan Method

This method complies with the Energy Standards, but it is expensive and may require additional space. Note that an airflow sensor and damper are required since fan airflow rate will vary as mixed air plenum pressure varies. The injection fan method (Figure 4-6) uses a separate outdoor air inlet and fan sized for the minimum ventilation airflow. This inlet contains an airflow monitoring station, and a fan with capacity control (e.g., discharge damper; VFD), which is modulated as required to achieve the desired ventilation rate. The discharge damper is recommended since a damper must be provided anyway to shut off the intake when the AHU is off, and also to prevent excess outdoor air intake when the mixed air plenum is very negative under peak conditions. (The fan is operating against a negative differential pressure and thus cannot stop flow just by slowing or stopping the fan.) This method works, but the cost is high and often requires additional space for the injection fan assembly.

Figure 4-6: Injection Fan with Dedicated Minimum Outdoor Air Damper



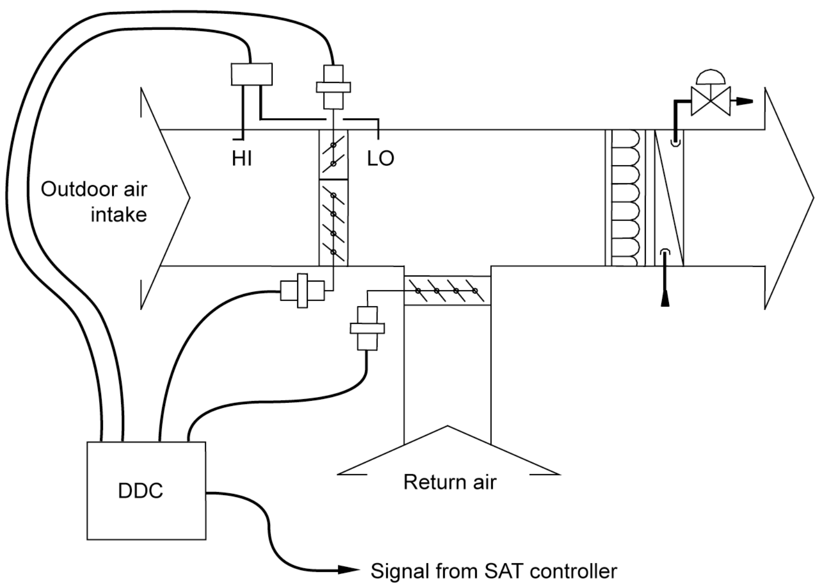
G. Dedicated Minimum Ventilation Damper with Pressure Control

This approach is low cost and takes little space. It can be accurate if the differential setpoint corresponding to the minimum outdoor air rate is properly set in the field. An inexpensive but effective design uses a minimum ventilation damper with differential pressure control (Figure 4-7). In this method, the economizer damper is broken into two pieces: a small two position damper controlled for minimum ventilation air and a larger, modulating, maximum outdoor air damper that is used in economizer mode. A differential pressure transducer is placed across the minimum outdoor air damper. During start-up, the air balancer opens the minimum outside air (OA) damper and return air damper, closes the economizer OA damper, runs the supply fan at design airflow, measures the OA airflow (using a hand-held velometer) and adjusts the minimum OA damper position until the OA airflow equals the design minimum OA airflow. The linkages on the minimum OA damper are then adjusted so that the current position is the “full open” actuator position. At this point the design pressure (DP) across the minimum OA damper is measured. This value becomes the DP setpoint. The principle used here is that airflow is constant across a fixed orifice (the open damper) at fixed DP.

As the supply fan modulates when the economizer is off, the return air damper is controlled to maintain the DP setpoint across the minimum ventilation damper.

The main downside to this method is the complexity of controls and the potential problems determining the DP setpoint in the field. It is often difficult to measure the outdoor air rate due to turbulence and space constraints.

Figure 4-7: Minimum Outdoor Air Damper with Pressure Control



Example 4-10

Question

Minimum VAV cfm:

If the minimum required ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for its VAV box when the design percentage of outdoor air in the supply is 20 percent?

Answer

The minimum allowed airflow may be as low as 150 cfm provided that enough outdoor air is supplied to all spaces combined to meet the requirements of §120.1(b)2 for each space individually.

4.3.6 Pre-Occupancy Purge

§120.1(c)2

Since many indoor air pollutants are out-gassed from the building materials and furnishings, the Energy Standards require that buildings having a scheduled operation be purged before occupancy §120.1(c)2. Immediately prior to occupancy, outdoor ventilation must be provided in an amount equal to the lesser of:

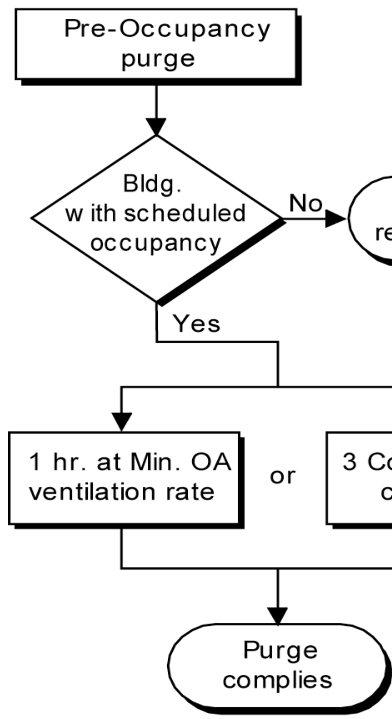
1. The minimum required ventilation rate for 1 hour.
2. 3 complete air changes.

Either criterion can be used to comply with the Energy Standards. Three complete air changes means an amount of ventilation air equal to 3 times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be less than an hour.

A pre-occupancy purge is not required for buildings or spaces that are not occupied on a scheduled basis, such as storage rooms. Also, a purge is not required for spaces provided with natural ventilation.

Where pre-occupancy purge is required, it does not have to be coincident with morning warm-up (or cool-down). The simplest means to integrate the two controls is to simply schedule the system to be occupied one hour prior to the actual time of anticipated occupancy. This allows the optimal start, warm-up or pull-down routines to bring the spaces up to (or down to) desired temperatures before opening the outdoor air damper for ventilation. This will reduce the required system heating capacity and ensure that the spaces will be at the desired temperatures and fully purged at the start of occupancy.

Figure 4-8: Pre-Occupancy Purge Flowchart



Example 4-11

Question

Purge Period:

What is the length of time required to purge a space 10 ft. high with an outdoor ventilation rate of 1.5 cfm/ft²?

Answer

For 3 air changes, each ft² of space must be provided with:

OA volume = 3 x 10 = 30 cf/ft²

At a rate of 1.5 cfm/ft², the time required is:

Time = 30 cf/ft² / 1.5 cfm/ft² = 20 minutes

Example 4-12

Question

Purge with Natural Ventilation:

In a building with natural ventilation, do the windows need to be left open all night to accomplish a building purge?

Answer

No. A building purge is required only for buildings with mechanical ventilation systems.

Example 4-13

Question

Purge with Occupancy Timer:

How is a purge accomplished in a building without a regularly scheduled occupancy whose system operation is controlled by an occupancy sensor?

Answer

There is no purge requirement for this building. Note that occupancy sensors and manual timers can only be used to control ventilation systems in buildings that are intermittently occupied without a predictable schedule.

4.3.7 Demand Controlled Ventilation

§120.1(c)3 and 4

Demand controlled ventilation (DCV) systems reduce the amount of ventilation supply air in response to a measured level of carbon dioxide (CO_2) in the breathing zone. The Energy Standards only permit CO_2 sensors for the purpose of meeting this requirement; VOC and so-called "IAQ" sensors are not approved as alternative devices to meet this requirement. The Energy Standards only permit DCV systems to vary the ventilation component that corresponds to occupant bioeffluents (this is basis for the 15 cfm/person portion of the ventilation requirement). The purpose of CO_2 sensors is to track occupancy in a space; however, there are many factors that must be considered when designing a DCV system. There is often a lag time in the detection of occupancy through the build-up of CO_2. This lag time may be increased by any factors that affect mixing, such as short circuiting of supply air or inadequate air circulation, as well as sensor placement and sensor accuracy. Build-up of odors, bioeffluents, and other health concerns may also lag changes in occupancy; therefore, the designers must be careful to specify CO_2 based DCV systems that are designed to provide adequate ventilation to the space by ensuring proper mixing, avoiding short circuiting, and proper placement and calibration of the sensors.

A. The Energy Standards requires the use of DVC systems for spaces with all of the following characteristics:

1. Served by single zone units with any controls or multiple zone systems with Direct Digital Controls (DDC) to the zone level, and
2. Has a design occupancy of 40 ft²/person or smaller (for areas without fixed seating where the design density for egress purposes in the CBC is 40 ft²/person or smaller), and
3. Has an air economizer.

B. There are five exceptions to this requirement:

1. The following spaces are permitted to use DCV but are not required to: classrooms, call centers, office spaces served by multiple zone systems that are continuously occupied during normal business hours with occupant density greater than 25 people per 1000 ft² per §120.1(b)2B (Table 4-13 and Table 4-14 above), healthcare facilities and medical buildings, and public areas of social services buildings.

   These spaces are exempted either due to concerns about equipment maintenance practices (schools and public buildings) or concerns about high levels of pathogens (social service buildings, medical buildings, healthcare facilities and to some extent classrooms).

2. Where the space exhaust is greater than the required ventilation rate minus 0.2 cfm/ft².

   This relates to the fact that spaces with high exhaust requirements won't be able to provide sufficient turndown to justify the cost of the DCV controls. An example of this is a restaurant seating area where the seating area air is used as make-up air for the kitchen hood exhaust.

3. DCV devices are not allowed in the following spaces: Spaces that have processes or operations that generate dusts, fumes, mists, vapors, or gases and are not provided with local exhaust ventilation, such as indoor operation of internal combustion engines or areas designated for unvented food service preparation, or beauty salons.

   This exception recognizes that some spaces may need additional ventilation due to contaminants that are not occupant borne. It addresses spaces like theater stages where theatrical fog may be used or movie theater lobbies where unvented popcorn machines may be emitting odors and vapors into the space in either case justifying the need for higher ventilation rates. DCV devices shall not be installed in spaces included in Exception 3.

4. Spaces with an area of less than 150 ft², or a design occupancy of less than 10 people per §120.1(b)2B (Table 4-13 and Table 4-14 above).

   This recognizes the fact that DCV devices may not be cost effective in small spaces such as a 15 ft x 10 ft conference room or spaces with only a few occupants at design conditions.

5. Spaces less than 1500 ft² that comply with §120.1(c)5 - Occupant Sensor Ventilation Control Devices.

   This exception states that an occupant sensor is allowed to reduce the amount of ventilation supply air in a vacant room.

Although not required, the Energy Standards permit design professionals to apply DCV on any intermittently occupied spaces served by either single-zone or multiple-zone equipment. §120.1(b)2 requires a minimum of 15 cfm of outdoor air per person times the expected number of occupants; however, it must be noted that these are minimum ventilation levels and the designers may specify higher ventilation levels if there are health related concerns that warrant higher ventilation rates.

CO_2 based DCV is based on several studies (Berg-Munch et al. 1986, Cain et al. 1983, Fanger 1983 and 1988, Iwashita et al. 1990, Rasmussen et al. 1985) that concluded that about 15 cfm of outdoor air ventilation per person will control human body odor such that roughly 80 percent of unadapted persons (visitors) will find the odor to be at an acceptable level. As activity level increases and bioeffluents increase, the rate of outdoor air required to provide acceptable air quality increases proportionally, resulting in the same differential CO2 concentration.

Note that CO_2 concentration only tracks indoor contaminants that are generated by occupants themselves and, to a lesser extent, their activities. It will not track other pollutants, particularly volatile organic compounds (VOCs) that off-gas from furnishings and building materials. Hence, where permitted or required by the Energy Standards, demand controlled ventilation systems cannot reduce the outdoor air ventilation rate below the floor rate listed in Energy Standards Table 120.1-A (typically 0.15 cfm/ft²) during normally occupied times.

DCV systems save energy if the occupancy varies significantly over time. Hence they are most cost effective when applied to densely occupied spaces like auditoriums, conference rooms, lounges or theaters. Because DCV systems must maintain the floor ventilation rate listed in Energy Standards Table 120.1-A, they will not be applicable to sparsely occupied buildings such as offices where the floor rate always exceeds the minimum rate required by the occupants (See Table 4-14).

C. Where DCV is employed (whether mandated or not) the controls must meet all of the following requirements:

1. Sensors must be provided in each room served by the system that has a design occupancy of 40 ft²/person or less, with no less than one sensor per 10,000 ft² of floor space. When a zone or a space is served by more than one sensor, signal from any sensor indicating that CO_2 is near or at the setpoint within a space, must trigger an increase in ventilation to the space. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. Design professional should ensure that sensors are placed throughout a large space, so that all areas are monitored by a sensor.
2. The CO_2 sensors must be located in the breathing zone (between 3 and 6 ft. above the floor or at the anticipated height of the occupant's head). Sensors in return air ducts are not allowed since they can result in under-ventilation due to CO_2 measurement error caused by short-circuiting of supply air into return grilles and leakage of outdoor air (or return air from other spaces) into return air ducts.
3. The ventilation must be maintained that will result in a concentration of CO_2 at or below 600 ppm above the ambient level. The ambient levels can either be assumed to be 400 ppm or dynamically measured by a sensor that is installed within four feet of the outdoor air intake. At 400 ppm outside CO_2 concentration, the resulting DCV CO_2 setpoint would be 1000 ppm. (Note that a 600 ppm differential is less than the 700 ppm that corresponds to the 15 cfm/person ventilation rate. This provides a margin of safety against sensor error, and because 1000 ppm CO_2 is a commonly recognized guideline value and referenced in earlier versions of ASHRAE Standard 62.)
4. Regardless of the CO_2 sensor's reading, the system is not required to provide more than the minimum ventilation rate required by §120.1(b). This prevents a faulty sensor reading from causing a system to provide more than the code required ventilation for system without DCV control. This high limit can be implemented in the controls.
5. The system shall always provide a minimum ventilation of the sum of the Energy Standards Table 120.1-A values for all rooms with DCV and §120.1(b)2 (Table

4-13) for all other spaces served by the system. This is a low limit setting that must be implemented in the controls.

6. The CO_2 sensors must be factory-certified to have an accuracy within plus or minus 75 ppm at 600 and 1000 ppm concentration when measured at sea level and 25°C (77°F), factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every 5 years. A number of manufacturers now have “self-calibrating” sensors that either adjust to ambient levels during unoccupied times or adjust to the decrease in sensor bulb output through use of dual sources or dual sensors. For all systems, the manufacturers of sensors must provide a document to installers that their sensors meet these requirements. The installer must make this certification information available to the builder, building inspectors and, if specific sensors are specified on the plans, to plan checkers.
7. When a sensor failure is detected, the system must provide a signal to reset the system to provide the minimum quantity of outside air levels required by §120.1(b)2 to the zone(s) serviced by the sensor at all times that the zone is occupied. This requirement ensures that the space is adequately ventilated in case a sensor malfunctions. A sensor that provides a high CO_2 signal on sensor failure will comply with this requirement.
8. For systems that are equipped with DDC to the zone level, the CO_2 sensor(s) reading for each zone must be displayed continuously, and recorded. The EMCS may be used to display and record the sensors’ readings. The display(s) must be readily available to maintenance staff so they can monitor the systems performance.

4.3.8 Occupant Sensor Ventilation Control Devices

§120.1(c)5

The use of occupant sensor ventilation control devices are mandated for multipurpose rooms less than 1000 ft^2 ; classrooms over 750 ft^2; and conference, convention, auditorium and meeting center rooms greater than 750 ft^2 that do not have processes or operations that generate dusts, fumes, vapors or gasses(by reference to §120.2(e)3). They are also an alternate method of compliance for spaces mandated to have DCV that are less than 1,500 ft^2 (Exception 5 to §120.1(c)3).

There are a few spaces where it appears that both DCV and occupant sensor ventilation controls are mandated (e.g. auditoriums greater than 750 ft^2). Exception 1 to §120.1(c)5 exempts occupant sensor ventilation controls if DCV is implemented as required by §120.1(c)4.

Where occupant sensor ventilation control devices are employed (whether mandated or not) the controls must meet all of the following requirements:

1. Sensors must meet the requirements of §110.9(b)4 and shall have suitable coverage to detect occupants in the entire space.
2. Sensors that are used for lighting can be used for ventilation as well as long as the ventilation system is controlled directly from the occupant sensor and is not subject to lighting overrides.
3. If a terminal unit serves several enclosed spaces, each space shall have its own occupant sensor and all sensors must indicate lack of occupancy before the zone airflow is cut off.

4. The occupant sensor override shall be disabled during preoccupancy purge (i.e. the terminal unit and central ventilation shall be active regardless of occupant status).
5. Supply fans on systems with all zones provided with occupant sensor ventilation control devices can cycle off if all zones are vacant provided that minimum ventilation to all zones is provided as follows:
6. For spaces with a design occupant density greater than or equal to 25 people per 1000 ft² (40 square foot or less per person); 25 percent of the rate listed in Table 120.1-A: Minimum Ventilation Rates.

To implement the last provision the supply fan on the unit serving the zones would have to cycle on for at least 15 minutes of every hour with the outside air damper at or above minimum position.

4.3.9 Fan Cycling

§120.1(c)5E

While §120.1(c)1 requires that ventilation be continuous during normally occupied hours when the space is usually occupied, Exception 2 allows the ventilation to be disrupted for not more than 30 minutes at a time. In this case the ventilation rate during the time the system is ventilating must be increased so the average rate over the hour is equal to the required rate.

It is important to review any related ventilation and fan cycling requirements in Title 8, which is the Division of Occupational Safety and Health (Cal/OSHA) regulations. Section 5142 specifies the operational requirements related to HVAC minimum ventilation. It states:

Operation:

1. The HVAC system shall be maintained and operated to provide at least the quantity of outdoor air required by the State Building Standards Code, Title 24, Part 2, California Administrative Code, in effect at the time the building permit was issued.
2. The HVAC system shall be operated continuously during working hours except:
    a. During scheduled maintenance and emergency repairs;
    b. During periods not exceeding a total of 90 hours per calendar year when a serving electric utility by contractual arrangement requests its customers to decrease electrical power demand; or
    c. During periods for which the employer can demonstrate that the quantity of outdoor air supplied by nonmechanical means meets the outdoor air supply rate required by (a)(1) of this Section. The employer must have available a record of calculations and/or measurements substantiating that the required outdoor air supply rate is satisfied by infiltration and/or by a nonmechanically driven outdoor air supply system.

Title 8 Section 5142(a)(1) refers to Title 24, Part 2 (the California Building Code) for the minimum ventilation requirements. Section 1203 in the California Building Code specifies the ventilation requirements, but simply refers to the California Mechanical Code, which is Title 24, Part 4.

Chapter 4 in the California Mechanical Code specifies the ventilation requirements. Section 402.3 states, “The system shall operate so that all rooms and spaces are continuously provided with the required ventilation rate while occupied.” Section 403.5.1 states, “Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full and part-load conditions." The required ventilation rates are thus not required whenever the zones are unoccupied. This section affirms that ventilation fans may be turned off during unoccupied periods. In addition, Section 403.6 states, "The system shall be permitted to be designed to vary the design outdoor air intake flow or the space or zone airflow as operating conditions change." This provides further validation to fan cycling as operating conditions change between occupied and unoccupied. A vacant zone has no workers present and is thus not subject to working hour's requirements until the zone is actually occupied by a worker. Finally, Title 24, Part 4, states; "Ventilation air supply requirements for occupancies regulated by the California Energy Commission are found in the California Energy Code." Thus, it refers to Title 24, Part 6 as the authority on ventilation.

Title 8 Section 5142(a)(2) states, "The HVAC system shall be operated continuously during working hours." This regulation does not indicate that the airflow, cooling, or heating needs to be continuous. If the HVAC system is designed to maintain average ventilation with a fan cycling algorithm, and is active in that mode, providing average ventilation air as required during working hours, it is considered to be operating continuously per its mode and sequence. During unoccupied periods, the HVAC system is turned off except for setback and it no longer operates continuously. During the occupied period, occupant sensors or CO2 sensors in the space provide continuous monitoring and the sequence is operating, cycling the fan and dampers as needed to maintain the ventilation during the occupied period. The HVAC system is operating with the purpose of providing ventilation, heating, and cooling continuously during the working hours. The heater, air conditioner, fans, and dampers all cycle on and off subject to their system controls to meet the requirements during the working hours.

Exceptions A, B, and C to Title 8 Section 5142(a)(2) all refer to a complete system shutdown where the required ventilation is not maintained.

Example 4-14

Question

Does a single zone air-handling unit serving a 2,000 ft² auditorium with fixed seating for 240 people require demand controlled ventilation?

Answer

Yes if it has an air-side economizer. There are three tests for the requirement.

The first test is whether the design occupancy is 40 ft²/person or less. This space has 2,000 ft²/240 people or 8.3 ft² /person.

The second test is that the unit is single zone.

The third is that it has an air-side economizer.

A single CO_2 sensor could be used for this space provided it is certified by the manufacturer to cover 2,000 ft² of space. The sensor must be placed directly in the space.

Example 4-15

Question

If two separate units are used to condition the auditorium in the previous example, is demand controlled ventilation required?

Answer

Yes, if they each meet the three tests.

Example 4-16

Question

The 2,000 ft^2 auditorium in the previous examples appears to require both demand controlled ventilation per Section 4.3.7 and occupant sensor ventilation control devices per Section 4.3.8? Is this the case?

Answer

No, the exception in Section 4.3.8 exempts occupant sensor ventilation controls if implemented as required in Section 4.3.7. Only demand controlled ventilation is required.

Example 4-17

Question

If a central AHU supplies five zones of office space (with a design occupant density of 100 ft²/person and two zones with conference rooms (with a design occupant density of 35 ft²/person) is it required to have demand controlled ventilation and if so, on which zones?

Answer

If the AHU has DDC controls to the zone and an airside economizer it is required to have DCV controls in both of the conference room zones.

The minimum OSA will be set for 0.15 cfm/ft² times the total area of all seven zones (the office and conference room zones) and the maximum required OSA does not need to exceed the sum of 0.15 cfm/ft² for the 5 office zones plus 15 cfm per person for the two conference rooms.

4.3.9.1 **Variable Air Volume (VAV) Changeover Systems**

Some VAV systems provide conditioned supply air, either heated or cooled, through a single set of ducting. These systems are called VAV changeover systems or, perhaps more commonly, variable volume and temperature (VVT™) systems, named after a control system distributed by Carrier Corp. In the event that heating is needed in some spaces at the same time that cooling is needed in others, the system must alternate between supplying heated and cooled air. When the supply air is heated, for example, the spaces requiring cooling are isolated (cut off) by the VAV dampers and must wait until the system switches back to cooling mode. In the meantime, they are generally not supplied with ventilation air.

Systems of this type may not meet the ventilation requirements if improperly applied. Where changeover systems span multiple orientations, the designer must make control provisions to ensure that no zone is shut off for more than 30 minutes at a time and that ventilation rates are increased during the remaining time to compensate. Alternatively, minimum damper position or airflow setpoints can be set for each zone to maintain supply air rates, but this can result in temperature control problems since warm air will be supplied to spaces that require cooling, and vice versa. Changeover systems that are applied to a common building orientation (e.g., all east or all interior) are generally the most successful since zones will usually have similar loads, allowing minimum airflow rates to be maintained without causing temperature control problems.

4.3.10 Adjustment of Ventilation Rate

§120.1(b) specifies the minimum required outdoor ventilation rate, but does not restrict the maximum. However, if the designer elects to have the space-conditioning system operate at a ventilation rate higher than the rate required by the Energy Standards, then the Energy Standards require that the space-conditioning system must be adjustable so that in the future the ventilation rate can be reduced to the amount required by the Energy Standards or the rate required for make-up of exhaust systems that are required for a process, for control of odors, or for the removal of contaminants within the space §120.1(e).

In other words, a system can be designed to supply higher than minimum outside air volumes provided dampers or fan speed can be adjusted to allow no more than the minimum volume if, at a later time, someone decides it is desirable. The Energy Standards preclude a system designed for 100 percent outdoor air, with no provision for any return air, unless the supply air quantity can be adjusted to be equal to the designed minimum outdoor air volume. The intent is to prevent systems from being designed that will permanently over-ventilate spaces.

4.3.11 Acceptance Requirements

§120.5

The Energy Standards have acceptance test requirements for:

1. Ventilation quantities at design airflow for constant volume systems §120.5(a)1 and NA7.5.1.2.
2. Ventilation quantities at design and minimum airflow for VAV systems §120.5(a)1 and NA7.5.1.1.
3. Ventilation system time controls §120.5(a)2 and NA7.5.2.
4. Demand controlled ventilation systems §120.5(a)5 and NA7.5.5.

These test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.5. They are described briefly in the following paragraphs.

Example 4-18

Question

Maintenance of Ventilation System:

In addition to these commissioning requirements for the ventilation system, are there any periodic requirements for inspection?

Answer

The Energy Standards do not contain any such requirements since they apply to the design and commissioning of buildings, not to its later operation. However, Section 5142 of the General Industry Safety Orders, Title 8, California Safety Code: Mechanically Driven Heating, Ventilating and Air Conditioning (HVAC) Systems to Provide Minimum Building Ventilation, states the following:

Inspection and Maintenance

(1) The HVAC system shall be inspected at least annually, and problems found during these inspections shall be corrected within a reasonable time.

(2) Inspections and maintenance of the HVAC systems shall be documented in writing. The employer shall record the name of the individual(s) inspecting and/or maintaining the system, the date of the inspection and/or maintenance, and the specific findings and actions taken. The employer shall ensure that such records are retained for at least five years.

(3) The employer shall make all records required by this section available for examination and copying, within 48 hours of a request, to any authorized representative of the Division (as defined in Section 3207 of Title 8), to any employee of the employer affected by this section, and to any designated representative of said employee of the employer affected by this Section.

4.3.11.1 **Ventilation Airflow**

NA7.5.1

Ventilation airflow has to be certified to be measured within 10 percent of the design airflow quantities at two points of operation: full design supply airflow (all systems) and (for VAV systems) at airflow with all VAV boxes at or near minimum position.
If airflow monitoring stations are provided, they can be used for these measurements.

4.3.11.2 **Ventilation System Time Controls and Preoccupancy Purge**

NA7.5.2

Programming for preoccupancy purge and HVAC schedules are checked and certified as part of the acceptance requirements. The sequences are also required to be identified by specification section paragraph number (or drawing sheet number) in the compliance documents.

4.3.11.3 **Demand Controlled Ventilation System**

NA7.5.5

Demand controlled ventilation systems are checked for compliance with sensor location, calibration (either factory certificate or field validation) and tested for system response with both a high signal (produced by a certified calibration test gas applied to the sensor) and low signal (by increasing the setpoint above the ambient level). A certificate of acceptance must be provided to the enforcement agency that the demand control ventilation system meets the Acceptance Requirements for Code Compliance. The certificate of acceptance must include certification from the manufacturers of sensor devices that they will meet the requirements of §120.1(c)4F and that they will provide a signal that indicates the CO_2 level in the range required by §120.1(c)4, certification from the controls manufacturer that they respond to the type of signal that the installed sensors supply and that they can be calibrated to the CO_2 levels specified in §120.1(c)4, and that the CO_2 sensors have an accuracy of within plus or minus 75 ppm at 600 and 1,000 ppm concentrations, and require calibration no more frequently than once every 5 years.

4.4 Pipe and Duct Distribution Systems

4.4.1 Mandatory Measures

4.4.1.1 **Requirements for Pipe Insulation**

§120.3
Energy Standards Table 120.3-A

Most piping conveying either mechanically heated or chilled fluids for space conditioning or service water heating must be insulated. The required thickness of piping insulation depends on the temperature of the fluid passing through the pipe, the pipe diameter, the function of the pipe within the system, and the insulation’s thermal conductivity.

Table 4-15 specifies the requirements in terms of inches of insulation with conductivity within a specific range. These conductivities are typical for fiberglass or foam pipe insulation. In this table, runouts are defined as being less than 2 inches in diameter, less than 12 ft long, and connected to fixtures or individual terminal units. Piping within fan coil units and within other heating or cooling equipment may be considered runouts for the purposes of determining the required pipe insulation.

Piping that does not require insulation includes the following:

1. Factory installed piping within space-conditioning equipment certified under §110.1 or §110.2, see Section 4.2 of this chapter. Nationally recognized certification programs that are accepted by the Energy Commission for certifying efficiencies of appliances and equipment are considered to meet the requirements for this exception.
2. Piping that conveys fluid with a design operating temperature range between 60°F and 105°F, such as cooling tower piping or piping in water loop heat pump systems.
3. Piping that serves process loads, gas piping, cold domestic water piping, condensate drains, roof drains, vents or waste piping.

   Note: Designers may specify exempt piping conveying cold fluids to be insulated in order to control condensation on the surface of the pipe. Examples may include cold domestic water piping, condensate drains and roof drains. In these cases, the insulation R-value is specified by the designer and is not subject to these regulations.
4. Where the heat gain or heat loss, to or from piping without insulation, will not increase building source energy use. For example, piping connecting fin-tube radiators within the same space would be exempt, as would liquid piping in a split system air conditioning unit.

   This exception would not exempt piping in solar systems. Solar systems typically have backup devices that will operate more frequently if piping losses are not minimized.
5. Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Metal piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing.

Conductivities and thicknesses listed in Table 4-15 are typical for fiberglass and foam. When insulating materials are used that have conductivities different from those listed here for the applicable fluid range, such as calcium silicate, Equation 4-1 may be used to calculate the required insulation thickness.

When a pipe carries cold fluids, condensation of water vapor within the insulation material may impair the effectiveness of the insulation, particularly for applications in very humid environments or for fluid temperatures below 40°F. Examples include refrigerant suction piping and low-temperature Thermal Energy Storage (TES) systems. In these cases, manufacturers should be consulted and consideration given to low permeability vapor barriers, or closed-cell foams.

The Energy Standards also require that exposed pipe insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

1. Insulation exposed to weather shall be installed with a cover suitable for outdoor service. The cover shall be water retardant and provides shielding from solar radiation that can cause degradation of the material. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure. Adhesive tape should not be used as insulation protection because during preventive maintenance, removal of the tape will damage the integrity of the original insulation.
2. Insulation covering chilled water piping and refrigerant suction piping located outside the conditioned space shall have a Class I or Class II vapor retarder. All penetrations and joints of which shall be sealed.

If the conductivity of the proposed insulation does not fall into the conductivity range listed in Table 4-15, the minimum thickness must be adjusted using the following equation:

Equation 4-7: Insulation Thickness

$$T = PR[(1 + t/PR)K/k - 1]$$

Where:

T = Minimum insulation thickness for material with conductivity K, inches.

PR = Pipe actual outside radius, inches.

t = Insulation thickness, inches (Table 4-15 for conductivity k).

K = Conductivity of alternate material at the mean rating temperature indicated in Table 4-15 for the applicable fluid temperature range, in Btu-in./(h-ft² -°F).

k = The lower value of the conductivity range listed in Table 4-15 for the applicable fluid temperature, Btu-in/(h-ft² -°F).

Table 4-15: Pipe Insulation Thickness

<table>
<tr><th rowspan="3">FLUID TEMPERATURE RANGE (°F)</th><th rowspan="3">CONDUCTIVITY RANGE
(in Btu-inch per hour per square foot per °F)</th><th rowspan="3">INSULATION MEAN RATING TEMPERATURE (°F)</th><th colspan="7">NOMINAL PIPE DIAMETER (in inches)</th></tr>
<tr><th colspan="2"><1</th><th colspan="2">1 to <1.5</th><th>1.5 to <4</th><th>4 to <8</th><th>≥8</th></tr>
<tr><th colspan="7">INSULATION THICKNESS REQUIRED (in inches)</th></tr>
<tr><td colspan="10">Space heating and service water heating systems (steam, steam condensate and hot water);</td></tr>
<tr><td>Above 350</td><td>0.32-0.34</td><td>250</td><td colspan="2">4.5</td><td colspan="2">5.0</td><td>5.0</td><td>5.0</td><td>5.0</td></tr>
<tr><td>251-350</td><td>0.29-0.32</td><td>200</td><td colspan="2">3.0</td><td colspan="2">4.0</td><td>4.5</td><td>4.5</td><td>4.5</td></tr>
<tr><td>201-250</td><td>0.27-0.30</td><td>150</td><td colspan="2">2.5</td><td colspan="2">2.5</td><td>2.5</td><td>3.0</td><td>3.0</td></tr>
<tr><td>141-200</td><td>0.25-0.29</td><td>125</td><td colspan="2">1.5</td><td colspan="2">1.5</td><td>2.0</td><td>2.0</td><td>2.0</td></tr>
<tr><td>105-140</td><td>0.22-0.28</td><td>100</td><td colspan="2">1.0</td><td colspan="2">1.5</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
<tr><td colspan="10">Space cooling systems (chilled water, refrigerant and brine)</td></tr>
<tr><td colspan="3"></td><td>Nonres</td><td>Res</td><td>Nonres</td><td>Res</td><td colspan="3"></td></tr>
<tr><td>40-60</td><td>0.21-0.27</td><td>75</td><td>0.5</td><td>0.75</td><td>0.5</td><td>0.75</td><td>1.0</td><td>1.0</td><td>1.0</td></tr>
<tr><td>Below 40</td><td>0.20-0.26</td><td>50</td><td colspan="2">1.0</td><td colspan="2">1.5</td><td>1.5</td><td>1.5</td><td>1.5</td></tr>
</table>

Energy Standards Table 120.3-A

Example 4-19

Question

What is the required thickness for calcium silicate insulation on a 4 inches diameter pipe carrying a 300°F fluid?

Answer

From Table 4-15, the required insulation thickness is 4.5 inches for a 4 inches pipe in the range of 251-350°F.

The lower of the range for mean conductivity at this temperature is listed as 0.29 (Btu-in.)/(h-ft²-°F). From manufacturer's data, it is determined that the conductivity of calcium silicate at 300°F is 0.45 Btu-in./(h-ft²-°F). The required thickness from equation 4-2 is therefore:

$$T = PR[(1 + t/PR)^{K/k} – 1]$$

$$T = 4[(1 + 4.5/4)^{(0.45/0.31)} – 1]$$

$$T = 8.9 \text{ inches}$$

When insulation is not available in the exact thickness calculated, the installed thickness should be the next larger available size.

4.4.1.2 Requirements for Air Distribution System Ducts and Plenums

§120.4

Poorly sealed or poorly insulated duct work can cause substantial losses of air volume and energy. All air distribution system ducts and plenums, including building cavities, mechanical closets, air handler boxes and support platforms used as ducts or plenums, are required to be installed, sealed, and insulated in accordance with the California Mechanical Code (CMC) Sections 601, 602, 603, 604, 605 and ANSI/SMACNA-006-2006 HVAC Duct Construction Standards Metal and Flexible 3rd Edition.

A. Installation and Insulation

§120.4(a)

Portions of supply-air and return-air ducts ductwork conveying heated or cooled air located in one or more of the following spaces shall be insulated to a minimum installed level of R-8:

1. Outdoors, or
2. In a space between the roof and an insulated ceiling; or
3. In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces; or
4. In an unconditioned crawlspace; or
5. In other unconditioned spaces.

Portions of supply-air ducts ductwork that are not in one of these spaces shall be insulated to a minimum installed level of R-4.2 (or any higher level required by CMC Section 605) or be enclosed in directly conditioned space.

B. CMC insulation requirements are reproduced in Table 4-16. The following are also required:

1. Mechanically fasten connections between metal ducts and the inner core of flexible ducts.
2. Joint and Seal openings with mastic, tape, aerosol sealant or other duct closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B or UL 723 (aerosol sealant).

All joints must be made airtight by use of mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B, or UL 723. Duct systems shall not use cloth-back, rubber adhesive duct tape regardless of UL designation, unless it is installed in combination with mastic and clamps.

When mastic or tape is used to seal openings greater than 1/4 in., a combination of mastic and mesh or mastic and tape must be used.

The Energy Commission has approved two cloth-backed duct tapes with special butyl or synthetic adhesives rather than rubber adhesive to seal flex duct to fittings. These tapes are:

1. Polyken 558CA or Nashua 558CA, manufactured by Berry Plastics, Tapes and Coatings Division; and
2. Shurtape PC 858CA, manufactured by Shurtape Technologies, Inc.

These tapes passed Lawrence Berkeley National Laboratory (LBNL) tests comparable to those that cloth-back rubber-adhesive duct tapes failed (the LBNL test procedure has been adopted by the American Society of Testing and Materials as ASTM E2342-03). These tapes are allowed to be used to seal flex duct to fittings without being in combination with mastic. These tapes cannot be used to seal other duct system joints, such as the attachment of fittings to plenums and junction boxes. These tapes have on their backing the phrase "CEC Approved," and a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition) to illustrate where they are not allowed to be used, and installation instructions in their packing boxes that explain how to install them on duct core to fittings and a statement that the tapes cannot be used to seal fitting to plenum and junction box joints.

C. Factory-Fabricated Duct Systems

§120.4(b)1

Factory-fabricated duct systems must meet the following requirements:

1. All factory-fabricated duct systems shall comply with UL 181 for ducts and closure systems, including collars, connections and splices, and be labeled as complying with UL181. UL181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.
2. Pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts comply with UL 181 and UL181A.
3. Pressure-sensitive tapes and mastics used with flexible ducts comply with UL181 and UL181B.
4. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

D. Field-Fabricated Duct Systems

§120.4(b)2

Field-fabricated duct systems must meet the following requirements:

1. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems comply with UL 181. Pressure-sensitive tapes, mastics, aerosol sealants or other closure systems shall meet applicable requirements of UL 181, UL 181A and UL 181B.
2. Mastic Sealants and Mesh:
   a. Sealants comply with the applicable requirements of UL 181, UL 181A, and UL 181B, and shall be non-toxic and water resistant.

   b. Sealants for interior applications shall pass ASTM C 731(extrudability after aging) and D 2202 (slump test on vertical surfaces), incorporated herein by reference.

   c. Sealants for exterior applications shall pass ASTM C 731, C 732 (artificial weathering test) and D 2202, incorporated herein by reference.

   d. Sealants and meshes shall be rated for exterior use.

3. Pressure-sensitive tapes shall comply with the applicable requirements of UL 181, UL 181A and UL 181B.

4. Drawbands used with flexible duct shall:

   a. Be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.

   b. Have a minimum tensile strength rating of 150 lbs.

   c. Be tightened as recommended by the manufacturer with an adjustable tensioning tool.

5. Aerosol-Sealant Closures.

   a. Aerosol sealants meet applicable requirements of UL 723 and must be applied according to manufacturer specifications.

   b. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

6. Joints and seams of duct systems and their components shall not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and drawbands.

E. Duct Insulation R-Values

§120.4(c), §120.4(d), §120.4(e)

Since 2001, the Energy Standards have included the following requirements for the labeling, measurement and rating of duct insulation:

1. Insulation R-values shall be based on the insulation only and not include air-films or the R-values of other components of the duct system.

2. Insulation R-values shall be tested C-values at 75°F mean temperature at the installed thickness, in accordance with ASTM C 518 or ASTM C 177.

3. The installed thickness of duct insulation for purpose of compliance shall be the nominal thickness for duct board, duct liner, factory made flexible air ducts and factory-made rigid ducts. For factory-made flexible air ducts, the installed thickness shall be determined by dividing the difference between the actual outside diameter and nominal inside diameter by two.

4. The installed thickness of duct insulation for purpose of compliance shall be 75 percent of its nominal thickness for duct wrap.

5. Insulated flexible air ducts must bear labels no further than 3 ft. apart that state the installed R-value (as determined per the requirements of the Energy Standards).

A typical duct wrap, nominal 1-1/2 inches and 0.75 pcf will have an installed rating of R-4.2 with 25 percent compression.

F. Protection of Duct Insulation

§120.4(f)

The Energy Standards require that exposed duct insulation be protected from damage by moisture, UV and physical abrasion including but not limited to the following:

1. Insulation exposed to weather shall be suitable for outdoor service; e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Insulation must be protected by an external covering unless the insulation has been approved for exterior use using a recognized federal test procedure.
2. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

Example 4-20

Question

What are the sealing requirements in a VAV system having a static pressure setpoint of 1.25 inches w.g. and a plenum return?

Answer

All duct work located within the return plenum must be sealed in accordance with the California Mechanical Code (CMC) Sections 601, 602, 603, 604, 605 and ANSI/SMACNA-006-2006 HVAC Duct Construction Standards Metal and Flexible 3rd Edition (refer to §120.4). Pressure-sensitive tape, heat-seal tape and mastic may be used, if it meets the applicable requirement of UL 181, 181A, 181B, to seal joints and seams which are mechanically fastened per the CMC.

Table 4-16: Duct Insulation Requirements

DUCT LOCATION[1]	INSULATION R-VALUE MECHANICALLY COOLED	HEATING ZONE	INSULATION R-VALUE HEATING ONLY
On roof on exterior building	6.3	<4,500 DD	2.1
		< 8,000 DD	4.2
Attics, garages, and crawl spaces	2.1	<4,500 DD	2.1
		<8,000 DD	4.2
In walks[2] and within floor to ceiling spaces[2]	2.1	<4,500 DD	2.1
		<8,000 DD	4.2
Within the conditioned space or in basements: return ducts in air plenums	None Required		None Required
Cement slab or within ground	None Required		None Required

[1]Vapor barriers shall be installed on supply ducts in spaces vented to the outside in geographic areas where the average July, August and September mean dew point temperature exceeds 60 degrees Fahrenheit.
[2] Insulation may be omitted on that portion of a duct which is located within a wall or a floor to ceiling space where:
a. Both sides of the space are exposed to conditioned air.
b. The space is not ventilated.
c. The spaces is not used as a return plenum.
d. The space is not exposed to unconditioned air.

Ceiling which form plenums need not be insulated
Note: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

Source: Uniform Mechanical Code §605

4.4.2 Prescriptive Requirements for Space Conditioning Ducts

Each of these prescriptive requirements, as applicable, must be met. If one or more applicable requirements cannot be met, the performance method may be used as explained in Chapter 11.

4.4.2.1 Duct Leakage

§140.4(l)

Ducts on small single zone systems with portions of the ductwork either outdoors or in uninsulated or vented ceiling spaces are required to be sealed and leak tested as specified in Reference Nonresidential Appendix NA1. This will generally only apply to small commercial projects that are one or two stories with packaged single zone units or split systems. Duct leakage testing only applies when all of the following are true:

1. The system is constant volume.
2. It serves occupiable space.
3. It serves less than 5,000 ft² of conditioned floor area.
4. 25 percent or more of the duct surface area is located in the outdoors, unconditioned space, a ventilated attic, in a crawl space or where the U-factor of the roof is greater than the U-factor of the ceiling, or the roof does not meet the requirements of §140.3(a)1B.

Where duct sealing and leakage testing is required, the ducts must be tested by a HERS certified agency to demonstrate a leakage rate of no more than 6 percent of the nominal supply fan flow.

Alterations to an existing space conditioning system may trigger the duct sealing requirement. For more information see Section 4.9.4.2.

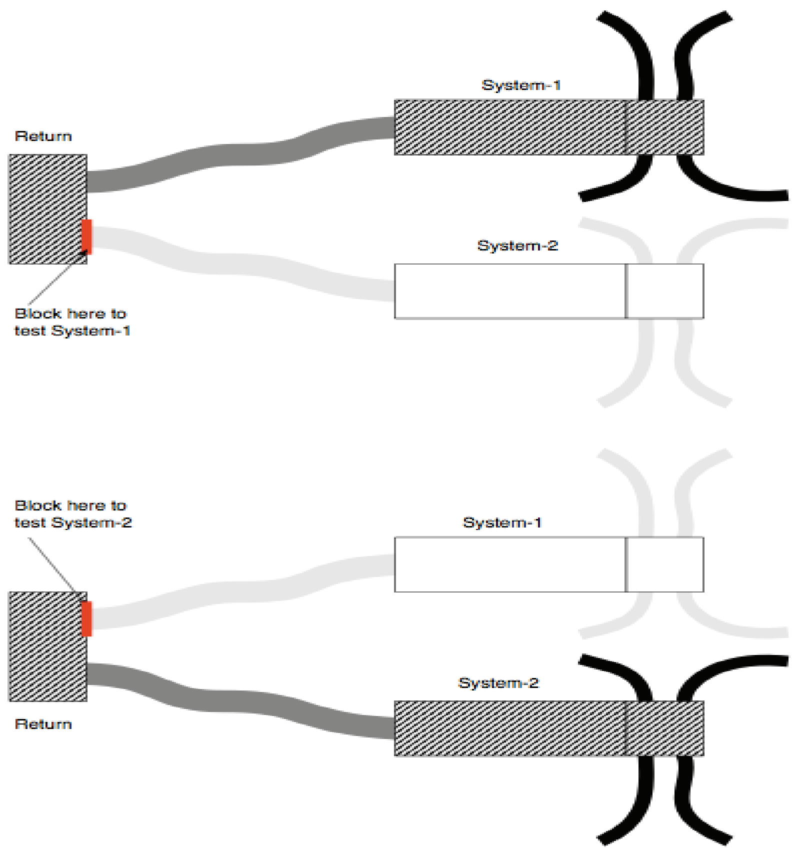
A. Duct Leakage Testing For Multiple Duct Systems With Common Return Ducts

If there are two or more duct systems in a building that are tied together at a common return duct, then each duct system should be tested separately, including the shared portion of the return duct system in each test. Under this scenario, the portions of the second duct system that is not being tested must be completely isolated from the portions of the ducts that are being tested, so the leakage from second duct system does not affect the leakage rate from the side that is being tested.

The diagram below represents the systems that are attached to a shared return boot or remote return plenum. In this case, the point in the return system that needs to be blocked off is readily accessible through the return grille.

The “duct leakage averaging” where both system are tested together as though it is one large system and divide by the combined tonnage to get the target leakage may not be used as it allows a duct system with more the 6% leakage to pass if the combined system’s leakage is 6% or less.

Figure 4-9: Example of Two Duct Systems with a Common Return



Example 4-21

Question

A new 20 ton single zone system with new ductwork serving an auditorium is being installed. Approximately ½ of its ductwork on the roof. Does it need to be leak tested?

Answer

Probably not; although this system meets the criteria of being single zone and having more than ¼ of the duct surface area on the roof, the unit probably serves more than 5,000 ft² of space. Most 15 and 20 ton units will serve spaces that are significantly larger than 5,000 ft². If the space is 5,000 ft² or less the ducts do need to be leak tested per §140.4(l).

Example 4-22

Question

A new 5 ton single zone system with new ductwork serving a 2,000 ft² office is being installed. The unit is a down discharge configuration and the roof has insulation over the deck. Does the ductwork need to be leak tested?

Answer

Probably not. Although this system meets the criteria of being single zone and serving less than 5,000 ft² of space, it does not have ¼ of its duct area in one of the spaces listed in §140.4(l). With the insulation on the roof and not on the ceiling, the plenum area likely meets the criteria of indirectly conditioned so no leakage testing is required.

B. Acceptance Requirements

The Energy Standards have acceptance requirements where duct sealing and leakage testing is required by §140.4(l).

These tests are described in the Chapter 13, Acceptance Requirements and the Reference Nonresidential Appendix NA7.

4.5 HVAC System Control Requirements

4.5.1 Mandatory Measures

This section covers controls that are mandatory for all system types, including:

- Heat pump controls for the auxiliary heaters.
- Zone thermostatic control including special requirements for hotel/motel guest rooms and perimeter systems.
- Shut-off and setback/setup controls.
- Infiltration control.
- Off-hours space isolation.
- Economizer fault detection and diagnostics (FDD).
- Control equipment certification.
- Direct Digital Controls (DDC).
- Optimum start/stop controls.

4.5.1.1 **Zone Thermostatic Controls**

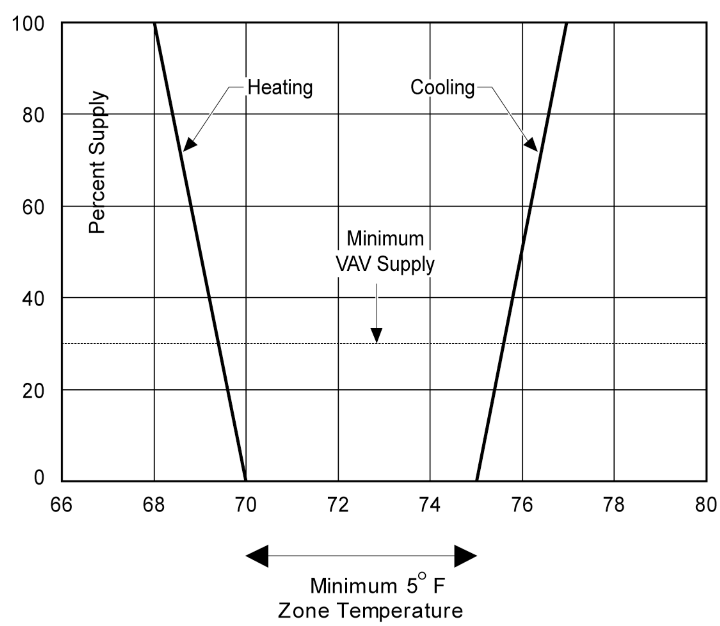
§120.2(a), (b) and (c)

Thermostatic controls must be provided for each space-conditioning zone or dwelling unit to control the supply of heating and cooling energy within that zone. The controls must have the following characteristics:

1. When used to control **heating**, the thermostatic control must be adjustable down to 55°F or lower.
2. When used to control **cooling**, the thermostatic control must be adjustable up to 85°F or higher.
3. When used to control both **heating and cooling**, the thermostatic control must be adjustable from 55°F to 85°F and also provide a temperature range or **dead band** of at least 5°F. When the space temperature is within the dead band, heating and cooling energy must be shut off or reduced to a minimum. A dead band is not required if the thermostat requires a manual changeover between the heating and cooling modes Exception to §120.2(b)*3*.
4. For all single zone, air conditioners and heat pumps all thermostats shall have setback capabilities with a minimum of four separate setpoints per 24 hour period. Also the thermostat must comply with the Occupant Controlled Smart Thermostat requirements of Reference Joint Appendix JA5, which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.
5. Systems equipped with DDC to the zone level, rather than zone thermostats, must be equipped with automatic demand shed controls as described later in Section 4.5.1.7.

The setpoint may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Figure 4-10: Proportional Control Zone Thermostat



Supplemental perimeter heating or cooling systems are sometimes used to augment a space-conditioning system serving both interior and perimeter zones. This is allowed provided controls are incorporated to prevent the two systems from conflicting with each other. If that were the case, then the Energy Standards require that:

1. The perimeter system must be designed solely to offset envelope heat losses or gains; and
2. The perimeter system must have at least one thermostatic control for each building orientation of 50 ft. or more; and
3. The perimeter system is controlled by at least one thermostat located in one of the zones served by the system.

The intent is that all major exposures be controlled by their own thermostat, and that the thermostat be located within the conditioned perimeter zone. Other temperature controls, such as outdoor temperature reset or solar compensated outdoor reset, do not meet these requirements of the Energy Standards.

Example 4-23

Question

Can an energy management system be used to control the space temperatures?

Answer

Yes, provided the space temperature setpoints can be adjusted, either locally or remotely. This section sets requirements for “thermostatic controls” which need not be a single device like a thermostat; the control system can be a broader system like a direct digital control (DDC) system. Note that some DDC systems employ a single cooling setpoint and a fixed or adjustable deadband. These systems comply if the deadband is adjustable or fixed at 5°F or greater.

Thermostats with adjustable setpoints and deadband capability are not required for zones that must have constant temperatures to prevent the degradation of materials, an exempt process, or plants or animals (Exception 1 to §120.2(b)4). Included in this category are manufacturing facilities, hospital patient rooms, museums, computer rooms, etc. Chapter 13 describes mandated acceptance test requirements for thermostat control for packaged HVAC systems.

4.5.1.2 Hotel/Motel Guest Rooms and High-Rise Residential Dwellings Thermostats

§120.2(c)

The Energy Standards require that thermostats in hotel and motel guest rooms have:

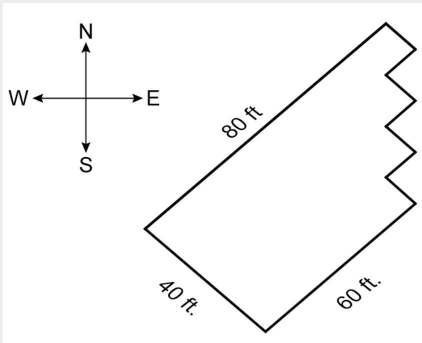
1. Numeric temperature setpoints in °F and °C, and
2. Setpoint stops that prevent the thermostat from being adjusted outside the normal comfort range (± 5°F or ± 3°C). These stops must be concealed so that they are accessible only to authorized personnel, and
3. Setback capabilities with a minimum of four separate setpoints per 24 hour period; in additions, for nonresidential buildings, The Energy Standards effectively prohibit thermostats

The Energy Standards require that thermostats in high-rise residential dwelling units have setback capabilities with a minimum of four separate setpoints per 24 hour period; in additions, for nonresidential buildings, the Energy Standards effectively prohibit thermostats.

Example 4-24

Question

What is the perimeter zoning required for the building shown here?



Answer

The southeast and northwest exposures must each have at least one perimeter system control zone, since they are more than 50 ft. in length. The southwest exposure and the serrated east exposure do not face one direction for more than 50 continuous ft. in length. They are therefore “minor” exposures and need not be served by separate perimeter system zones, but may be served from either of the adjacent zones.

Example 4-25

Question

Pneumatic thermostats are proposed to be used for zone control. However, the model specified cannot be adjusted to meet the range required by §120.2(a) to (c). How can this system comply?

Answer

§120.2(a) to (c) applies to “thermostatic controls” which can be a system of thermostats or control devices, not necessarily a single device. In this case, the requirement could be met by using multiple thermostats. The pneumatic thermostats could be used for zone control during occupied hours and need only have a range consistent with occupied temperatures (e.g. 68°F to 78°F), while two additional electric thermostats could be provided, one for setback control (adjustable down to 55°F) and one for set-up (adjustable up to 85°F). These auxiliary thermostats would be wired to temporarily override the system to maintain the setback/setup setpoints during off-hours.

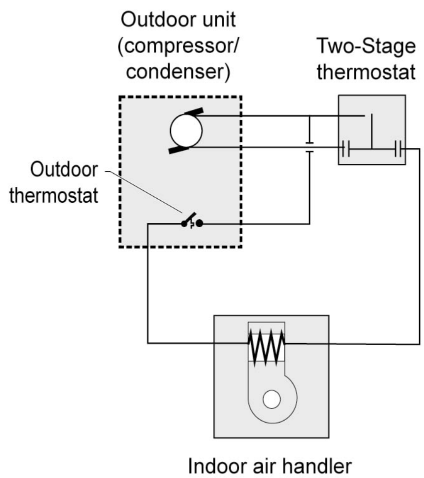
4.5.1.3 Heat Pump Controls

§110.2(b) and §120.2(d)

Heat pumps with electric resistance supplemental heaters must have controls that limit the operation of the supplemental heater to defrost and as a second stage of heating when the heat pump alone cannot satisfy the load. The most effective solution is to specify an electronic thermostat designed specifically for use with heat pumps. This “anticipatory” thermostat can detect if the heat pump is raising the space temperature during warm-up fast enough to warrant locking out the auxiliary electric resistance heater.

This requirement can also be met using conventional electronic controls with a two-stage thermostat and an outdoor lockout thermostat wired in series with the auxiliary heater. The outdoor thermostat must be set to a temperature where the heat pump capacity is sufficient to warm up the space in a reasonable time (e.g., above 40°F). This conventional control system is depicted schematically below in Figure 4-11.

Figure 4-11: Heat Pump Auxiliary Heat Control, Two-Stage and Outdoor Air Thermostats



4.5.1.4 **Shut-off and Temperature Setup/Setback**

§120.2(e)1,2 and 3

For specific occupancies and conditions, each space-conditioning system must be provided with controls that comply with the following requirements:

A. The control can automatically shut off the equipment during unoccupied hours and shall have one of the following:

1. An automatic time switch device must with the same characteristics that lighting devices must have, as described in Chapter 5, and a manual override accessible to the occupants that allows the system to operate up to four hours. The manual override can be included as a part of the control device, or as a separate override control.
2. An occupancy sensor. Since a building ventilation purge is required prior to normal occupancy, an occupancy sensor may be used to control the availability of heating and cooling, but should not be used to control the outdoor ventilation system.
3. A 4-hour timer that can be manually operated to start the system. As with occupancy sensors, the same restrictions apply to controlling outdoor air ventilation systems.

Exception to §120.2(e)1: The mechanical system serving retail stores and associated malls, restaurants, grocery stores, churches, or theaters equipped with 7-day programmable timers do not have to comply with the above requirements.

B. When shut down, the controls shall automatically restart the system to maintain:

1. A setback heating thermostat setpoint, if the system provides mechanical heating. *Exception:* Thermostat setback controls are not required in nonresidential buildings in areas where the Winter Median of Extremes outdoor air temperature is greater than 32°F.
2. A setup cooling thermostat setpoint, if the system provides mechanical cooling. *Exception:* Thermostat setup controls are not required in nonresidential buildings in areas where the Summer Design Dry Bulb 0.5 percent temperature is less than 100°F.

C. Occupant Sensor Ventilation Coil and Setback

Multipurpose room less than 1,000 ft^2, classrooms greater than 750 ft^2, conference, convention, auditorium and meeting center rooms greater than 750 ft^2 that do not have processes or operations that generate dusts, fumes, vapors or gasses shall be equipped with occupant sensor(s) to accomplish the following when occupants are not present:

1. Slightly widen the thermal deadband: Automatically setup the operating cooling temperature set point by 2°F or more and setback the operating heating temperature set point by 2˚F or more; and
2. Automatically reset the minimum required ventilation rate with an occupant sensor ventilation control device according to Section 4.3.8.

This scenario requires an additional control sequence for built-up VAV systems or a thermostat that can accept an occupancy sensor input and has three scheduling modes (occupied, standby, and unoccupied) for packaged equipment. A thermostat with three scheduling modes works as follows:

- The unoccupied period is scheduled as usual for the normal unoccupied period, e.g. nighttime.
- The occupied period is scheduled as usual for the normal occupied period, e.g. daytime.
- When the morning warm-up occurs, the thermostat's occupied schedule is used to establish the heating/cooling temperature setpoints.
- Upon completion of the morning warm-up, the standby setpoint schedule on the thermostat is enabled.

This schedule remains in effect until occupancy is sensed (then enabling the occupied setpoint schedule) or until the normally scheduled unoccupied period occurs. After the period of occupancy ends (e.g. a conference room is vacated) and the time delay expires as programmed into the occupancy sensor, the standby setpoint schedule on the thermostat is enabled.

The following chart shows an example of how the three scheduling modes might be programmed for a cooling setup of 4°F and a heating setback of 4°F.

Example Thermostat Setpoints for Three Modes

	Cooling, °F	Heating, °F
Occupied	75	70
Standby	78	67
Unoccupied	80	62

E. Exceptions for automatic shut-off, setback and setup, and occupant sensor setback:

1. *Exception to 1, 2 and 3:* It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously
2. *Exception to 1, 2 and 3:* It can be demonstrated to the satisfaction of the enforcement agency that shutdown, setback, and setup will not result in a decrease in overall building source energy use
3. *Exception to 1, 2 and 3:* Systems have a full load demand less than 2 kW, or 6,826 Btu/h, if they have a readily accessible manual shut-off switch. Included is the

energy consumed within all associated space-conditioning systems including compressors, as well as the energy consumed by any boilers or chillers that are part of the system.

4. *Exception to 1 and 2:* Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch.
5. *Exception to 3:* If demand control ventilation is implemented as required by 4.3.7.

F. Hotel/Motel Guest Room Controls:

§120.2(e)4

Hotel and motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 30 minutes after the guest room has been vacated, setpoints are setup at least +5°F (+3°C) in cooling mode and set-down at least -5°F (-3°C) in heating mode.

Example 4-26

Question

Can occupancy sensors be used in an office to shut off the VAV boxes during periods the spaces are unoccupied?

Answer

Yes, only if the ventilation is provided through operable openings. With a mechanical ventilation design the occupancy sensor could be used to reduce the VAV box airflow to the minimum allowed for ventilation. It should not shut the airflow off completely, ventilation must be supplied to each space at all times when the space is usually occupied.

Example 4-27

Question

Must a 48,000 ft² building with 35 fan coil units have 35 time switches?

Answer

No. More than one space-conditioning system may be grouped on a single time switch, subject to the area limitations required by the isolation requirements (see Isolation). In this case, the building would need two isolation zones, each no larger than 25,000 ft², and each having its own time switch.

Example 4-28

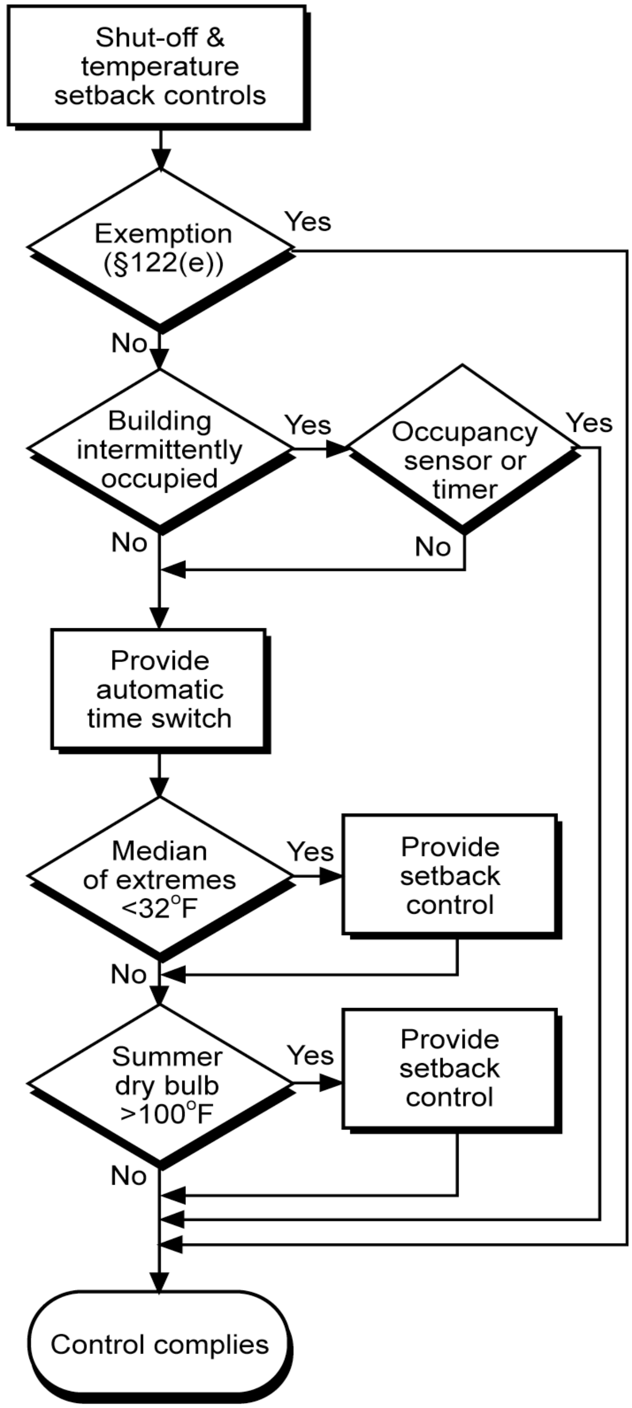
Question

Can a thermostat with setpoints determined by sensors (such as a bi-metal sensor encased in a bulb) be used to accomplish a night setback?

Answer

Yes. The thermostat must have two heating sensors, one each for the occupied and unoccupied temperatures. The controls must allow the setback sensor to override the system shutdown.

Figure 4-12: Shut-Off and Setback Controls Flowchart



These provisions are required by the Energy Standards to reduce the likelihood that shut-off controls will be circumvented to cause equipment to operate continuously during unoccupied hours.

Example 4-29

Question

If a building has a system comprised of 30 fan coil units, each with a 300-watt fan, a 500,000 Btu/h boiler, and a 30-ton chiller, can an automatic time switch be used to control only the boiler and chiller (fan coils operate continuously)?

Answer

No. The 2 kW criteria applies to the system as a whole, and is not applied to each component independently. While each fan coil only draws 300 W, they are served by a boiler and chiller that draw much more. The consumption for the system is well in excess of 2 kW.

Assuming the units serve a total area of less than 25,000 ft² (see Isolation), one time switch may control the entire system.

4.5.1.5 Infiltration Control

§120.2(f)

Outdoor air supply and exhaust equipment must incorporate dampers that automatically close when fans shut down.

Fans shut down when ventilation or conditioned air is not necessary for the building, which only occurs when a normally scheduled unoccupied period begins (such as overnight or a weekend for office buildings. The dampers may either be motorized, or of the gravity type, however only motorized dampers that remain closed when the fan turns on would be capable of accomplishing the best practice below

Best Practice

Though the Energy Standards only specify fan shut down, as a best practice outside air dampers should also remain completely closed during the unoccupied periods, even when the fan turns on to provide setback heating or cooling. However, to avoid instances of insufficient ventilation, or sick building syndrome, the designer should specify that the outside air dampers open and provide ventilation if:

- The unoccupied period is a 1-hour pre-occupancy purge ventilation, as per §120.1(c)2.
- The damper is enabled by an occupant sensor in the building as per §120.1(c)5, indicating that there are occupants that demand ventilation air.
- The damper is enabled by an override signal as per §120.2(e)1, which includes an occupancy sensor but also an automatic time switch control device or manually operated 4-hour timer.

Exception 1: Damper control is not required where it can be demonstrated to the satisfaction of the enforcement agency that the space-conditioning system must operate continuously.

Exception 2: Nor is damper control required on gravity ventilators or other non-electrical equipment, provided that readily accessible manual controls are incorporated..

Exceptions 3 and 4: Damper control is also not required at combustion air intakes and shaft vents, or where prohibited by other provisions of law. If the designer elects to install dampers or shaft vents to help control stack-induced infiltration, the damper should be motorized and controlled to open in a fire in accordance with applicable fire codes.

4.5.1.6 Isolation Area Controls

§120.2(g)

Large space-conditioning systems serving multiple zones may waste considerable quantities of energy by conditioning all zones when only a few zones are occupied. Typically, this occurs during evenings or weekends when only a few people are working. When the total area served by a system exceeds 25,000 ft², the Energy Standards require that the system be designed, installed and controlled with area isolation devices to minimize energy consumption during these times. The requirements are:

1. The building shall be divided into isolation areas, the area of each not exceeding 25,000 ft². An isolation area may consist of one or more zones.
2. An isolation area cannot include spaces on different floors.
3. Each isolation area shall be provided with isolations devices such as valves or dampers that allow the supply of heating or cooling to be setback or shut off independently of other isolation areas.
4. Each isolation area shall be controlled with an automatic time switch, occupancy sensor, or manual timer. The requirements for these shut-off devices are the same as described previously in 4.5.1.4. As discussed previously for occupancy sensors, a building purge must be incorporated into the control sequences for normally occupied spaces, so occupancy sensors and manual timers are best limited to use in those areas that are intermittently occupied.

Any zones requiring continuous operation do not have to be included in an isolation area.

Example 4-30

Question

How many isolation zones does a 55,000-ft² building require?

Answer

At least three. Each isolation zone may not exceed 25,000-ft².

A. Isolation of Zonal Systems

Small zonal type systems such as water loop heat pumps or fan coils may be grouped on automatic time switch devices, with control interlocks that start the central plant equipment whenever any isolation area is occupied. The isolation requirements apply to equipment supplying heating and cooling only; central ventilation systems serving zonal type systems do not require these devices.

B. Isolation of Central Air Systems

Figure 4-13 below depicts four methods of area isolation with a central variable air volume system:

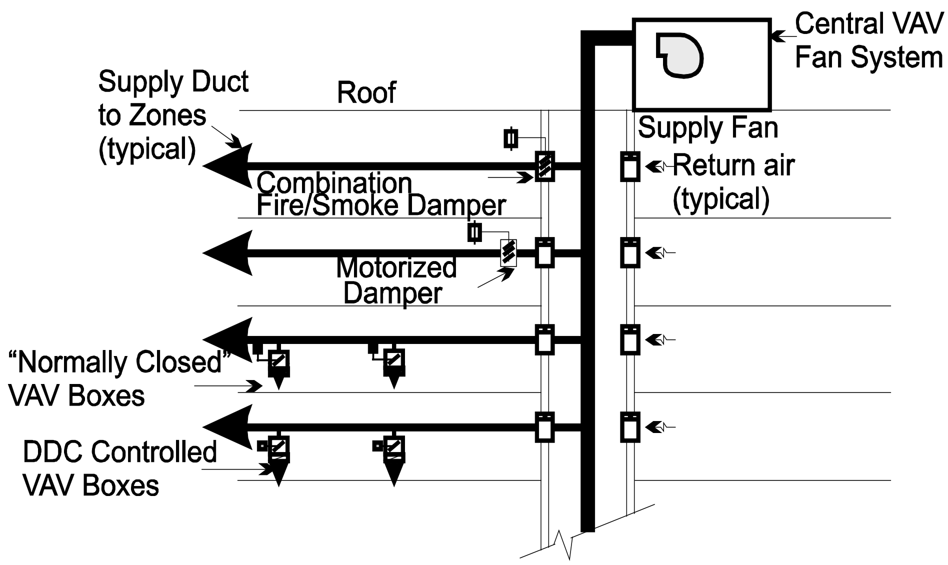
1. On the lowest floor, programmable DDC boxes can be switched on a separate time schedule for each zone or blocks of zones. When unoccupied, the boxes can be programmed to have zero minimum volume setpoints and unoccupied setback/setup setpoints. Note this form of isolation can be used for sections of a single floor distribution system.
2. On the second floor, normally closed pneumatic or electric VAV boxes are used to isolate zones or groups of zones. In this scheme the control source (pneumatic air or control power) for each group is switched on a separate control signal from an

individual time schedule. Again this form of isolation can be used for sections of a single floor distribution system.

3. On the third floor, isolation is achieved by inserting a single motorized damper on the trunk of the distribution ductwork. With the code requirement for fire/smoke dampers (see next bullet) this method is somewhat obsolete. When applied this method can only control a single trunk duct as a whole. Care must be taken to integrate the motorized damper controls into the fire/life safety system.

4. On the top floor, a combination fire smoke damper is controlled to provide the isolation. Again this control can only be used on a single trunk duct as a whole. Fire/smoke dampers required by code can be used for isolation at virtually no cost provided that they are wired so that the fire life-safety controls take precedence over off-hour controls. (Local fire officials generally allow this dual usage of smoke dampers since it increases the likelihood that the dampers will be in good working order in the event of a fire.) Note that no isolation devices are required on the return.

Figure 4-13: Isolation Methods for a Central VAV System



Example 4-31

Question

Does each isolation area require a ventilation purge?

Answer

Yes. Consider each isolation area as if it were a separate air handling system, each with its own time schedule, setback and setup control, etc.

C. Turndown of Central Equipment

Where isolation areas are provided it is critical that the designer design the central systems (fans, pumps, boilers and chillers) to have sufficient stages of capacity or turndown controls to operate stably as required to serve the smallest isolation area on the system. Failure to do so may cause fans to operate in surge, excessive equipment cycling and loss of temperature control. Schemes include:

1. Application of demand based supply pressure reset for VAV fan systems. This will generally keep variable speed driven fans out of surge and can provide 10:1 turndown.
2. Use of pony chillers, an additional small chiller to be used at partial load conditions, or unevenly split capacities in chilled water plants. This may be required anyway to serve 24/7 loads.
3. Unevenly split boiler plants.

4.5.1.7 Automatic Demand Shed Controls

§120.2(h)

HVAC systems with DDC to the zone level must be programmed to allow centralized demand shed for non-critical zones as follows:

1. The controls shall have a capability to remotely setup the operating cooling temperature set points by four degrees or more in all non-critical zones on signal from a centralized contact or software point within an Energy Management Control System (EMCS).
2. The controls shall be capable of remotely setdown the operating heating temperature set points by four degrees or more in all non-critical zones on signal from a centralized contact or software point within an EMCS.
3. The controls shall have capabilities to remotely reset the temperatures in all non-critical zones to original operating levels on signal from a centralized contact or software point within an EMCS.
4. The controls shall be programmed to provide an adjustable rate of change for the temperature setup and reset.
5. The controls shall have the following features:
   a. Disabled. Disabled by authorized facility operators; and
   b. Manual control. Manual control by authorized facility operators to allow adjustment of heating and cooling set points globally from a single point in the EMCS; and
   c. Automatic Demand Shed Control. Upon receipt of a demand response signal, the space-conditioning systems shall conduct a centralized demand shed, as specified in 1 and 2 above, for non-critical zones during the demand response period.

The Energy Standards defines a critical zone as a zone serving a process where reset of the zone temperature setpoint during a demand shed event might disrupt the process, including but not limited to data centers, telecom/private branch exchange (PBX) rooms, and laboratories.

To comply with this requirement, each non-critical zone temperature control loop will need a switch that adds in an offset on the cooling temperature setpoint on call from a central demand shed signal. A rate of change limiter can either be built into the zone control or into the functional block for the central offset value. The central demand shed signal can be activated either through a global software point or a hardwired digital contact.

This requirement is enhanced with an acceptance test to ensure that the system was programmed as required.

4.5.1.8 **Economizer Fault Detection and Diagnostics**

§120.2(i)

Economizer Fault Detection and Diagnostics (FDD) is a mandatory requirement for all newly installed air-cooled packaged direct-expansion units with the following:

- an air handler mechanical cooling capacity greater than or equal to 54,000 Btu/hr.
- an air economizer.

The FDD system can be either a stand-alone unit or integrated. A stand-alone FDD unit is added onto the air handler, while an integrated FDD system is included in the air handler system controller or is part of the EMCS.

Where required, the FDD system shall meet the following requirements:

1. The following temperature sensors shall be permanently installed to monitor system operation: outside air, supply air, and return air; and
2. Temperature sensors shall have an accuracy of ±2°F over the range of 40°F to 80°F; and
3. The controller shall have the capability of displaying the value of each sensor; and
4. The controller shall provide system status by indicating the following conditions:
    a. Free cooling available.
    b. Economizer enabled.
    c. Compressor enabled.
    d. Heating enabled, if the system is capable of heating.
    e. Mixed air low limit cycle active.
5. The unit controller shall manually initiate each operating mode so that the operation of compressors, economizers, fans, and heating system can be independently tested and verified; and
6. Faults shall be reported using one of the following options:
    a. An EMCS that is regularly monitored by facility personnel.
    b. Displayed locally on one or more zone thermostats or a device within 5 feet of a zone thermostat, clearly visible, at eye level and meet the following requirements:
        i. On the thermostat, device, or an adjacent written sign, there must be instructions displayed for how to contact the appropriate building personnel or an HVAC technician to service the fault.
        ii. In buildings with multiple tenants, the fault notification shall either be within property management offices or in a common space accessible by the property or building manager.
    c. Reported to a fault management application that automatically provides notification of the fault to a remote HVAC service provider. This allows the service provider to coordinate with an HVAC technician to service the fault.
7. The FDD system shall have the minimum capability of detecting the following faults:
    a. Air temperature sensor failure/fault. This failure mode is a malfunctioning air temperature sensor, such as the outside air, discharge air, or return air

temperature sensor. This could include mis-calibration, complete failure either through damage to the sensor or its wiring, or failure due to disconnected wiring.

b. Not economizing when it should. In this case, the economizer should be enabled, but for some reason it's not providing free cooling. This leads to an unnecessary increase in mechanical cooling energy. Two examples are the economizer high limit setpoint is too low, say 55˚F, or the economizer is stuck closed.

c. Economizing when it should not. This is opposite to the previous case of not economizing when it should. In this case, conditions are such that the economizer should be at minimum ventilation position but for some reason it is open beyond the correct position. This leads to an unnecessary increase in heating and cooling energy. Two examples are the economizer high limit setpoint is too high, say 82˚F, or the economizer is stuck open.

d. Damper not modulating. This issue represents a stuck, disconnected, or otherwise inoperable damper that does not modulate open and closed. It is a combination of the previous two faults: not economizing when it should, and economizing when it should not.

e. Excess outdoor air. This failure mode is the economizer provides an excessive level of ventilation, usually much higher than is needed for design minimum ventilation. It causes an energy penalty during periods when the economizer should not be enabled, that is, during cooling mode when outdoor conditions are higher than the economizer high limit setpoint. During heating mode, excess outdoor air will increase heating energy.

8. The FDD system shall be certified to the Energy Commission, by the manufacturer of the FDD system, to meet the requirements 1 through 7 above. The manufacturer submittal package is available in Joint Appendices *JA6.3 Economizer Fault Detection and Diagnostics Certification Submittal Requirements*.

4.5.1.9 **Direct Digital Controls**

§120.2(j)

New to the 2016 Energy Standards is the requirement to include Direct Digital Controls in buildings for new construction, additions or alterations. Previously, the Energy Standards did not require the installation of DDC, however if a builder did install DDC it would trigger code sections of Title 24 requiring specific energy saving measures that can be effectively implemented with DDC. This new requirement (for DDC systems in building applications, where appropriate) will increase building energy savings that were not previously captured.

The requirement for DDC will mostly impact smaller buildings, since it is already common practice to install DDC in medium and large buildings; primarily due to the size and complexity of HVAC systems of medium and large buildings, which DDC is well suited to operate. Small buildings in the past did not require DDC and therefore could not take advantage of basic energy savings strategies.

DDC systems facilitate energy saving measures through monitoring and regulating the HVAC systems and optimizing their efficient operation. With most buildings requiring DDC, the following energy saving measures will be triggered if DDC is to the zone level:

1. Demand Control Ventilation (mandatory) - Section 4.3.7
2. Automatic Demand Shed Controls (mandatory) - Section 4.5.1.7
3. Optimum Start/Stop Controls (mandatory) - Section 4.5.1.10

4. Setpoint Reset Controls for Variable Air Volume Systems (prescriptive) - Section 4.5.2.3

For further explanation, see the appropriate compliance manual sections for the measures listed above.

The Energy Standards mandate DDC for only certain building applications with minimum qualifications or equipment capacities, as specified in Table 120.2-A of the Energy Standards, see Table 4-17 below for a duplicate of this table.

Table 4-17: DDC Applications and Qualifications

BUILDING STATUS	APPLICATIONS	QUALIFICATIONS
Newly Constructed Buildings	Air handling system and all zones served by the system	Individual systems supplying more than three zones and with design heating or cooling capacity of 300 kBtu/h and larger
Newly Constructed Buildings	Chilled water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design cooling capacity of 300 kBtu/h (87.9 kW) and larger
Newly Constructed Buildings	Hot water plant and all coils and terminal units served by the system	Individual plants supplying more than three zones and with design heating capacity of 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	Zone terminal unit such as VAV box	Where existing zones served by the same air handling, chilled water, or hot water systems that have DDC
Additions or Alterations	Air handling system or fan coil	Where existing air handling system(s) and fan coil(s) served by the same chilled or hot water plant have DDC
Additions or Alterations	New air handling system and all new zones served by the system	Individual systems with with design heating or cooling capacity of 300 kBtu/h and larger and supplying more than three zones and more than 75 percent of zones are new
Additions or Alterations	New or upgraded chilled water plant	Where all chillers are new and plant design cooling capacity is 300 kBtu/h (87.9 kW) and larger
Additions or Alterations	New or upgraded hot water plant	Where all boilers are new and plant design heating capacity is 300 kBtu/h (87.9 kW) and larger

Table 120.2-A of the Energy Standards

Buildings that do not meet the specified minimum qualifications are not required to install DDC.

Follow the logic flowchart in Figure 4-14 to determine if a DDC system is required for newly constructed buildings or for additions or alterations to buildings. The Building Status Flowchart will indicate which equipment flowchart (Figure 4-15 through Figure 4-19) should be used for each type of HVAC equipment that will be installed in the building.

The logic of the equipment flowcharts will indicate whether DDC is required for the building, how DDC should be applied to the equipment and whether DDC is required to be installed to the zone level.

Figure 4-14: Building Status Flowchart

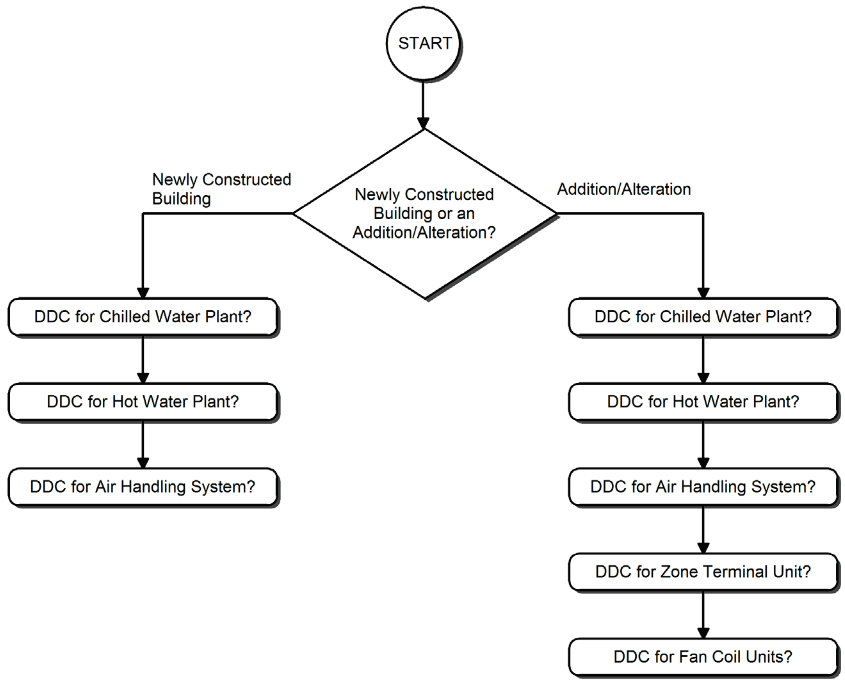


Figure 4-15: Chilled Water Plant Flowchart

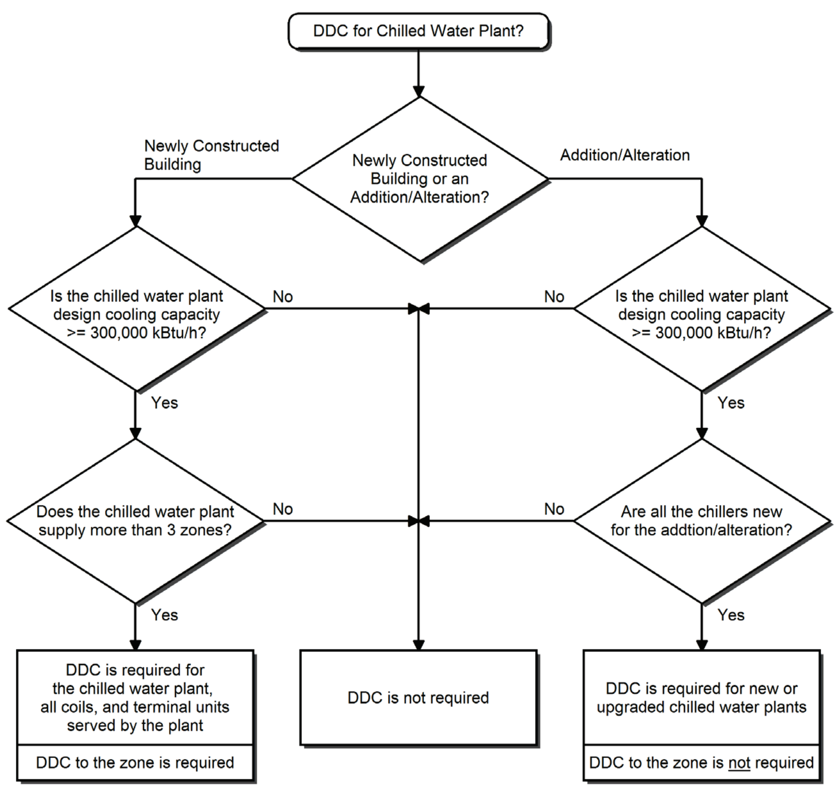


Figure 4-16: Hot Water Plant Flowchart

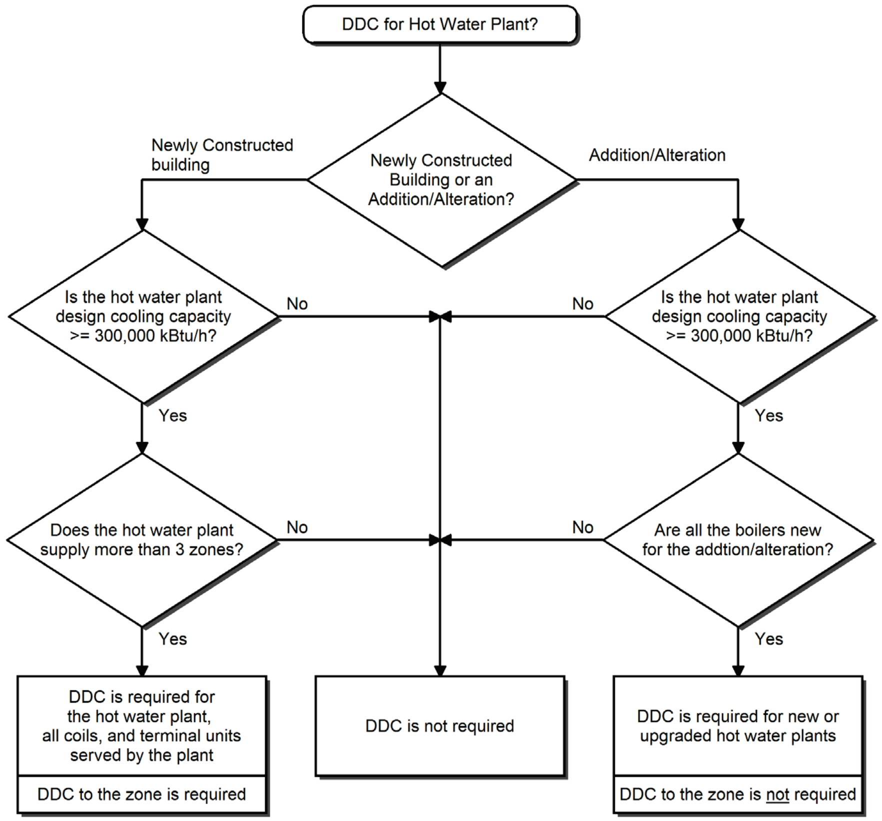


Figure 4-17: Air Handling System Flowchart

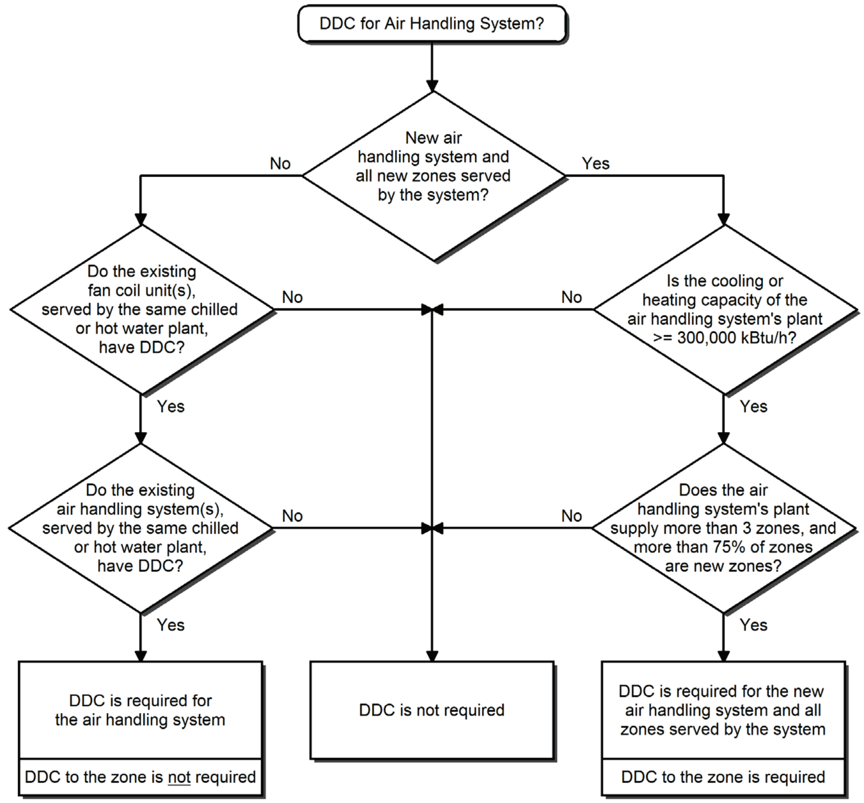


Figure 4-18: Zone Terminal Unit Flowchart

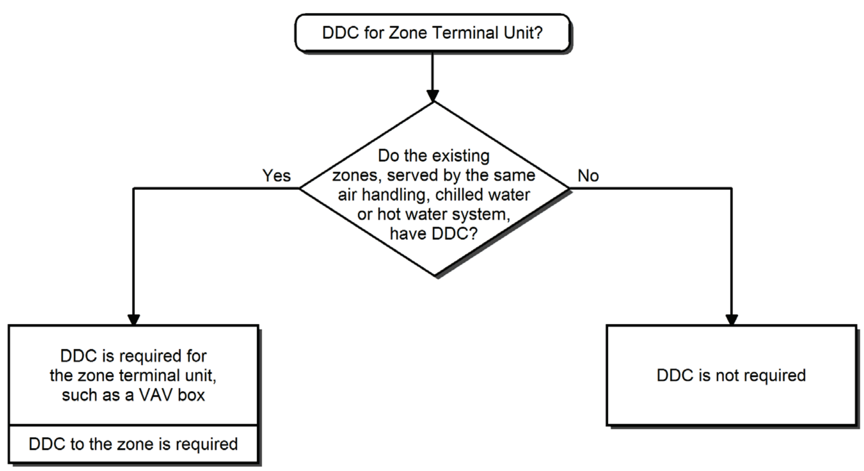
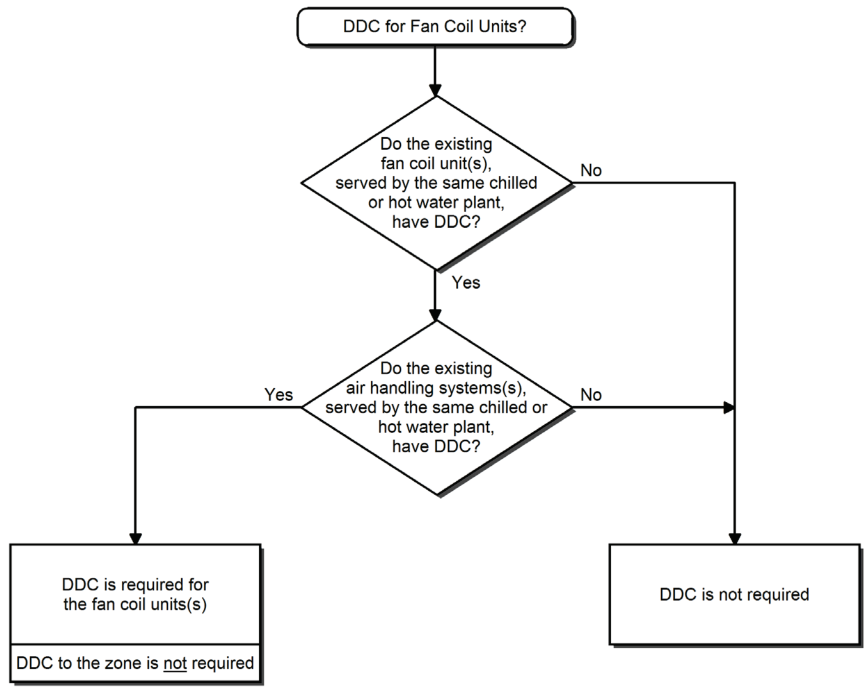


Figure 4-19: Fan Coil Units Flowchart



For additions or alterations to buildings, zones that are not part of the addition or alteration are not required to be retrofitted with DDC. Pre-existing DDC systems in buildings are not required to be retrofitted so DDC is to the zone.

Example 4-32

Question

If a newly constructed building has a HVAC system comprised of an air handling system, serving 4 zones and a chilled water plant with a design cooling capacity of 250,000 Btu/h, is DDC required?

Answer

No. Although the HVAC system is serving more than 3 zones, the chilled water plant does not meet the minimum design cooling capacity of 300,000 Btu/h (300 kBtu/h). A DDC system would be required if the design cooling capacity was 300,000 Btu/h or larger.

Example 4-33

Question

If an addition to a building requires a new VAV box, is DDC required?

Answer

Yes or No. The answer is dependent upon whether there is already a DDC system for the zones served by the same air handling, chilled water or hot water system. Essentially this is to ensure that if a DDC system is already installed, than it must be continued throughout the building, including the addition.

Example 4-34

Question

If a building's chilled water plant is upgraded with new chillers that have a design capacity of 500 kBtu/h and serves 3 zones, is DDC required?

Answer

Yes. The criteria that triggers the DDC requirement is that the plant upgrade is installing **new** chillers with a cooling capacity greater than 300 kBtu/h. In this case, the number of zones is irrelevant for determining if DDC is required.

The Energy Standards now require the mandated DDC system to have the following capabilities to ensure that the full energy saving benefits of DDC:

1. Monitor zone and system demand for fan pressure, pump pressure, heating and cooling
2. Transfer zone and system demand information from zones to air distribution system controllers and from air distribution systems to heating and cooling plant controllers
3. Automatically detect those zones and systems that may be excessively driving the reset logic and generate an alarm or other indication to the system operator
4. Readily allow operator removal of zone(s) from the reset algorithm
5. For new buildings, trending and graphically displaying input and output points, and
6. Resetting setpoints in non-critical zones upon a signal; from a centralized contract or software point as described in 4.5.1.7.

4.5.1.10 **Optimum Start/Stop Controls**

§120.2(k)

New to the 2016 Energy Standards are requirements for optimum start/stop controls when DDC is to the zone level.

Optimum start/stop controls are an energy saving technique where the HVAC system determines the optimum time to turn on or turn off the HVAC system so that the space reaches the appropriate temperature during occupied hours only, without wasting energy to condition the space during unoccupied hours; applies both to heating and cooling.

Optimum start controls are designed to automatically adjust the start time of a space conditioning system each day with the intent of bringing the space temperature to the desired occupied temperature levels at the beginning of scheduled occupancy. The controls shall take in to account the space temperature, outside ambient temperature, occupied temperature, amount of time prior to scheduled occupancy, and if present, the floor temperatures of a mass radiant floor slab systems.

Optimum stop controls are designed to automatically adjust the stop time of a space conditioning system each day with the intent of letting the space temperature coast to the unoccupied temperature levels after the end of scheduled occupancy. The controls shall take in to account the space temperature, outside ambient temperature, unoccupied temperature, and the amount of time prior to scheduled occupancy.

4.5.2 Prescriptive Requirements

4.5.2.1 Space Conditioning Zone Controls

§140.4(d)

Each space-conditioning zone shall have controls that prevent:

1. Reheating of air that has been previously cooled by mechanical cooling equipment or an economizer.
2. Recooling of air that has been previously heated. This does not apply to air returned from heated spaces.
3. Simultaneous heating and cooling in the same zone, such as mixing or simultaneous supply of air that has been previously mechanically heated and air that has been previously cooled, either by cooling equipment or by economizer systems.

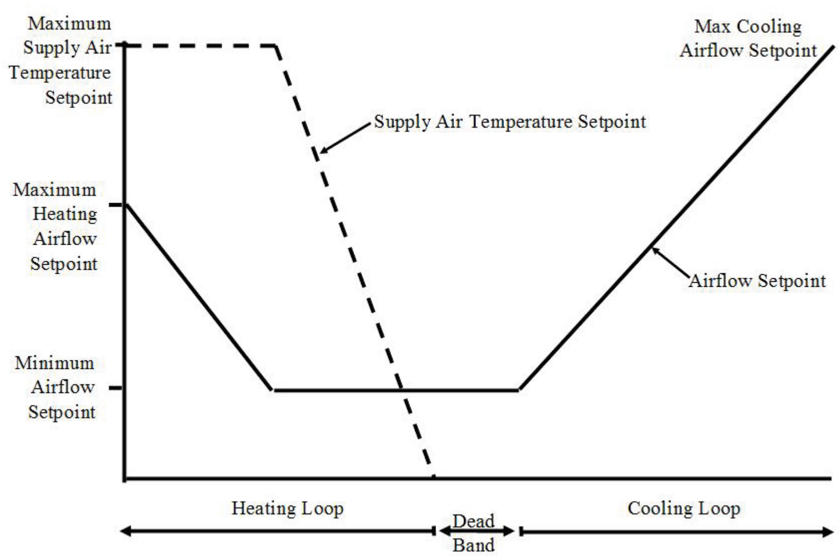
Certain exceptions exist for space conditioned zones with one of the following:

1. Special pressurization relationships or cross contamination control needs. Laboratories are an example of spaces that might fall in this category.
2. Site-recovered or site-solar energy providing at least 75 percent of the energy for reheating, or providing warm air in mixing systems.
3. Specific humidity requirements to satisfy exempt process needs. Computer rooms are explicitly not covered by this exception.
4. Zones with a peak supply air quantity of 300 cfm or less.
5. Zones served by variable air volume systems that are designed and controlled to reduce the volume of reheated, recooled or mixed air to a minimum. The controls must meet all of the following:
   a. For each zone with direct digital controls (DDC):
      i. The volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of:
         1. 50 percent of the peak primary airflow; or
         2. The design zone outdoor airflow rate per Section 4.3
      ii. The volume of primary air in the dead band shall not exceed the larger of:
         1. 20 percent of the peak primary airflow; or
         2. The design zone outdoor airflow rate per Section 4.3
      iii. The first stage of heating consists of modulating the zone supply air temperature setpoint up to a maximum setpoint no higher than 95ºF while the airflow is maintained at the deadband flow rate
      iv. The second stage of heating consists of modulating the airflow rate from the deadband flow rate up to the heating maximum flow rate.
   b. For each zone without DDC, the volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of the following:
      i. 30 percent of the peak primary airflow; or
      ii. The design zone outdoor airflow rate per Section 4.3.

For systems with DDC to the zone level, the controls must be able to support two different maximums: one each for heating and cooling. This control is depicted in Figure 4-20 below. In cooling, this control scheme is similar to a traditional VAV reheat box control. The difference is what occurs in the deadband between heating and cooling and in the heating mode. With traditional VAV control logic, the minimum airflow rate is typically set to the largest rate allowed by code. This airflow rate is supplied to the space in the deadband and heating modes. With the "dual maximum" logic, the minimum rate is the lowest allowed by code (e.g. the minimum ventilation rate) or the minimum rate the controls system can be set to (which is a function of the VAV box velocity pressure sensor amplification factor and the accuracy of the controller to convert the velocity pressure into a digital signal). As the heating demand increases, the dual maximum control first resets the discharge air temperature (typically from the design cold deck temperature up to 85 or 90°F) as a first stage of heating then, if more heat is required, it increases airflow rate up to a “heating” maximum airflow setpoint, which is the same value as what traditional control logic uses as the minimum airflow setpoint. Using this control can save significant fan, reheat and cooling energy while maintaining better ventilation effectiveness as the discharge heating air is controlled to a temperature that will minimize stratification.

This control requires a discharge air sensor and may require a programmable VAV box controller. The discharge air sensor is very useful for diagnosing control and heating system problems even if they are not actively used for control.

Figure 4-20: Dual-Maximum VAV Box Control Diagram



For systems without DDC to the zone (such as electric or pneumatic thermostats), the airflow that is reheated is limited to a maximum of the larger either 30 percent of the peak primary airflow or the minimum airflow required to ventilate the space.

Example 4-35

Question

What are the limitations on VAV box minimum airflow setpoint for a 1,000 ft² office having a design supply of 1,100 cfm and 8 people?

Answer

For a zone with pneumatic thermostats, the minimum cfm cannot exceed the larger of:

a. 1,100 cfm x 30 percent = 330 cfm; or

b. The minimum ventilation rate which is the larger of

1) 1,000 ft² x 0.15 cfm/ft² = 150 cfm; and

2) 8 people x 15 cfm/person = 120 cfm

Thus the minimum airflow setpoint can be no larger than 330 cfm.

For a zone with DDC to the zone, the minimum cfm in the deadband cannot exceed the larger of:

a. 1,100 cfm x 20 percent = 220 cfm; or

b. The minimum ventilation rate which is the larger of

1) 1,000 ft² x 0.15 cfm/ft² = 150 cfm; and

2) 8 people x 15 cfm/person = 120 cfm

Thus the minimum airflow setpoint in the dead band can be no larger than 220 cfm. And this can rise to 1100 cfm X 50 percent or 550 cfm at peak heating.

For either control system, based on ventilation requirements, the lowest minimum airflow setpoint must be at least 150 cfm, or transfer air must be provided in this amount.

4.5.2.2 Economizers

§140.4(e)

An economizer must be fully integrated and must be provided for each individual cooling air handler system that has a total mechanical cooling capacity over 54,000 Btu/h. The economizer may be either:

1. An air economizer capable of modulating outside air and return air dampers to supply 100 percent of the design supply air quantity as outside air; or
2. A water economizer capable of providing 100 percent of the expected system cooling load at outside air temperatures of 50°F dry-bulb and 45°F wet-bulb and below.

Depicted below in Figure 4-21 is a schematic of an air-side economizer. All air-side economizers have modulating dampers on the return and outdoor air streams.

Best Practice:

To provide 100 percent of the design supply air, designers will need to specify an economizer with a nominal capacity sufficient to deliver the design air flow rate when the supply air damper is in the full open position, and the return air damper is completely closed.

An appropriately sized economizer can also be estimated by determining the face velocity passing through the economizer by using the design airflow and the area of the economizer damper/duct opening.

The design airflow (cfm) should be available from the mechanical drawings or air handler cutsheet. The minimum area (ft^2) through which air is flowing from the outside to the fan can be measured in the field, or it can be found on the economizer damper cutsheet if the economizer damper is the smallest area. Dividing the design airflow by the smallest area will give the velocity of the air in ft/min.
Appropriately sized economizers that can supply 100% of the supply airflow without large pressure drops typically have face velocities of less than 2,000 ft/min.

To maintain acceptable building pressure, systems with an airside economizer must have provisions to relieve or exhaust air from the building. In Figure 4-21, three common forms of building pressure control are depicted:

- Option 1 barometric relief.
- Option 2 a relief fan generally controlled by building static pressure.
- Option 3 a return fan often controlled by tracking the supply.

Figure 4-22 depicts an integrated air-side economizer control sequence. On first call for cooling the outdoor air damper is modulated from minimum position to 100 percent outdoor air. As more cooling is required, the damper remains at 100 percent outdoor air as the cooling coil is sequenced on.

Graphics of water-side economizers are presented in Section 4.10.7.2 at the end of this chapter.

Figure 4-21: Air-Side Economizer Schematic

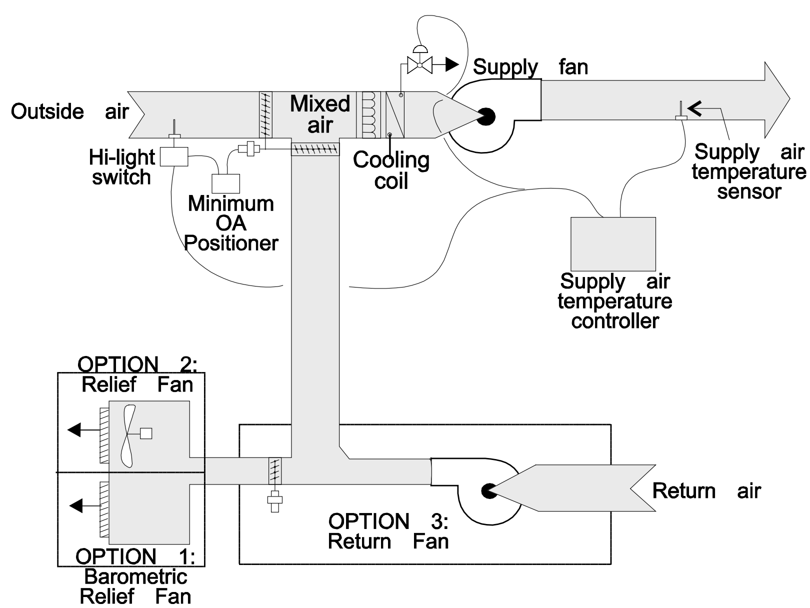
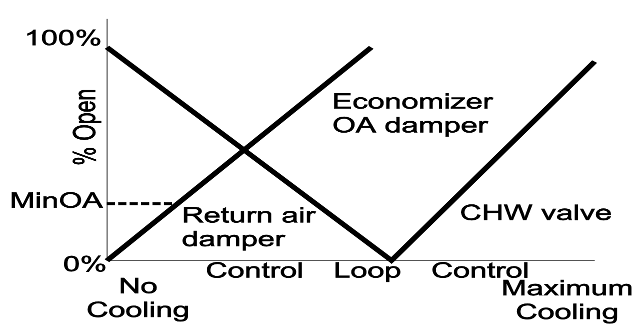


Figure 4-22: Typical Air-Side Economizer Control Sequencing



A. Economizers are not required where:

Exceptions to §140.4(e)1

1. Outside air filtration and treatment for the reduction and treatment of unusual outdoor contaminants make compliance infeasible.
2. Increased overall building TDV energy use results. This may occur where economizers adversely impact other systems, such as humidification, dehumidification or supermarket refrigeration systems.
3. Systems serving high-rise residential living quarters and hotel/motel guest rooms.
4. If cooling capacity is less than or equal to 54,000 Btu/h
5. Where cooling systems have the cooling efficiency that meets or exceeds the cooling efficiency improvement requirements in Table 4-18.
6. Fan systems primarily serving computer room(s). See §140.9 (a) for computer room economizer requirements.

B. If an economizer is required, it must be:

§140.4(e)2

1. Designed and equipped with controls that do not increase the building heating energy use during normal operation. This prohibits the application of single-fan dual-duct systems and traditional multizone systems using the Prescriptive Approach of compliance. With these systems, the operation of the economizer to pre-cool the air entering the cold deck also precools the air entering the hot deck and thereby increases the heating energy.

   Exception: when at least 75 percent of the annual heating is provided by site-recovered or site-solar energy.

2. Fully integrated into the cooling system controls so that the economizer can provide partial cooling even when mechanical cooling is required to meet the remainder of the cooling load. On packaged units with stand-alone economizers, a two-stage thermostat is necessary to meet this requirement.

The requirement that economizers be designed for concurrent operation is not met by some popular water economizer systems, such as those that use the chilled water system to convey evaporatively-cooled condenser water for “free” cooling. Such systems can provide 100 percent of the cooling load, but when the point is reached where condenser water temperatures cannot be sufficiently cooled by evaporation; the system controls throw the entire load to the mechanical chillers. Because this design cannot allow simultaneous economizer and refrigeration system operation, it does not meet the requirements of this section. An integrated water-side economizer which uses condenser water to precool the CHWR before it reaches the chillers (typically using a plate-and-frame heat exchanger) can meet this integrated operation requirement.

Table 4-18: Economizer Trade-Off Table For Cooling Systems

Climate Zone	Efficiency Improvement[a]
1	70%
2	65%
3	65%
4	65%
5	70%
6	30%
7	30%
8	30%
9	30%
10	30%
11	30%
12	30%
13	30%
14	30%
15	30%
16	70%

Energy Standards Table 140.4-A

[a] If a unit is rated with an IPLV, IEER or SEER, then to eliminate the required air or water economizer, the applicable minimum cooling efficiency of the HVAC unit must be increased by the percentage shown. If the HVAC unit is only rated with a full load metric, such as EER or COP cooling, then that metric must be increased by the percentage shown.

C. Air-Side Economizer High Limit Switches

§140.4(e)3

If an economizer is required by §140.4(e)1, and an air economizer is used to meet the requirement, the air side economizer is required to have high-limit shut-off controls that comply with Table 4-19.

1. The first column identifies the high limit control category. There are three categories allowed in this prescriptive requirement: Fixed Dry Bulb; Differential Dry Bulb; and Fixed Enthalpy + Fixed Dry Bulb.
2. The second column represents the California climate zone. “All” indicates that this control type complies in every California climate.
3. The third and fourth columns present the high-limit control setpoints required.

The Energy Standards eliminated the use of Fixed Enthalpy, Differential Enthalpy and Electronic Enthalpy controls. Research on the accuracy and stability of enthalpy controls led to their elimination (with the exception of use when combined with a fixed dry-bulb sensor). The enthalpy based controls can be employed if the project uses the performance approach however the performance model will show a penalty due to the inaccuracy of the enthalpy sensors.

Table 4-19: Air Economizer High Limit Shut Off Control Requirements

Device Type[a]	Climate Zones	Required High Limit (Economizer Off When): Equation[b]	Description
Fixed Dry Bulb	1, 3, 5, 11-16	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
	2, 4, 10	T_{OA} > 73°F	Outdoor air temperature exceeds 73°F
	6, 8, 9	T_{OA} > 71°F	Outdoor air temperature exceeds 71°F
	7	T_{OA} > 69°F	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	1, 3, 5, 11-16	T_{OA} > T_{RA}°F	Outdoor air temperature exceeds return air temperature
	2, 4, 10	T_{OA} > T_{RA}-2°F	Outdoor air temperature exceeds return air temperature minus 2°F
	6, 8, 9	T_{OA} > T_{RA}-4°F	Outdoor air temperature exceeds return air temperature minus 4°F
	7	T_{OA} > T_{RA}-6°F	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy[c] + Fixed Drybulb	All	h_{OA} > 28 Btu/lb[c] or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air[c] or Outdoor air temperature exceeds 75°F

[a] Only the high limit control devices listed are allowed to be used and at the setpoints listed. Others such as Dew Point, Fixed Enthalpy, Electronic Enthalpy, and Differential Enthalpy Controls, may not be used in any climate zone for compliance with §140.4(e)1. unless approval for use is provided by the Energy Commission Executive Director

[b] Devices with selectable (rather than adjustable) setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

[c] At altitudes substantially different than sea level, the Fixed Enthalpy limit value shall be set to the enthalpy value at 75°F and 50percent relative humidity. As an example, at approximately 6,000 foot elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

Energy Standards Table 140.4-B

D. Air Economizer Construction

§140.4(e)4

If an economizer is required by §140.4(e)1, and an air economizer is used to meet the requirement, then the air economizer, and all air dampers shall have the following features:

1. A 5-year factory warranty for the economizer assembly.
2. Certification by the manufacturer that the that the economizer assembly, including but not limited to outdoor air damper, return air damper, drive linkage, and actuator, have been tested and are able to open and close against the rated airflow and pressure of the system for at least 60,000 damper opening and closing cycles.
3. Economizer outside air and return air dampers shall have a maximum leakage rate of 10 cfm/sf at 250 Pascals (1.0 in. w.g) when tested in accordance with AMCA Standard 500-D. The leakage rates for the outside and return dampers shall be certified to the Energy Commission in accordance with §110.0.
4. If the high-limit control uses either a fixed dry-bulb, or fixed enthalpy control, the control shall have an adjustable setpoint.

5. Economizer sensors shall be calibrated within the following accuracies.
   a. Drybulb and wetbulb temperatures accurate to ±2°F over the range of 40°F to 80°F.
   b. Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
   c. Relative Humidity (RH) accurate to ± 5 percent over the range of 20 percent to 80 percent RH
4. Data of sensors used for control of the economizer shall be plotted on a sensor performance curve.
5. Sensors used for the high limit control shall be located to prevent false readings, e.g. including but not limited to being properly shielded from direct sunlight.
6. Relief air systems shall be capable of providing 100 percent outside air without over-pressurizing the building.

E. Compressor Unloading

§140.4(e)5

Systems that include and air economizer must comply with the following requirements:

1. Unit controls shall have mechanical capacity controls interlocked with economizer controls such that the economizer is at 100 percent open position when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45°F.
2. Direct Expansion (DX) units greater than 65,000 Btu/hr that control the capacity of the mechanical cooling directly based on occupied space temperature shall have a minimum of 2 stages of mechanical cooling capacity.
3. DX units not within the scope of 2, shall comply with the requirements in Table 4-20, and have controls that do not false load the mechanical cooling system by limiting or disabling the economizer or by any other means, except at the lowest stage of mechanical cooling capacity.

Table 4-20: Direct Expansion (DX) Unit Requirements For Cooling Stages And Compressor Displacement

Cooling Capacity	Minimum Number of Mechanical Cooling Stages	Minimum Compressor Displacement
≥65,000 Btu/h and < 240,000 Btu/h	3 stages	≤ 35% full load
≥ 240,000 Btu/h	4 stages	≤ 25% full load

Energy Standards Table 140.4-C

Chapter 13 of this manual describes mandated acceptance test requirements for economizers.

If the economizer is factory-calibrated the economizer acceptance test is not required at installation. A calibration certificate of economizer control sensors (outdoor air temperature, return air temperature, etc.) must be submitted to the local code enforcement agency in the permit application.

Figure 4-23: Economizer Flowchart

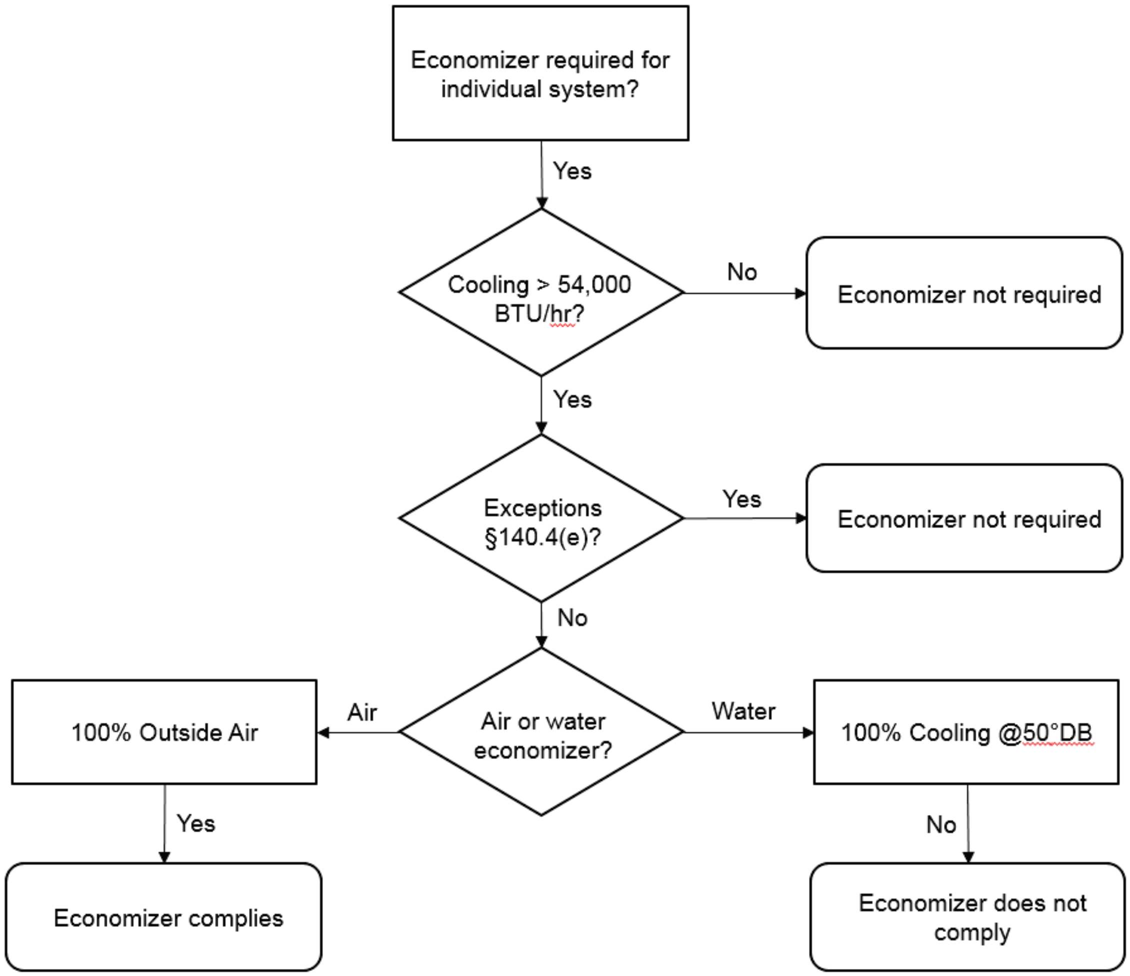
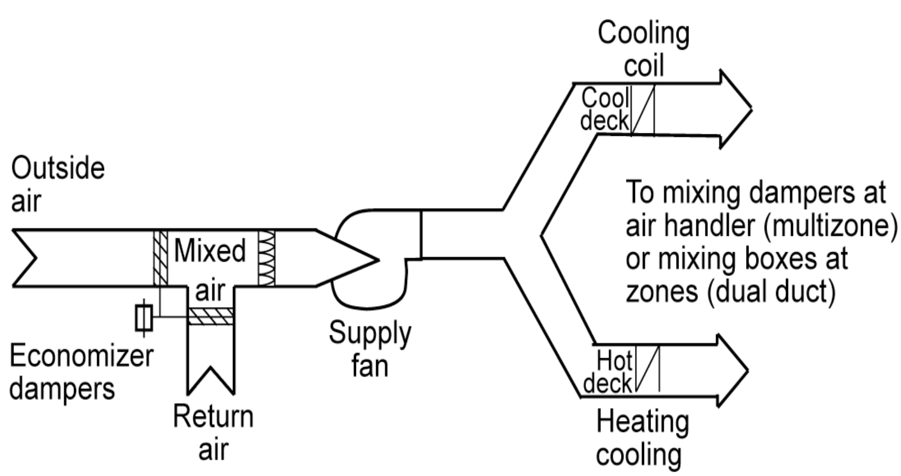


Figure 4-24: Single-Fan Dual-Duct System



Example 4-36

Question

If my design conditions are 94°Fdb/82°Fwb can I use my design cooling loads to size a water-side economizer?

Answer

No. The design cooling load calculations must be rerun with the outdoor air temperature set to 50°Fdb/45°Fwb. The specified tower, as well as cooling coils and other devices, must be checked to determine if it has adequate capacity at this lower load and wet-bulb condition.

Example 4-37

Question

Will a strainer cycle water-side economizer meet the prescriptive economizer requirements? (Refer to Figure 4-33)

Answer

No. It cannot be integrated to cool simultaneously with the chillers.

Example 4-38

Question

Does a 12 ton packaged AC unit in climate zone 10 need an economizer?

Answer

Yes and the economizer must be equipped with an economizer fault detection and diagnostic system. However the requirement for an economizer can be waived if the AC unit's efficiency is greater than or equal to an EER of 14.3. Refer to Table 4-18

4.5.2.3 **VAV Supply Fan Controls**

§140.4(c)2 and §140.4(m)

Both single and multiple zone systems are required to have VAV supply based on the system type as described in Table 4-21. The VAV requirements for supply fans are as follows:

1. Single zone systems (where the fans are controlled directly by the space thermostat) shall have a minimum of 2 stages of fan speed with no more than 66 percent speed when operating on stage 1 while drawing no more than 40 percent full fan power when running at 66 percent speed.
2. All systems with air-side economizers to satisfy Section 4.5.2.2 are required to have a minimum of 2 speeds of fan control during economizer operation.
3. Multiple zone systems shall limit the fan motor demand to no more than 30 percent of design wattage at 50 percent design air volume.

Variable speed drives can be used to meet any of these three requirements.

Actual fan part load performance, available from the fan manufacturer, should be used to test for compliance with item 3 above. Figure 4-25 shows typical performance curves for different types of fans. As can be seen, both air foil fans and backward inclined fans using either discharge dampers or inlet vanes consume more than 30 percent power at 50 percent flow when static pressure set point is one-third of total design static pressure using certified manufacturer's test data. These fans will not normally comply with these requirements unless a variable speed drive is used.

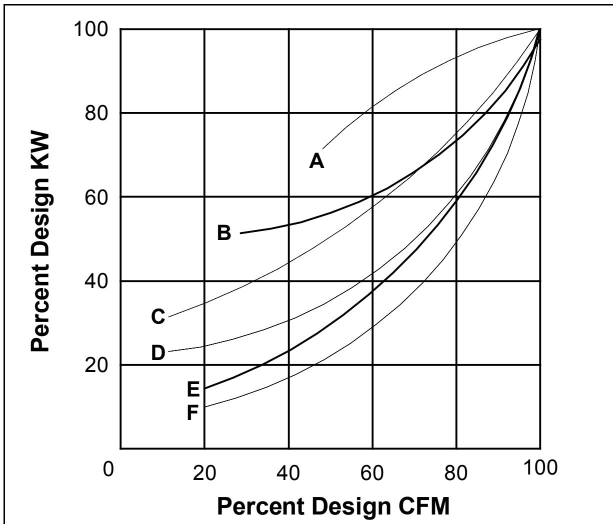
VAV fan systems that don't have DDC to the zone level are required to have the static pressure sensor located in a position such that the control setpoint is ≤1/3 of the design static pressure of the fan. For systems without static pressure reset the further the sensor is from the fan the more energy will be saved. For systems with multiple duct branches in the distribution you must provide separate sensors in each branch and control the fan to satisfy the sensor with the greatest demand. When locating sensors, care should be taken to have at least one sensor between the fan and all operable dampers (e.g. at the bottom of a supply shaft riser before the floor fire/smoke damper) to prevent loss of fan static pressure control.

For systems with DDC to the zone level the sensor(s) may be anywhere in the distribution system and the duct static pressure setpoint must be reset by the zone demand. Typically this is done by one of the following methods:

1. Controlling so that the most open VAV box damper is 95 percent open.
2. Using a "trim and respond" algorithm to continually reduce the pressure until one or more zones indicate that they are unable to maintain airflow rate setpoints.
3. Other methods that dynamically reduce duct static pressure setpoint as low as possible while maintaining adequate pressure at the VAV box zone(s) of greatest demand.

Reset of supply pressure by demand not only saves energy but it also protects fans from operation in surge at low loads. Chapter 13, Acceptance Requirements, describes mandated acceptance test requirements for VAV system fan control.

Figure 4-25: VAV Fan Performance Curve



A. Air foil or backward inclined centrifugal fan with discharge dampers

B. Air foil centrifugal fan with inlet vanes

C. Forward curved centrifugal fan with discharge dampers or riding curve

D. Forward curved centrifugal fan with inlet vanes

E. Vane-axial fan with variable pitch blades

F. Any fan with variable speed drive (mechanical drives will be slightly less efficient)

Table 4-21: Fan Control Systems

Cooling System Type	Fan Motor Size	Cooling Capacity
DX Cooling	any	≥ 65,000 Btu/hr
Chilled Water and Evaporative	≥ 1/4 HP	any

Energy Standards Table 140.4-D

4.5.2.4 **Supply-Air Temperature Reset Control**

§140.4(f)

Mechanical space-conditioning systems supplying heated or cooled air to multiple zones must include controls that automatically reset the supply-air temperature in response to representative building loads, or to outdoor air temperature. The controls must be capable of resetting the supply-air temperature by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.

For example, if the design supply temperature is 55°F and the design room temperature is 75°F, then the difference is 20°F, and 25 percent is 5°F. Therefore, the controls must be capable of resetting the supply temperature from 55°F to 60°F.

Air distribution zones that are likely to have constant loads, such as interior zones, shall have airflow rates designed to meet the load at the fully reset temperature. Otherwise, these zones may prevent the controls from fully resetting the temperature, or will unnecessarily limit the hours when the reset can be used.

Supply air reset is required for VAV reheat systems even if they have VSD fan controls. The recommended control sequence is to lead with supply temperature setpoint reset in cool weather where reheat might dominate the equation and to keep the chillers off as long as possible, then return to a fixed low setpoint in warmer weather when the chillers are likely to be on. During reset, employ a demand-based control that uses the warmest supply air temperature that satisfies all of the zones in cooling.

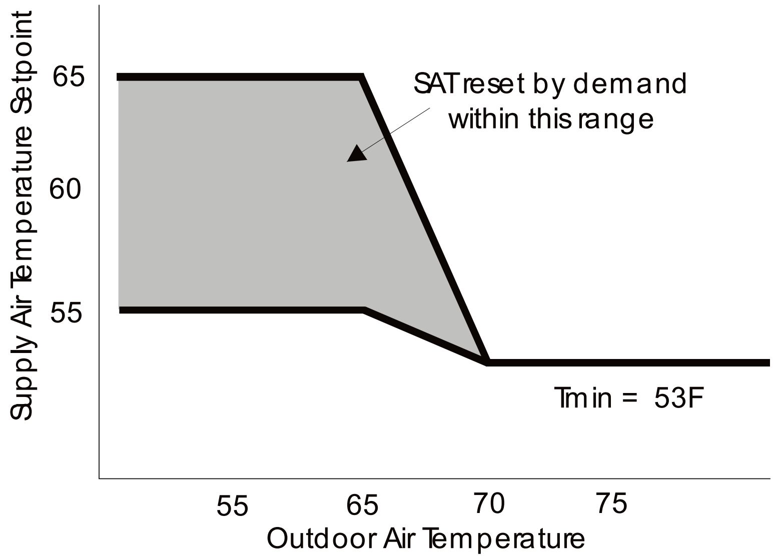
This sequence is described as follows: during occupied mode, the setpoint is reset from T-min (53°F) when the outdoor air temperature is 70°F and above, proportionally up to T-max when the outdoor air temperature is 65°F and below. T-max shall range from 55°F to 65°F and shall be the output of a slow reverse-acting proportional-integral (PI) loop that maintains the cooling loop of the zone served by the system with the highest cooling loop at a setpoint of 90 percent (See Figure 4-26).

Supply temperature reset is also required for constant volume systems with reheat justified on the basis of special zone pressurization relationships or cross-contamination control needs.

Supply-air temperature reset is not required when:

1. The zone(s) must have specific humidity levels required to meet exempt process needs. Computer rooms cannot use this exception.
2. Where it can be demonstrated to the satisfaction of the enforcement agency that supply air reset would increase overall building energy use.
3. The space-conditioning zone has controls that prevent reheating and recooling and simultaneously provide heating and cooling to the same zone.

Figure 4-26: Energy Efficient Supply Air Temperature Reset Control for VAV Systems



Recommended Supply Air Temperature Reset Method

4.5.2.5 Heat Rejection Fan Control

§140.4(h)

When the fans on cooling towers, closed-circuit fluid coolers, air-cooled condensers and evaporative condensers are powered by a fan motor or 7.5 hp or larger, the system must be capable of operating at 2/3 of full speed or less and have controls that automatically change the fan speed to control the leaving fluid temperature or condensing temperature or pressure of the heat rejection device. Fan speed controls are exempt when:

1. Fans powered by motors smaller than 7.5 hp.
2. Heat rejection devices included as an integral part of the equipment listed in Table 4-1 through Table 4-11.
3. Condenser fans serving multiple refrigerant circuits or flooded condensers.
4. Up to 1/3 of the fans on a condenser or tower with multiple fans where the lead fans comply with the speed control requirement.

Example 4-39

Question

A chilled water plant has a three-cell tower with 10 hp motors on each cell. Are speed controls required?

Answer

Yes. At minimum the designer must provide 2-speed motors, pony motors or variable speed drives on two of the three fans for this tower.

4.5.2.6 **Hydronic System Measures**

§140.4(k)

A. Hydronic Variable Flow Systems

§140.4(k)1

Hot water and chilled water systems are required to be designed for variable flow. Variable flow is provided by using 2-way control valves. The Energy Standards only require that flow is reduced to the greater of 50 percent design flow (or less) or the minimum flow required by the equipment manufacturer for operation of the central plant equipment.

There are two exceptions for this requirement:

1. Systems that include no more than three control valves.
2. Systems having a total pump system power less than or equal to 1.5 hp.

It is not necessary for each individual pump to meet the variable flow requirement. These requirements can be met by varying the total flow for the entire pumping system in the plant. Strategies that can be used to meet these requirements include but are not limited to variable frequency drives on pumps and staging of the pumps.

It should be noted that the primary loop on a primary/secondary or primary/secondary/tertiary system could be designed for constant flow even if the secondary or tertiary loop serves more than 3 control valves. This is allowed because the primary loop does not directly serve any coil control valves. However the secondary (and tertiary loops) of these systems must be designed for variable flow if they have 4 or more control valves.

The flow limitations are provided for primary-only variable flow chilled water systems where a minimum flow is typically required to keep a chiller on-line. In these systems minimum flow can be provided with either a bypass with a control valve or some 3-way valves to ensure minimum flow at all times. The system with a bypass valve is more efficient as it only provides bypass when absolutely required to keep the plant on line.

For hot water systems application of slant-tube or bent tube boilers will provide the greatest flow turndown. Typically copper fin tube boilers require a higher minimum flow.

Example 4-40

Question

In my plant, I am trying to meet the variable flow requirements of Section 4.5.2.6. Must each individual pump meet these requirements for the plant to comply with the Energy Standards?

Answer

No, individual pumps do not need to meet the variable flow requirements of this section. As long as the entire plant meets the variable flow requirements, the plant is in compliance. For example, the larger pumps may be equipped with variable frequency drives or the pumps can be staged in a way that can meet these requirements.

B. Isolation for Chillers and Boilers

§140.4(k)2 and3

Plants with multiple chillers or boilers are required to provide either isolation valves or dedicated pumps and check valves to ensure that flow will only go through the chillers or boilers that are staged on. Chillers that are piped-in series for the purpose of increased temperature differential shall be considered as one chiller.

C. Chilled and Hot Water Reset

§140.4(k)4

Similar to the requirements for supply air temperature reset, chilled and hot water systems that have a design capacity > 500,000 Btu/h are required to provide controls to reset the hot or cold water temperature setpoints as a function of building loads or the outdoor air temperature. This reset can be achieved either using a direct indication of demand (usually cooling or heating valve position) or an indirect indication of demand (typically outdoor air temperature). On systems with DDC controls reset using valve position is recommended.

There is an exception to this requirement for hydronic systems that are designed for variable flow complying with 4.5.2.6.A (§140.4(k)1).

D. Isolation Valves for Water-Loop Heat Pump Systems

§140.4(k)5

Water circulation systems serving water-cooled air conditioner and hydronic heat pump systems that have a design circulation pump brake horsepower >5 bhp are required to be provided with 2-way isolation valves that close whenever the compressor is off. These systems are also required to be provided with the variable speed drives and pressure controls described in the following section.

Although this is not required on central tenant condenser water systems (for water-cooled AC units and HPs) it is a good idea to provide the 2-way isolation valves on these systems as well. In addition to providing pump energy savings, these 2-way valves can double as head-pressure control valves to allow aggressive condenser water reset for energy savings in chilled water plants that are also cooled by the towers.

E. VSDs for Pumps Serving Variable Flow Systems

§140.4(k)6

Variable Flow Controls - Pumps on variable flow systems that have a design circulation pump brake horsepower > 5 bhp are required to have either variable speed drives or a different control that will result in pump motor demand of no more than 30 percent of design wattage at 50 percent of design water flow.

Pressure Sensor Location and Setpoint

1. For systems without direct digital control of individual coils reporting to the central control panel, differential pressure must be measured at the most remote heat exchanger or the heat exchanger requiring the most pressure. This includes chilled water systems, condenser water systems serving water-cooled air conditioning (AC) loads and water-loop heat pump systems.
2. For systems with direct digital control of individual coils with a central control panel, the static pressure set point must be reset based on the valve requiring the most pressure and the setpoint shall be no less than 80 percent open. The pressure sensor(s) may be mounted anywhere.

Exceptions are provided for hot-water systems and condenser water systems that only serve water-cooled chillers. The hot water systems are exempted because the heat from the added pumping energy of the pump riding the curve provides a beneficial heat that reduces the boiler use. This reduces the benefit from the reduced pumping energy.

F. Hydronic Heat Pump (WLHP) Controls

§140.4(k)7

Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection and heat addition must have controls that are capable of providing a heat pump water supply temperature dead band of at least 20°F between initiation of heat rejection and heat addition by the central devices. Exceptions are provided where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20°F shall be allowed.

4.5.2.7 Window/Door Switches for Mechanical System Shut-off

§140.4(n)

If a directly conditioned zone has a thermostat and has one or more manually operable wall or roof openings to the outdoors, then the openings must all have sensors that communicate to the HVAC system. The HVAC controller must be capable of shutting off the heating or cooling to that zone if the sensor detects that the opening has remained open for more than 5 minutes. This can be accomplished by either the resetting the heating setpoint to 55°F or the heating can be disabled altogether. If the HVAC system is in cooling mode, then similarly this requirement can be satisfied by resetting the cooling setpoint to 90°F unless the outside air temperature is less than the space temperature, in which case the cooling setpoint can be reset or not. If the zone is in cooling and the outside air temperature is less than the space temperature then additional infiltration from the opening provides economizer free cooling and is not an additional cooling load on the mechanical system.

This requirement does not require that any openings be operable but if there are operable openings then they must comply with this requirement.

Note that mechanical ventilation as required by Section 4.3.2 must still be provided. The mechanical system shut off pertains to the space conditioning equipment only. Mechanical ventilation must still be provided if the space does not fall under the natural ventilation criteria. Systems that meet the ventilation requirements with natural ventilation, rather than mechanical ventilation, are not exempt from the window/door switch requirement. Thus, in the same way that most homeowners typically choose between opening the windows and running the heating/cooling, window/door switches will now cause occupants to choose between opening windows/doors and allowing full heating/cooling.

Manually operable openings to the outdoors include manually operable windows, skylights, and doors that do not have automatic closing devices (e.g. sliding balcony doors). Motorized openings (e.g. motorized skylights) are still considered manually operable if occupants can open the openings as desired and they will stay open until manually closed.

If a zone serves more than one room then only the openings in the room with the thermostat are required to be interlocked. For example, if three perimeter private offices are served by a single VAV box then only the operable openings in the office with the thermostat need to be interlocked. The windows in the offices that do not have a thermostat do not need to be interlocked.

If there is a large room with more than one zone then only the zones with operable windows in them need to be interlocked. For example, if a large open office has a perimeter zone and an interior zone in the same room and there are operable windows in the perimeter zone but not the interior zone then only the perimeter zone needs to be interlocked to the windows.

Alterations to existing buildings are exempt from this requirement. Additions to existing buildings only have to comply if the operable opening(s) and associated zone are new.

4.5.3 Acceptance Requirements

There are a number of acceptance requirements related to control systems. These include:

1. Automatic time switch control devices.
2. Constant volume package unit.
3. Air-side economizers.
4. VAV supply fan controls.
5. Hydronic system controls.

These tests are described in Chapter 13 as well as the Reference Nonresidential Appendix NA7.

4.6 HVAC System Requirements

There are no acceptance tests for these requirements.

4.6.1 Mandatory Requirements

4.6.1.1 Water Conservation Measures for Cooling Towers

§110.2(e)

§110.2(e) establishes mandatory requirements for the efficient use of water in the operation of open (direct) and closed (indirect) cooling towers. The building standard applies to the new construction and retrofit of commercial, industrial and institutional cooling towers with a rated capacity of 150 tons or greater. For these towers all of the following are required:

1. The towers shall be equipped with either conductivity or flow-based controls to control cycles of concentration based on local water quality conditions. The controls shall automate system bleed and chemical feed based on conductivity, or in proportion to metered makeup volume, metered bleed volume, recirculating pump run time, or bleed time. Where employed, conductivity controllers shall be installed in accordance with manufacturer's specifications.
2. Design documents have to document maximum achievable cycles of concentration based on local water supply as reported by the local water supplier, and using a calculator approved by the Energy Commission. The calculator shall determine maximum cycles based on a Langelier Saturation Index (LSI) of 2.5 or less. An approved calculator can be downloaded from the Energy Commission's website: http://www.energy.ca.gov/title24/2013standards/documents/maximum_cycles_calculator.xls
3. The towers shall be equipped with a flow meter with an analog output for flow. This can be connected to the water treatment control system using either a hardwired connection or gateway.
4. The towers shall be equipped with an overflow alarm to prevent overflow of the sump in case of makeup water valve failure. This requires either a water level sensor or a moisture detector in the overflow drain. The alarm contact should be connected to the building Energy Management Control System to initiate an EMCS alarm to alert the operators.
5. The towers shall be equipped with drift eliminators that achieve a maximum rated drift of 0.002 percent of the circulated water volume for counter-flow towers and 0.005percent for cross-flow towers.

As water is evaporated off the tower, the concentration of dissolved solids like calcium carbonate and silica will increase. The pH of the water will also change. With high levels of silica or dissolved solids you will get deposits on the tower fill or clogging in the tower nozzles which will reduce the tower's heat rejection capacity. High pH is a concern for metal tower basins and structural members. As the thresholds of these contaminants of concern are approached the automated controls should bleed some of the concentrated water out and dilute it with make-up water. The bleed can be controlled by measurement of make-up water flow (an indirect measurement of water drift and evaporation) or through conductivity (a measurement of the dissolved solids). The term "*cycles of concentration*" is the metric of how concentrated the contaminants are at the controlled level. The right value depends on the characteristics of the supply water, the rate of tower drift, the weather characteristics, and the load on the tower. Good practice is to maintain the following levels:

- Silica levels should be maintained at ≤ 150 ppm
- The Langelier Saturation Index should be maintained at ≤ 2.5 (see explanation of LSI below)
- pH in new cooling towers using galvanized metal should be maintained at ≤ 8.3 until metal is passivated, which occurs after 3-6 months of operation

To meet compliance, an Energy Commission-approved calculator (NRCC-MCH-06-E) allows the building owner to enter makeup water quality parameters including conductivity, alkalinity, calcium hardness, magnesium hardness, and silica. These values are available from the local water supplier in the most recent annual Consumer Confidence Report or Water Quality Report. These reports are generally posted on the water supplier’s website, or by contacting the local water supplier by telephone. Many water districts have multiple sources of water which often are changed seasonally. For example many water districts use a reservoir in the winter and spring then switch to well water in the summer and fall. Each supply will typically have different characteristics so the water treatment and control cycles of concentration should be seasonally shifted as well.

After entering the required water quality data, the user must also enter skin temperature; the default value of 110 degrees Fahrenheit is acceptable. Lastly, target tower cycles of concentration is entered into the calculator. The calculator calculates the Langelier Saturation Index (LSI) based on the cycles of concentration entered by the user. The maximum value of the LSI is 2.5; therefore, the user should enter the highest cycles of concentration value in 0.10 units that results in a calculated LSI not to exceed 2.5. The resulting cycles of concentration is considered by the Commission to be the Maximum Achievable Cycles of Concentration and must be recorded on the mechanical compliance document (NRCC-MCH-06-E), to which a copy of the Consumer Confidence Report or Water Quality Report must be attached. The Professional Engineer of Record must sign the compliance document (NRCC-MCH-06-E) attesting to the calculated maximum cycles of concentration.

Example 4-41

Question

What is the Langelier Saturation Index (LSI)?

Answer

The Langelier Saturation Index (LSI) predicts scaling. The LSI indicates whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate, and is a function of hardness, alkalinity, conductivity, pH and temperature. LSI is expressed as the difference between the actual system pH and the saturation pH.

Example 4-42

Question

Where can I find data for makeup water quality?

Answer

Water agencies are required to make their annual water quality data available to the public. Water quality data is generally organized into an annual Consumer Confidence Report or Water Quality Report, which can often be found posted on the water agency's website by searching for the key words "water quality". Since many water districts have more than one water supply ask for a report for each source

Example 4-43

Question

What if all, or some, of the water quality data is not provided in the Consumer Confidence Report or Water Quality Report?

Answer

Some data may be available by calling the local water agency's Water Quality Division. For example, agencies are not required to test for and report alkalinity; however, they often do test for it and will provide data over the phone or in an email. You can also check with water treatment firms that are doing business in the area. They often have test data that they will share. Finally you can hire a water treatment firm to take samples of the water to test.

4.6.1.2 Low Leakage Air Handling Unit (AHU)

§110.2(f), §140.1 and §150.1(b)

The standard provides a compliance credit for low leakage AHUs. To achieve this credit you must meet the qualifications in Reference Joint Appendix JA9 and verify installation in accordance with the procedures specified in Reference Residential Appendix RA3.1.4.3.9. In order for an AHU to qualify as low leakage the AHU manufacturer must certify to the Energy Commission that the AHU complies with ASHRAE Standard 193. Once installed the AHU and distribution system is pressurized and the leakage measured according to the testing methods in RA 3.1.4.3.1. The credit is achieved by specifying the leakage amount in the approved compliance software which would use the inputted amount of duct leakage rather than use the default duct leakage rates that are based on either new or altered ducts.

4.6.2 Prescriptive Requirements

4.6.2.1 Sizing and Equipment Selection

§140.4(a)

The Energy Standards require that mechanical heating and cooling equipment (including electric heaters and boilers) to be the smallest size available, within the available options of the desired equipment line that meets the design heating and cooling loads of the building or spaces being served. Depending on the equipment, oversizing can be either a penalty or benefit to energy usage. For vapor compression equipment, gross oversizing can drastically increase the energy usage and in some cases cause premature failure from short cycling of compressors. Boilers and water-heaters generally suffer lower efficiencies and higher standby losses if they are oversized. On the other hand, cooling towers, cooling coils, and variable speed driven cooling tower fans can actually improve in efficiency if oversized. Oversized distribution ductwork and piping can reduce system pressure losses and reduce fan and pump energy.

When equipment is offered in size increments, such that one size is too small and the next is too large, the larger size may be selected.

Packaged HVAC equipment may serve a space having substantially different heating and cooling loads. The unit size should be selected on the larger of the loads, based on either capacity or airflow. The capacity for the other load should be selected as required to meet the load, or if very small, should be the smallest capacity available in the selected unit. For example, packaged air-conditioning units with gas heat are usually sized on the basis of cooling loads. The furnace is sized on the basis of airflow, and is almost always larger than the design heating load.

Equipment may be oversized provided one or more of the following conditions are met:

1. It can be demonstrated to the satisfaction of the enforcing agency that oversizing will not increase building source energy use; or
2. Oversizing is the result of standby equipment that will operate only when the primary equipment is not operating. Controls must be provided that prevent the standby equipment from operating simultaneously with the primary equipment; or
3. Multiple units of the same equipment type are used, each having a capacity less than the design load, but in combination having a capacity greater than the design load. Controls must be provided to sequence or otherwise optimally control the operation of each unit based on load.

4.6.2.2 Load Calculations

§140.4(b)

For the purposes of sizing HVAC equipment, the designer shall use all of the following criteria for load calculations:

1. The heating and cooling system design loads must be calculated in accordance with the procedures described in the ASHRAE Handbook, Fundamentals Volume, Chapter 30, Table 1. Other load calculation methods, e.g. ACCA, SMACNA, etc., are acceptable provided that the method is ASHRAE-based. When submitting load calculations of this type, the designer must accompany the load calculations with a written affidavit certifying that the method used is ASHRAE-based. If the designer is unclear as to whether or not the calculation method is ASHRAE-based, the vendor or organization providing the calculation method should be contacted to verify that the method is derived from ASHRAE.
2. Indoor design conditions of temperature and relative humidity for general comfort applications are not explicitly defined. Designers are allowed to use any temperature conditions within the “comfort envelope” defined by ANSI/ASHRAE 55-1992 or Chapter 8 of the ASHRAE Handbook, Fundamentals Volume. Winter humidification or summer dehumidification is not required.
3. Outdoor design conditions shall be selected from Reference Joint Appendix JA2, which is based on data from the ASHRAE Climatic Data for Region X, for the following design conditions:
    a. Heating design temperatures shall be no lower than the temperature listed in the Heating Winter Median of Extremes value.
    b. Cooling design temperatures shall be no greater than the 0.5 percent Cooling Dry Bulb and Mean Coincident Wet Bulb values.

   c. Cooling design temperatures for cooling towers shall be no greater than the 0.5 percent cooling design wet bulb values.

4. Outdoor Air Ventilation loads must be calculated using the ventilation rates required in Section 4.3.
5. Envelope heating and cooling loads must be calculated using envelope characteristics including square footage, thermal conductance, solar heat gain coefficient or shading coefficient and air leakage, consistent with the proposed design.
6. Lighting loads shall be based on actual design lighting levels or power densities consistent with Chapter 5.
7. People sensible and latent gains must be based on the expected occupant density of the building and occupant activities as determined under Section 4.3. If ventilation requirements are based on a cfm/person basis, then people loads must be based on the same number of people as ventilation. Sensible and latent gains must be selected for the expected activities as listed in 2005 ASHRAE Handbook, Fundamentals Volume, Chapter 30, Table 1.
8. Loads caused by a process shall be based on actual information (not speculative) on the intended use of the building.
9. Miscellaneous equipment loads include such things as duct losses, process loads and infiltration and shall be calculated using design data compiled from one or more of the following sources:
   a. Actual information based on the intended use of the building; or
   b. Published data from manufacturer’s technical publications or from technical societies, such as the ASHRAE Handbook, HVAC Applications Volume; or
   c. Other data based on the designer’s experience of expected loads and occupancy patterns.
10. Internal heat gains may be ignored for heating load calculations.
11. A safety factor of up to 10 percent may be applied to design loads to account for unexpected loads or changes in space usage.
12. Other loads such as warm-up or cool-down shall be calculated using one of the following methods:
    a. A method using principles based on the heat capacity of the building and its contents, the degree of setback, and desired recovery time; or
    b. The steady state design loads may be increased by no more than 30 percent for heating and 10 percent for cooling. The steady state load may include a safety factor of up to 10 percent as discussed above in Item 11.
13. The combination of safety factor and other loads allows design cooling loads to be increased by up to 21 percent (1.10 safety x 1.10 other), and heating loads by up to 43 percent (1.10 safety x 1.30 other).

Example 4-44

Question

Do the sizing requirements restrict the size of duct work, coils, filter banks, etc. in a built-up system?

Answer

No. The intent of the Energy Standards is to limit the size of equipment, which if oversized will consume more energy on an annual basis. Coils with larger face areas will usually have lower pressure drops than otherwise, and may also allow the chilled water temperature to be higher, both of which may result in a decrease in energy usage. Larger filter banks will also usually save energy. Larger duct work will have lower static pressure losses, which may save energy, depending on the duct's location, length, and degree of insulation.

Oversizing fans, on the other hand, may or may not improve energy performance. An oversized airfoil fan with inlet vanes will not usually save energy, as the part load characteristics of this device are poor. But the same fan with a variable frequency drive may save energy. Controls are also an important part of any system design.

The relationship between various energy consuming components may be complex, and is left to the designer's professional judgment. Note however, that when components are oversized, it must be demonstrated to the satisfaction of the enforcement agency that energy usage will not increase.

4.6.2.3 **Fan Power Consumption**

§140.4(c)

Maximum fan power is regulated in individual fan systems where the total power of the supply (including fan-powered terminal units), return and exhaust fans within the ***fan system*** exceed 25 hp at design conditions (see Section 4.10 for definitions). A system consists of only the components that must function together to deliver air to a given area; fans that can operate independently of each other comprise separate systems. Included are all fans associated with moving air from a given space-conditioning ***system*** to the conditioned spaces and back to the source, or to exhaust it to the outdoors.

The 25 hp total criteria apply to:

1. All supply and return fans within the space-conditioning system that operate at peak load conditions.
2. All exhaust fans at the system level that operate at peak load conditions. Exhaust fans associated with economizers are not counted, provided they do not operate at peak conditions.
3. Fan-powered VAV boxes, if these fans run during the cooling peak. This is always the case for fans in series type boxes. Fans in parallel boxes may be ignored if they are controlled to operate only when zone heating is required, and are normally off during the cooling peak.
4. Elevator equipment room exhausts, or other exhausts that draw air from a conditioned space, through an otherwise unconditioned space, to the outdoors.

The criteria are applied individually to each space-conditioning system. In buildings having multiple space-conditioning systems, the criteria apply only to the systems having fans whose total demand exceeds 25 hp.

Not included are fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building.

For the purposes of the 25 hp criteria, horsepower is the brake horsepower as listed by the manufacturer for the design conditions, plus any losses associated with the drive, including belt losses or variable frequency drive losses. If the brake horsepower is not known, then the nameplate horsepower should be used.

If drive losses are not known, the designer may assume that direct drive efficiencies are 1.0, and belt drives are 0.97. Variable speed drive efficiency should be taken from the manufacturer's literature; if it includes a belt drive, it should be multiplied by 0.97.

Total fan horsepower need not include the additional power demand caused solely by air treatment or filtering systems with final pressure drops of more than 1 inch water gauge (w.g.). It is assumed that conventional systems may have filter pressure drops as high as 1 inch w.g.; therefore only the horsepower associated with the portion of the pressure drop exceeding 1 in., or fan system power caused solely by process loads, may be excluded.

For buildings whose systems exceed the 25 hp criteria, the total space-conditioning system power requirements are:

1. Constant volume fan systems. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 0.8 W/cfm of supply air.
2. Variable air volume (VAV) systems. The total fan power index at design conditions of each fan system with total horsepower over 25 hp shall not exceed 1.25 W/cfm of supply air; and
3. Air-treatment or filtering systems. For systems with air-treatment or filtering systems, calculate the adjusted fan power index using Energy Standards Equation 140.4-A:

Equation 4-8 – (Energy Standards Equation 140.4-A) Adjusted Total Fan Power Index

Adjusted total fan power index = Fan power index X Fan Adjustment

$$\text{Fan Adjustment} = 1 - \left(\frac{SP_a - 1}{SP_f} \right)$$

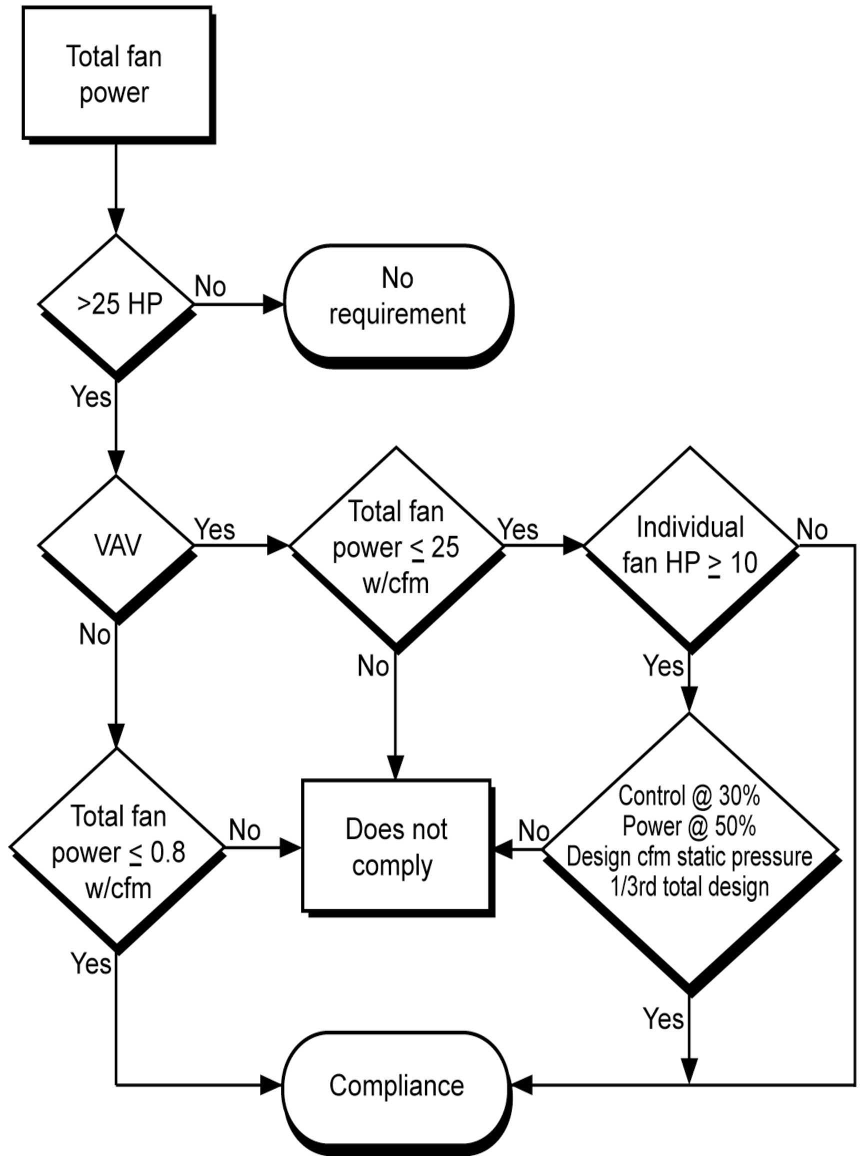
Where:

SP_a = Air pressure drop across the air-treatment or filtering system.

SP_f = Total pressure drop across the fan.

The total system power demand is based on brake horsepower at design static and cfm, and includes drive losses and motor efficiency. If the motor efficiency is not known, values from Reference Nonresidential Appendix NA3 may be used.

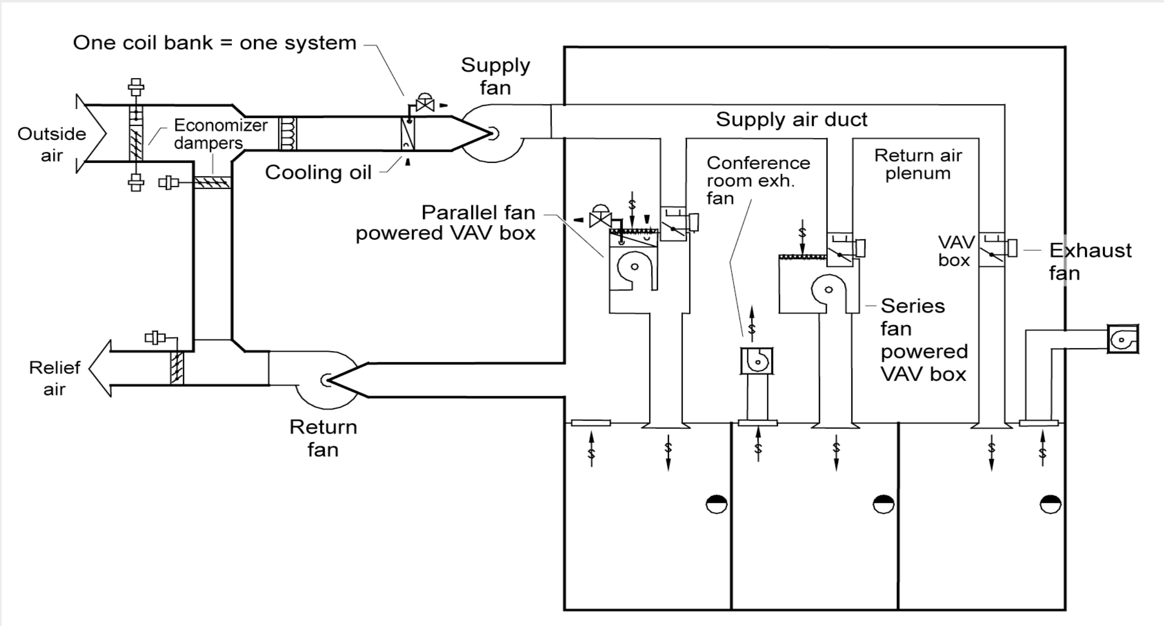
Figure 4-27: Fan Power Flowchart



Example 4-45

Question

In the system depicted below, which fans are included in the fan power criteria?



Answer

The fans included are those that operate during the design cooling load. These include the supply fan, the return fan, the series fan-powered VAV box(es), the general exhaust fan, and conference room exhaust fans other than those that are manually controlled. The parallel fan-powered VAV box(es) are not included as those fans only operate during a call for zone heating.

Example 4-46

Question

If a building has five zones with 15,000 cfm air handlers that are served by a common central plant, and each air handler has a 15 hp supply fan, does the 25 hp limit apply?

Answer

No. Each air handler, while served by a common central plant, is a separate fan system. Since the demand of each air handler is only 15 hp, the 25 hp criteria does not apply.

Example 4-47

Question

The space-conditioning system in a laboratory has a 30 percent filter with a design pressure drop at change out of 0.5 inch w.g., and an 80 percent filter with a design pressure drop of 1.2 inch w.g. The design total static pressure of the fan is 5.0 inch w.g. What percentage of the power may be excluded from the W/cfm calculation?

Answer

The total filter drop at change out (final pressure drop) is 0.5 inch + 1.2 inch = 1.7 inch w.g. The amount that may be excluded is 1.7 inch - 1.0 inch = 0.7 inch w.g. The percentage of the horsepower that may be excluded is 0.7 inch /5.0 inch = 14 percent

If the supply fan requires 45 BHP, the adjusted horsepower of the supply fan in the W/cfm calculation is

45 BHP x (1 – 14 percent) = 38.7 BHP

The horsepower of any associated return or exhaust fan is not adjusted by this factor, as the filters have no impact on these fans.

Example 4-48

Question

What is the maximum allowed power consumption for the fans in a VAV bypass system?

Answer

A VAV bypass, while variable volume at the zone level, is constant volume at the fan level. If the total fan power demand of this system exceeds 25 hp, then the fan power may not exceed 0.8 W/cfm.

Example 4-49

Question

What is the power consumption of a 20,000 cfm VAV system having an 18 bhp supply fan, a 5 bhp return fan, a 3 bhp economizer relief fan, a 2 hp outside air ventilation fan and a 1 hp toilet exhaust fan? Note that the exhaust and outside air ventilation fans are direct drive and listed in hp not bhp. The supply and return fans are controlled with variable frequency drives having an efficiency of 96 percent.

Answer

The economizer fan is excluded provided it does not run at the time of the cooling peak.

Power consumption is then based on the supply; return, outdoor and toilet exhaust fans. The ventilation fan is direct drive so its efficiency is 1. The supply and return fans have default drive efficiencies of 0.97. From Tables NA3-1 and NA3-2 from Reference Nonresidential Appendix NA3, the assumed efficiencies of the motors are 91.7 percent and 87.5 percent for a 25 and 7.5 hp 4-pole motor respectively. Fan power demand in units of horsepower must first be calculated to determine whether the requirements apply:

a. 18 bhp / (0.97 x 0.917 x 0.96) = 21.1 hp

b. 5 bhp / (0.97 x 0.875 x 0.96) = 6.1 hp

Total power consumption, adjusted for efficiencies, is calculated as:

21.1 hp + 6.1 hp + 2 hp + 1 hp = 30.2 hp

Since this is larger than 25 hp, the limitations apply. W/cfm is calculated as:

30.2 hp x 746 W/cfm/20,000 cfm = 1.13 W/cfm

The system complies because power consumption is below 1.25 W/cfm. Note that, while this system has variable frequency drives, they are only required by the Energy Standards for the 18 bhp fan since each other fan is less than 10 hp.

4.6.2.4 **Fractional HVAC Motors for Fans**

§140.4(c)4

HVAC fan motors that are less than1 hp or less and 1/12 hp or greater shall be electronically-commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions. These motors shall also have the means to adjust motor speed for either balancing or remote control. Belt-driven fans may use sheave adjustments for airflow balancing in lieu of a varying motor speed.

This requirement can be met with either electronically commutated motors or brushless DC motors. These motors have higher efficiency than PSC motors and inherently have speed control that can be used for VAV operation or balancing.

This requirement includes fan-powered terminal units, fan-coil units, exhaust fans, transfer fans, and supply fans. There are two exceptions to this requirement:

1. Motors in fan-coil units and terminal units that operate only when providing heating to the space served. This includes parallel style fan-powered VAV boxes and heating only fan-coils.
2. Motors that are part of space conditioning equipment certified under §110.1 or §110.2. This includes supply fans, condenser fans, ventilation fans for boilers and other fans that are part of equipment that is rated as a whole.

4.6.2.5 **Electric-Resistance Heating**

§140.4(g), §141.0

The Energy Standards strongly discourage the use of electric-resistance space heat. Electric-resistance space heat is not allowed in the prescriptive approach except where:

1. Site-recovered or site-solar energy provides at least 60 percent of the annual heating energy requirements; or
2. A heat pump is supplemented by an electric-resistance heating system, and the heating capacity of the heat pump is more than 75 percent of the design heating load at the design outdoor temperature, determined in accordance with the Energy Standards; or
3. The total capacity of all electric-resistance heating systems serving the entire building is less than 10 percent of the total design output capacity of all heating equipment serving the entire building; or
4. The total capacity of all electric-resistance heating systems serving the building, excluding those that supplement a heat pump, is no more than 3 kW; or
5. An electric-resistance heating system serves an entire building that:
    a. Is not a high-rise residential or hotel/motel building.
    b. Has a conditioned floor area no greater than 5,000 ft².
    c. Has no mechanical cooling.
    d. Is in an area where natural gas is not currently available and an extension of a natural gas system is impractical, as determined by the natural gas utility.
6. In alterations where the existing mechanical systems use electric reheat (when adding variable air volume boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application.

7. In an addition where the existing variable air volume system with electric reheat is being expanded the added capacity cannot exceed 50 percent of the existing installed electric reheat capacity under any one permit.

The Energy Standards in effect allow a small amount of electric-resistance heat to be used for local space heating or reheating (provided reheat is in accordance with these regulations).

Example 4-50

Question

If a heat pump is used to condition a building having a design heating load of 100,000 Btu/h at 35°F, what are the sizing requirements for the compressor and heating coils?

Answer

The compressor must be sized to provide at least 75 percent of the heating load at the design heating conditions, or 75,000 Btu/h at 35°F. The Energy Standards do not address the size of the resistance heating coils. Normally, they will be sized based on heating requirements during defrost.

4.6.2.6 Cooling Tower Flow Turndown

§140.4(h)3

The Energy Standards require that open cooling towers with multiple condenser water pumps be designed so that all cells can be run in parallel with the larger of:

1. The flow that is produced by the smallest pump, or
2. 50 percent of the design flow for the cell.

Note that in a large plant at low load operation you would typically run less than all of the cells at once. This is allowed in the Energy Standards.

Cooling towers are very efficient at unloading (the fan energy drops off as the cube of the airflow). It is always more efficient to run the water through as many cells as possible; 2 fans at 1/2 speed use less than 1/3 of the energy of 1 fan at full speed for the same load. Unfortunately there is a limitation with flow on towers, the flow must be sufficient to provide full coverage of the fill. If the nozzles don’t fully wet the fill, air will go through the dry spots providing no cooling benefit and cause the water at the edge of the dry spot to flash evaporate depositing dissolved solids on the fill.

Luckily the cooling tower manufacturers do offer low-flow nozzles (and weirs on basin type towers) to provide better flow turndown. This typically only costs $100 to $150 per tower cell. As it can eliminate the need for a tower isolation control point this provides energy savings at a reduced first cost.

Example 4-51

Question

If a large central plant has five equally sized chillers and five equally sized cooling tower cells do all of the cooling tower cells need to operate when only one chiller is on-line?

Answer

No you would probably only run three cells with one chiller. The cooling tower cells must be designed to run at 33 percent of their nominal design flow. With two to five chillers running you would run all of the cells of cooling tower. With only one chiller running you would run three cells. In each case you would need to keep the tower flow above the minimum that it was designed for.

4.6.2.7 **Centrifugal Fan Limitation**

§140.4(h)4

Open cooling towers with a combined rated capacity of 900 gpm and greater at 95°F condenser water return, 85°F condenser water supply and 75°F outdoor wet-bulb temperature are prohibited to use centrifugal fans. The 95°F condenser water return, 85°F condenser water supply and 75°F outdoor wet-bulb temperature are test conditions for determining the rated flow capacity in gpm. Centrifugal fans use approximately twice the energy as propeller fans for the same duty. There are a couple of exceptions to this requirement.

1. Cooling towers that are ducted (inlet or discharge) or have an external sound trap that requires external static pressure capability.
2. Cooling towers that meet the energy efficiency requirement for propeller fan towers in Table 4-7.

Centrifugal fans may be used on closed circuit fluid coolers.

As with all prescriptive requirements centrifugal fan cooling towers may be used when complying with the performance method. The budget building will be modeled using propeller towers.

4.6.2.8 **Chiller Efficiency**

§140.4(i)

In Table 4-4, there are two sets of efficiency for almost every size and type of chiller. Path A representing fixed speed compressors and Path B representing variable speed compressors. For each path there are two efficiency requirements: a full load efficiency and an integrated part-load efficiency. Path A typically has a higher full load efficiency and a lower part-load efficiency than Path B. In all of the California climates the cooling load varies enough to justify the added cost for a Path B chiller. This is a prescriptive requirement so Path B is used in the base case model in the Performance method.

There are a number of exceptions provided to this requirement:

1. Chillers with an electrical service of > 600V. This is due to the fact that the cost of VSDs is much higher on medium voltage service.
2. Chillers attached to a heat recovery system with a design heat recovery capacity >40 percent of the chiller's design cooling capacity. Heat recovery typically requires operation at higher lifts and compressor speeds.
3. Chillers used to charge thermal energy storage (TES) systems with a charging temperature of <40°F. This again requires a high lift operation for chillers
4. In a building with more than 3 chillers only 3 are required to meet the Path B efficiencies.

4.6.2.9 **Limitation on Air Cooled Chillers**

§140.4(j) and §141.0

New central cooling plants and cooling plant expansions will be limited on the use of air-cooled chillers. For both the limit is 300 tons per plant.

In the studies provided to support this requirement, air cooled chillers always provided a higher life-cycle cost than water cooled chillers even accounting for the water and chemical treatment costs.

There are a few exceptions to this requirement:

1. Where the water quality at the building site fails to meet manufacturer's specifications for the use of water-cooled chillers.

   This exception recognizes that some parts of the state have exceptionally high quantities of dissolved solids that could foul systems or cause excessive chemical treatment or blow down.

2. Chillers that are used to charge a thermal energy storage (TES) system with a design temperature of less than 40°F.

   This addresses the fact that air-cooled chillers can operate very efficiently at low ambient air temperatures. Since TES systems operate for long hours at night, these systems may be as efficient as a water-cooled plant. Note that the chiller must be provided with head pressure controls to achieve these savings.

3. Air cooled chillers with minimum efficiencies approved by the Energy Commission pursuant to §10-109(d).

   This exception was provided in the event that an exceptionally high efficiency air cooled chiller was developed. None of the high-efficiency air-cooled chillers currently evaluated are as efficient as a water-cooled systems using the lowest chiller efficiency allowed by §110.2.

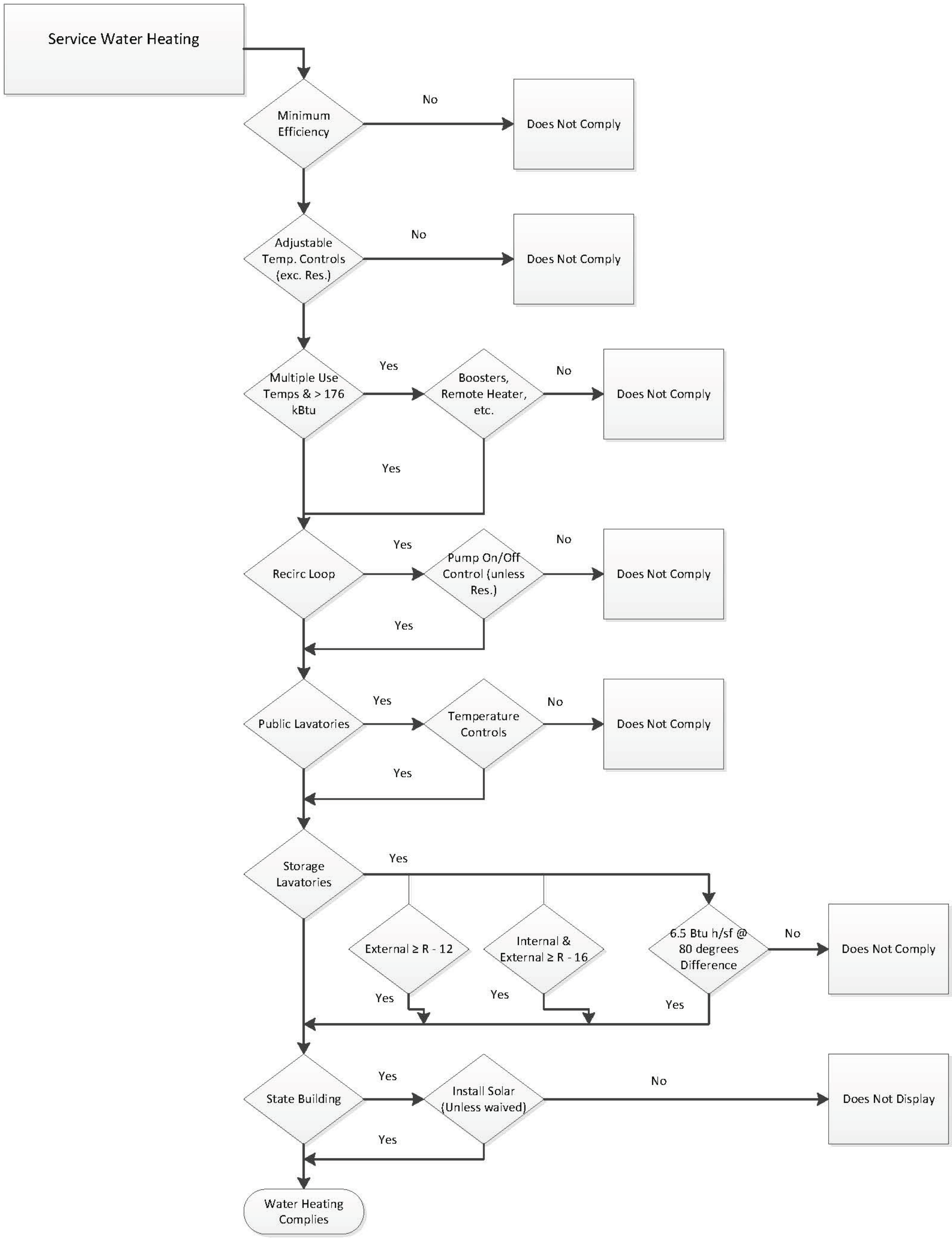
4.7 Water Heating Requirements

§140.5

All of the requirements for service hot water that apply to nonresidential occupancies are mandatory measures. There are additional requirements for high-rise residential, hotels and motels which must also comply with the Residential Energy Standards §150.1(c)8 which are described below, as well as in the Residential Compliance Manual.

There are no acceptance requirements for water heating systems or equipment, however, high-rise residential, hotels and motel water heating systems must meet the distribution system eligibility criteria for that portion of the system that is applicable.

Figure 4-28: Service Water Heating Flowchart



4.7.1 Service Water Systems Mandatory Requirements

4.7.1.1 Efficiency and Control

§110.3(a)

Any service water heating equipment must have integral automatic temperature controls that allow the temperature to be adjusted from the lowest to the highest allowed temperature settings for the intended use as listed in Table 3, Chapter 50 of the ASHRAE Handbook, HVAC Applications Volume.

Service water heaters installed in residential occupancies need not meet the temperature control requirement of §110.3(a)1.

4.7.1.2 Multiple Temperature Usage

§110.3(c)1

On systems that have a total capacity greater than 167,000 Btu/h, outlets requiring higher than service water temperatures as listed in the ASHRAE Handbook, HVAC Applications Volume shall have separate remote heaters, heat exchangers, or boosters to supply the outlet with the higher temperature. This requires the primary water heating system to supply water at the lowest temperature required by any of the demands served for service water heating. All other demands requiring higher temperatures should be served by separate systems, or by boosters that raise the temperature of the primary supply.

4.7.1.3 Controls for Hot Water Distribution Systems

§110.3(c)2

Service hot water systems with a circulating pump or with electrical heat trace shall include a control capable of automatically turning off the system when hot water is not required. Such controls include automatic time switches, interlocks with HVAC time switches, occupancy sensors, and other controls that accomplish the intended purpose.

4.7.1.4 Public Lavatories

§110.3(c)3

Lavatories in public restrooms must have controls that limit the water supply temperature at the fixtures to 110°F. Where service water heater supplies only restrooms, the heater thermostat may be set to no greater than 110°F to satisfy this requirement; otherwise controls such as automatic mixing valves must be installed.

4.7.1.5 Storage Tank Insulation

§110.3(c)4

Unfired water heater storage tanks and backup tanks for solar water heating systems must have one of the following:

1. External insulation with an installed R-value of at least R-12.
2. Internal and external insulation with a combined R-value of at least R-16.
3. The heat loss of the tank based on an 80 degree F water-air temperature difference shall be less than 6.5 Btu per hour per ft². This corresponds to an effective resistance of R-12.3.

4.7.1.6 **Service Water Heaters in State Buildings**

§110.3(c)6

High-rise residential buildings constructed by the State of California shall have solar water heating systems. The solar system shall be sized and designed to provide at least 60 percent of the energy needed for service water heating from site solar energy or recovered energy. There is an exception when buildings for which the state architect determines that service water heating is economically or physical infeasible. See the Compliance Options section below for more information about solar water heating systems.

4.7.1.7 **Pipe Insulation Thickness**

§120.3

There are updated pipe insulation thickness requirements applicable to nonresidential water heating pipes. For pipes with conductivity ranges within those specified in Table 4-17, the nominal pipe diameters grouping ranges are changed, as well as the thickness of insulation required for each pipe diameter range. The table is repeated below for ease of reference:

Table 4-22: Pipe Insulation

FLUID TEMPERATURE RANGE (°F)	CONDUCTIVITY RANGE (in Btu-inch per hour per square foot per °F)	INSULATION MEAN RATING TEMPERATURE (°F)	NOMINAL PIPE DIAMETER (in inches)						
			1 and less		1 to <1.5		1.5 to < 4	4 to < 8	8 and larger
			INSULATION THICKNESS REQUIRED (in inches)						
Space heating, Hot Water systems (steam, steam condensate and hot water) and Service Water Heating Systems (recirculating sections, all piping in electric trace tape systems, and the first 8 feet of piping from the storage tank for nonrecirculating systems)									
Above 350	0.32-0.34	250	4.5		5.0		5.0	5.0	5.0
251-350	0.29-0.31	200	3.0		4.0		4.5	4.5	4.5
201-250	0.27-0.30	150	2.5		2.5		2.5	3.0	3.0
141-200	0.25-0.29	125	1.5		1.5		2.0	2.0	2.0
105-140	0.22-0.28	100	1.0		1.5		1.5	1.5	1.5
Space cooling systems (chilled water, refrigerant and brine)									
			Nonres	Res	Nonres	Res			
40-60	0.21-0.27	75	0.5	0.75	0.5	0.75	1.0	1.0	1.0
Below 40	0.20-0.26	50	1.0		1.5		1.5	1.5	1.5

Energy Standards Table 120.3-A

4.7.1.8 **Systems with Recirculation Loops**

§110.3(c)5

Service water systems that have central recirculation distribution must include all of the following mandatory features. The intent of these measures is to optimize performance and allow for lower cost of maintenance. These requirements are applicable to nonresidential occupancies as well as high-rise residential and hotel/motel systems.

A. Air Release Valves

§110.3(c)5A

The constant supply of new water and leaks in system piping or components during normal operation of the pump may introduce air into the circulating water. Entrained air in the water can result in a loss of pump head pressure and pumping capacity, which adversely impacts the pumps' efficiency and life expectancy. Entrained air may also contribute to increased cavitation.

Cavitation is the formation of vapor bubbles in liquid on the low pressure (suction) side of the pump. The vapor bubbles generally condense back to the liquid state after they pass into the higher pressure side of the pump. Cavitation can contribute to a loss of head pressure and pumping capacity; may produce noise and vibration in the pump; may result in pump impeller corrosion; all of which impacts the pumps' efficiency and life expectancy.

Entrained air and cavitation should be minimized by the installation of an air release valve. The air release valve must be located no more than 4 ft from the inlet of the pump, and must be mounted on a vertical riser with a length of at least 12 inches. Alternatively, the pump shall be mounted on a vertical section of the return piping.

B. Recirculation Loop Backflow Prevention

§110.3(c)5B

Temperature and pressure differences in the water throughout a recirculation system can create potentials for backflows. This can result in cooler water from the bottom of the water heater tank and water near the end of the recirculation loop flowing backwards towards the hot water load and reducing the delivered water temperature.

To prevent this from occurring, the Energy Standards require that a check valve or similar device be located between the recirculation pump and the water heating equipment.

C. Equipment for Pump Priming/Pump Isolation Valves

§110.3(c)5C&D

A large number of systems are allowed to operate until complete failure simply because of the difficulty of repair or servicing. Repair labor costs can be reduced significantly by planning ahead and designing for easy pump replacement when the pump fails. Provision for pump priming and pump isolation valves help reduces maintenance costs.

To meet the pump priming equipment requirement, a hose bib must be installed between the pump and the water heater. In addition, an isolation valve shall be installed between the hose bib and the water heating equipment. This configuration will allow the flow from the water heater to be shut off, allowing the hose bib to be used for bleeding air out of the pump after pump replacement.

The requirement for the pump isolation valves will allow replacement of the pump without draining a large portion of the system. The isolation valves shall be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as in item C.

D. Connection of Recirculation Lines

§110.3(c)5E

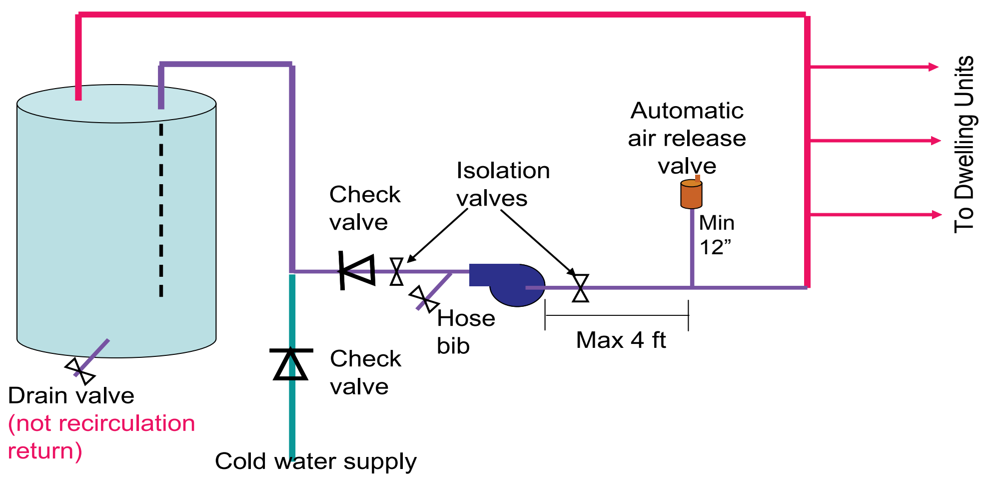
Manufacturer's specifications should always be followed to assure optimal performance of the system. The cold water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

E. Backflow Prevention in Cold Water Supply

§110.3(c)5F

The dynamic between the water in the heater and the cold water supply are similar to those in the recirculation loop. Thermosyphoning can occur on this side of this loop just as it does on the recirculation side of the system. To prevent this, the Energy Standards require a check valve to be installed on the cold water supply line. The valve should be located between the hot water system and the next closest tee on the cold water supply line. Note that the system shall comply with the expansion tank requirements as described in the California Plumbing Code Section 608.3.

Figure 4-29: Backflow Prevention



4.7.2 Mandatory Requirements Applicable to High-Rise Residential and Hotel/Motel

In addition to the mandatory requirements listed above, there are mandatory requirements that will apply to water heating systems for hotels, motels and high-rise residential buildings only. All of these requirements are tied to the mandatory requirements in §150.1(c)8 for residential occupancies. Depending on whether the water heating system has a central system or uses individual water heaters will change whether the mandatory features that are listed above apply.

4.7.2.1 **Storage Tank Insulation Requirements**

§150.0(j)1

For unfired supplemental tanks R-12 must be installed if the internal insulation of the unfired tank is less than R-16.

4.7.2.2 **Water piping insulation thickness and conductivity**

§150.0(j)2

All domestic hot water system piping conditions listed below, whether buried or not-buried, must be insulated. The insulation thickness and conductivity shall be determined from the fluid temperature range and nominal pipe diameter as required by Table 4-22.

- The first five feet of pipe of hot and cold water from the storage tank must be insulated. In the case of a building with a central distribution system this requirement means that the cold supply line to the central water heater would have to be insulated. For building with central recirculation systems the hot water supply to each unit must be insulated to meet this requirement and the kitchen piping insulation requirement.
- Any pipe in the distribution system that is ¾ inch or larger must be insulated. This includes pipe in the central distribution system and in the distribution system serving the individual units.
- Any piping that is associated with a recirculation loop must be insulated. If the domestic hot water heater system serving the dwelling unit uses any type of recirculation insulation of the entire length of the distribution loop would be required. Insulation would also be required in the case of a dwelling unit with a combined hydronic system that uses any portion of the domestic hot water loop to circulate water for heating. Insulation would not be required on the branches or twig serving the point of use.
- All piping from the heating source to a storage tank or between storage tanks must be insulated.
- All hot water piping from the water heater or source of hot water for each dwelling unit to the kitchen must be insulated.
- All piping buried below grade must be insulated. In addition, all piping below grade must be installed in a waterproof and non-crushable casing or sleeve. The internal cross-section or diameter of the casing or sleeve shall be large enough to allow for insulation of the hot water piping. Pre-insulated pipe with integrated protection sleeve will also meet this requirement.

There are exceptions to the requirements for pipe insulation, as described below:

- In attics and crawlspaces, pipes completely covered with at least 4 inches of insulation are not required to have pipe insulation. Any section of pipe not covered with at least 4 inches of insulation must be insulated.
- In walls, all of the requirements must be met for compliance with Quality Insulatio Installation (QII) as specified in the Reference Residential Appendix RA3.5. Otherwise the section of pipe not meeting the QII specifications must be insulated.
- The last segment of piping that penetrates walls and delivers hot water to the sink or appliance does not require insulation.
- Piping that penetrates framing members shall not be required to have pipe insulation for the distance of the framing penetration. Piping that penetrates metal framing shall use grommets, plugs, wrapping or other insulating material to assure that no contact is made with the metal framing. Insulation shall butt securely against all framing members.

4.7.3 Prescriptive Requirements Applicable to High-Rise Residential and Hotel/Motel

For water heating recirculation systems for high-rise residential and hotel/motel buildings, the code actually references back to the Residential Prescriptive requirements. The following paragraphs recap these requirements.

4.7.3.1 Solar Water Heating

§150.1(c)8Biii

Solar water heating is prescriptively required for water heating systems serving multiple dwelling units, whether it is a motel/hotel or high-rise multifamily building. The minimum solar savings fraction (SSF) is dependent on the climate zone: 0.20 for CZ 1 through 9, and 0.35 for CZ 10 through 16. The Energy Standards do not limit the solar water heating equipment or system type, as long as they are SRCC certified and meet the orientation, tilt and shading requirement specified in RA 4.4. Installation of a solar water heating system exempts multifamily buildings from needing to set aside solar zone for future solar PV installation (§110.10(b)1B). The following paragraphs offer some high-level design considerations for multifamily building solar water heating systems.

A high-priority factor for solar water heating system design is component sizing. Proper sizing of the solar collectors and solar tank ensures that the system take full advantage of the sun's energy while avoiding the problem of overheating. While the issue of freeze protection has been widely explored (development of various solar water heating system types is a reflection of this evolution), the issue of overheating is often not considered as seriously as it should be. This is especially critical for multifamily-sized systems, due to load variability.

To be conservative, the highest SSF requirement called for by the 2016 Energy Standards is 35%. Industry standard sizing for an active system is generally 1.5 ft^2 collector area per gallon capacity for solar tank. For more detailed guidance and best practices, there are many publicly available industry design guidelines. Two such resources developed by/in association with government agencies are Building America Best Practices Series: Solar Thermal and Photovoltaic Systems[2] , and California Solar Initiative – Thermal: Program Handbook[3].Because of the new solar water heating requirement and prevalence of recirculation hot water systems in multifamily buildings, it is essential to re-iterate the importance of proper integration between the hot water recirculation system and the solar water heating system. Industry stakeholders recommend the recirculation hot water return to be connected back to the system *downstream* of the solar storage tank. This eliminates the unnecessary wasted energy used to heat up water routed back from the recirculation loop that may have been sitting in the solar water tank if no draw has occurred over a prolonged period of time.

Another design consideration is the layout and placement of collectors and solar tank. The design should minimize the length of plumbing, thus reduce pipe surface areas susceptible to heat loss and reduce the quantity of piping materials needed for the installation. The distance between collectors and solar tank should also be as short as practically possible.

[2] http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf

[3] [3] http://www.gosolarcalifornia.ca.gov/documents/CSI-Thermal_Handbook.pdf

4.7.3.2 Dual Recirculation Loop Design

150.1(c)8Bii

A dual-loop design is illustrated in Figure 4-30. In a dual-loop design, each loop serves half of the dwelling units. According to plumbing code requirements, the pipe diameters can be downsized compared to a loop serving all dwelling units. The total pipe surface area is effectively reduced, even though total pipe length is about the same as that of a single-loop design. For appropriate pipe sizing guidelines, please refer to the Universal Plumbing Code.

Figure 4-30: Example of a Dual-Loop Recirculation System

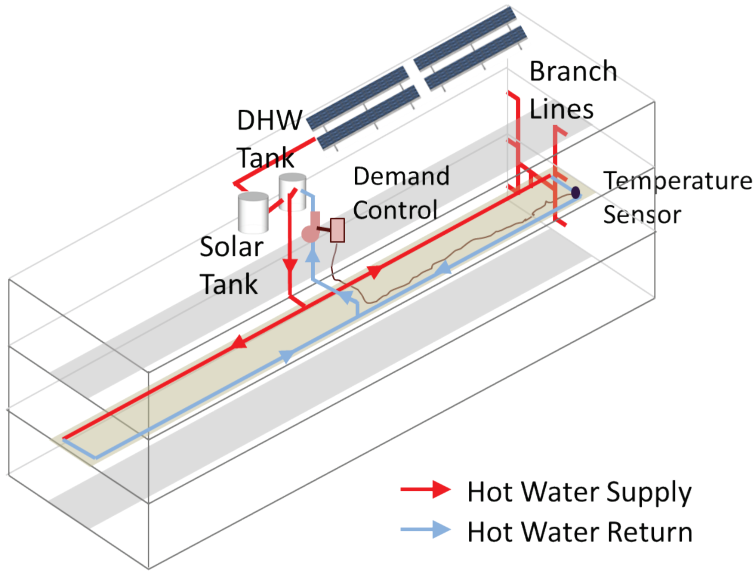
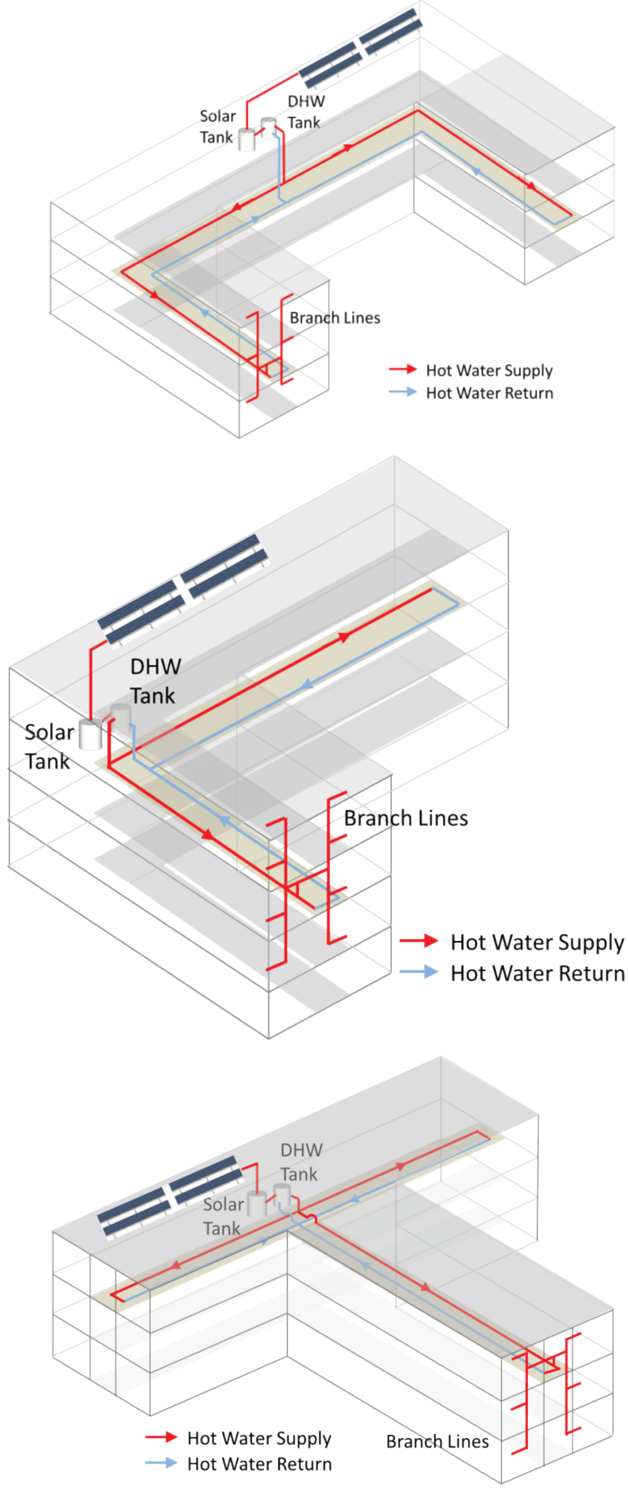


Figure 4-30 provides an example of how to implement dual-loop design in a low-rise multi-family building with a simple layout. In this example, the water heating equipment is located in the middle of top floor with each recirculation loop serving exactly half of the building. The recirculation loops are located in the middle floor to minimize branch pipe length to each of the dwelling units. The Figure 4-30 also illustrates how the solar water heating system and demand control are integrated.

For buildings with complicated layouts, an optimum design for recirculation loops depends on the building geometry. In general, the system should be designed to have each loop serving the equal number of dwelling units in order to minimize pipe sizes. For systems serving buildings with distinct sections, e.g. two wings in an “L” shaped building, it is better to dedicate a separate recirculation loop to each of the sections. Very large buildings and buildings with more than two sections should consider using separate central water heating systems for each section or part of the building. In all cases, a simplified routing of recirculation loops should be used to keep recirculation pipes as short as possible. Figure 4-31 shows examples of dual-loop recirculation system designs in buildings that have complicated floor planes.

Figure 4-31: Examples of dual-loop recirculation system designs in buildings that have complicated floor plans



Location of water heating equipment in the building should be carefully considered to properly implement the dual-loop design. The goal is to keep overall pipe length as short as possible, as an example, for buildings that do not have complicated floor plans; the designer should consider locating the water heating equipment at the center of the building footprint rather than at one end of the building which helps to minimize the pipe length needed. If a water heating system serves several distinct building sections, the water heating equipment would preferably nest in between these sections.

With the prescriptive solar water heating requirement in the 2016 Energy Standards it is especially important to consider the integration between the hot water recirculation system and the solar water heating system. Based on feedback from industry stakeholders, most solar water heating systems are only configured to operate as a pre-heater for the primary gas water heating equipment. In other words, recirculation hot water returns are usually plumbed back to the gas water heating storage tanks, not directly into the solar tank. This means recirculation loop designs should be mostly based on the building floor plan and are relatively independent of the solar water heating system. Consider that the system's gas water heating equipment and solar tank should be located close together to avoid heat loss from the piping that connects the two systems. The preferred configuration is to place both the gas water heating equipment and solar tank on the top floor near the solar collector so that the total system pipe length can be reduced. Minimizing pipe length helps to reduce DHW system energy use as well as system plumbing cost.

4.7.3.3 **Demand Recirculation Control**

The prescriptive requirement for DHW systems serving multiple dwelling units requires the installation of a demand recirculation control to minimize pump operation. Note that demand circulation control is different than the demand control used in single dwelling units. Demand controls for central recirculation systems are based on hot water demand and recirculation return temperatures. The temperature sensor should be installed at the last branch pipe along the recirculation loop.

Any system that does not meet the prescriptive requirements must instead meet the *Standard Design Building* energy budget or otherwise follow the performance compliance approach.

4.7.4 Pool and Spa Heating Systems

§110.4

Pool and spa heating systems must be certified by the manufacturer and listed by the Energy Commission as having:

1. An efficiency that complies with the Appliance Efficiency Regulations; and
2. An on-off switch mounted on the outside of the heater in a readily accessible location that allows the heater to be shut-off without adjusting the thermostat setting; and
3. A permanent, easily readable, and weatherproof plate or card that gives instructions for the energy efficient operation of the pool or spa, and for the proper care of the pool or spa water when a cover is used; and
4. No electric resistance heating. The only exceptions are:
    a. Listed packaged units with fully insulated enclosures and tight fitting covers that are insulated to at least R-6. Listed package units are defined in the National Electric Code and are typically sold as self-contained, UL Listed spas; or
    b. Pools or spas deriving at least 60 percent of the annual heating energy from site solar energy or recovered energy.

If a pool or spa does not currently use solar heating collectors for heating of the water, piping must be installed to accommodate any future installation. Contractors can choose 3 options to allow for the future addition of solar heating equipment:

1. Leave at least 36 inches of pipe between the filter and heater to allow for the future addition of solar heating equipment.
2. Plumb separate suction and return lines to the pool dedicated to future solar heating.
3. Install built-up or built-in connections for future piping to solar water heating. An example of a built-in connection could be a capped off tee fitting between the filter and heater.

Pool and spa heating systems with gas or electric heaters for outdoor use must use a pool cover. The pool cover must be fitted and installed during the final inspection.

All pool systems must be installed with the following:

1. Directional inlets must be provided for all pools that adequately mix the pool water.
2. A time switch or similar control mechanism shall be provided for pools to control the operation of the circulation control system, to allow the pump to be set or programmed to run in the off-peak demand period, and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

§110.5

Pool and spa heaters are not allowed to have pilot lights.

4.8 Performance Approach

Under the performance approach, the energy use of the building is modeled using a compliance software program approved by the California Energy Commission. This section presents some basic details on the modeling of building mechanical systems. Program users and those checking for enforcement should consult the most current version of the user's manuals and associated compliance supplements for specific instructions on the operation of the program. All compliance software programs, however, are required to have the same basic modeling capabilities.

More information on how to model the mechanical systems and components are included in Chapter 9, Performance Approach, and in the program vendor's compliance supplement.

The compliance rules used by the computer methods in generating the energy budget and compliance credits are detailed in the Nonresidential Alternative Calculation Methods (ACM) Approval Manual and are based on features required for prescriptive compliance.

There are minimum modeling capabilities required for programs that are used for the performance approach. All certified programs are tested for conformance with the requirements of the Nonresidential ACM. The designer has to use an approved program to show compliance.

Compliance is shown by running two models: a base case budget building that nominally just meets the mandatory and prescriptive requirements and a proposed building that represents the actual building's proposed envelope, lighting and mechanical systems. To create a level playing field the basecase and proposed designs are compared using the same assumptions of occupancy, proscribed climatic conditions and operating schedules. The results are compared using standardized time of use rates, or Time Dependent Valuations (TDV) of energy cost.

The proposed building complies if its annual TDV is less than or equal to that of the budget building. Reference Appendix JA3 describes the derivation of the TDV energy multipliers.

It is important to note that compliance in the Performance Approach is across all building systems. The design team can use more glass than with the prescriptive approach and comply by making a more efficient HVAC system. Energy can be traded off between prescriptive requirements in Envelope, HVAC, Indoor Lighting and Covered Processes.

The ACM defines the modeling rules for developing the base-case model of the building and mechanical systems. The base-case HVAC system(s) are based on the proposed HVAC system(s) according to the following specific characteristics:

- Occupancy type.
- Floor area of building.
- Number of floors, and zoning.

The following are some examples of how to get credit in the Performance Approach from HVAC systems:

- Use of high efficiency equipment that exceeds the minimum requirements of §110.1 and §110.2.
- Application of economizers where they are not required.
- Oversizing ducts and pipes to reduce fan and pump energy.
- Use of heat recovery for space or water heating.
- Use of thermal energy storage systems or building mass to move cooling off peak.
- Reduce reheating and recooling.
- Use of thermally driven cooling equipment, such as absorption chillers.

4.9 Additions and Alterations

4.9.1 Overview

This section addresses how the Energy Standards apply to mechanical systems for additions and alterations to existing buildings.

Application of the Energy Standards to existing buildings is often more difficult than for new buildings because of the wide variety of conditions that can be experienced in the field. In understanding the requirements, two general principles apply:

1. Existing systems or equipment are not required to meet the Energy Standards.
2. New systems and equipment are required to meet both the mandatory measures and the prescriptive requirements or the performance requirements as modeled in conjunction with the envelope and lighting design.

When heating, cooling or service water heating are provided for an alteration or addition by expanding an existing system, in general, that existing system need not comply with the mandatory measures or prescriptive requirements. However, any altered component must meet all applicable mandatory measures and prescriptive.

4.9.1.1 **Relocation of Equipment**

When existing heating, cooling, or service water heating systems or components are moved within a building, the existing systems or components need not comply with mandatory measures nor with the prescriptive or performance compliance requirements.

Performance approach may also be used to demonstrate compliance for alterations. Refer to Chapter 11, Performance Approach, for more details.

4.9.2 Mandatory Measures – Additions and Alterations

New mechanical equipment or systems in additions and/or alterations must comply with the mandatory measures as listed below. Additional information on these requirements is provided in earlier sections of this Chapter.

Table 4-23: Requirements for Additions and Alterations

Mandatory Measure	Application to Additions and Alterations
§110.1 – Mandatory Requirements for Appliances (see Section 4.2)	The California Appliance Efficiency Regulations apply to small to medium sized heating equipment, cooling equipment and water heaters. These requirements are enforced for all equipment sold in California and therefore apply to all equipment used in additions or alterations.
§110.2 – Mandatory Requirements for Space-Conditioning Equipment (see Section 4.2)	This section sets minimum efficiency requirements for equipment not covered by §110.1. Any equipment used in additions or alterations must meet these efficiency requirements.
§110.3 – Mandatory Requirements for Service Water-Heating Systems and Equipment (see Section 4.2)	This section sets minimum efficiency and control requirements for water heating equipment. It also sets requirements for recirculating hot water distribution systems. All new equipment installed in additions and/or alterations shall meet the requirements. The recirculation loop requirements of §110.3(c)5 apply when water heating equipment and/or plumbing is changed.
§110.4 – Mandatory Requirements for Pool and Spa Heating Systems and Equipment (see Sections 4.2 and 4.7).	The pool requirements of §110.4 do not apply for maintenance or repairs of existing pool heating or filtration systems.
§110.5 – Natural Gas Central Furnaces, Cooking Equipment, and Pool and Spa Heaters: Pilot Lights Prohibited (see Section 4.2)	Any new gas appliances installed in additions or alterations shall not have a standing pilot light, unless one of the exceptions in §110.5 is satisfied.
§120.1 – Requirements for Ventilation (see Section 4.3)	Systems that are altered or new systems serving an addition shall meet the outside air ventilation and control requirements, as applicable. When existing systems are extending to serve additions or when occupancy changes in an existing building (such as the conversion of office space to a large conference room), the outside air settings at the existing air handler may need to be modified and in some cases, new controls may be necessary.

§120.2 – Required Controls for Space-Conditioning Systems (see Section 4.5)	§120.2(a) requires a thermostat for any new zones in additions or new zones created in an alteration. §120.2(b) requires that new thermostats required by §120.2(a) meet the minimum requirements. §120.2(c) applies to hotel/motel guest rooms only when the system level controls are replaced; replacement of individual thermostats are considered a repair. However, §120.2(c) applies to all new thermostats in high rise residential, including replacements. §120.2(d) requires that new heat pumps used in either alterations or additions have controls to limit the use of electric resistance heat, per §110.2(b). This applies to any new heat pump installed in conjunction with an addition and/or alteration. §120.2(e) requires that new systems in alterations and additions have scheduling and setback controls. §120.2(f) requires that outside air dampers automatically close when the fan is not operating or during unoccupied periods, and remain closed during setback heating and cooling. This applies when a new system or air handling unit is replaced in conjunction with an addition or alteration. §120.2(g) requires that areas served by large systems be divided into isolation areas so that heating, cooling and/or the supply of air can be provided to just the isolation areas that need it and other isolation areas can be shut off. This applies to additions larger than 25,000 ft^2 and to the replacement of existing systems when the total area served is greater than 25,000 ft^2. §120.2(h) requires that direct digital controls (DDC) that operate at the zone level be programmed to enable non-critical loads to be shed during electricity emergencies. This requirement applies to additions and/or alterations anytime DDC are installed that operate at the zone level. §120.2(i) requires a Fault Detection and Diagnostic System (FDD) for all new air-cooled packaged direct expansion units used in either additions or alterations equipped with an economizer and mechanical cooling capacity equal to or greater than 54,000 Btu/hr in accordance with §120.2(i)2. through §120.2(i)8. §120.2(j) requires direct digital controls (DDC) in new construction, additions or alterations for certain applications and qualifications. It also requires certain capabilitis for mandated DDC systems. §120.2(k) requires that optimum start/stop when DDC is to the zone level.
§120.3 – Requirements for Pipe Insulation (see Section 4.4)	The pipe insulation requirements apply to any new piping installed in additions or alterations.
§120.4 – Requirements for Air Distribution System Ducts and Plenums (see Section 4.4)	The duct insulation, construction and sealing requirements apply to any new ductwork installed in additions or alterations.
§120.5 – Required Nonresidential Mechanical System Acceptance (See Chapter 13)	Acceptance requirements are triggered for systems or equipment installed in additions and alterations they same way they are for new buildings or systems.

4.9.3 Requirements for Additions

4.9.3.1 **Prescriptive Approach**

All new additions must comply with the following prescriptive requirements:

- §140.4 – Prescriptive Requirements for Space Conditioning Systems
- §140.5 – Prescriptive Requirements for Service Water-Heating Systems

For more detailed information about the prescriptive requirements, refer to following sections of this chapter:

- Section 4.5.2 - HVAC Controls
- Section 4.6.2 - HVAC System Requirements

4.9.3.2 **Performance Approach**

The performance approach may also be used to demonstrate compliance for new additions. When using the performance approach for additions §141.0(a)2B defines the characteristics of the standard design building.

Refer to Chapter 11, Performance Approach, for more details.

4.9.3.3 **Acceptance Tests**

Acceptance tests must be conducted on the new equipment or systems when installed in new additions. For more detailed information, see Chapter 13.

4.9.4 Requirements for Alterations

4.9.4.1 **Prescriptive Requirements – New or Replacement Equipment**

New space conditioning systems or components other than space conditioning ducts must meet applicable prescriptive requirements of Sections 4.5.2 and 4.6.2 (§140.4).

Minor equipment maintenance such as replacement of filters or belts does not trigger the prescriptive requirements. Equipment replacement such as the installation of a new air handler or cooling tower would be subject to the prescriptive requirements. Another example is if an existing VAV system is expanded to serve additional zones, the new VAV boxes are subject to zone controls of Section 4.5. Details on prescriptive requirements may be found in other sections of this chapter.

Replacements of electric resistance space heaters for high rise residential apartments are also exempt from the prescriptive requirements. Replacements of electric heat or electric resistance space heaters are allowed where natural gas is not available.

For alterations there are special rules for:

1. New or Replacement Space Conditioning Systems or Components in §141.0(b)2C.
2. Altered Duct Sytems in §141.0(b)2D.
3. Altered Space –Conditioning Systems in §141.0(b)2E.
4. Service water heating has to meet all of §140.5 with the exception of the solar water heating requirements in §141.0(b)2L.

4.9.4.2 **Prescriptive Requirements – Air Distribution Ducts**

§141.0(b)2D

When new or replacement space-conditioning ducts are installed to serve an existing building, the new ducts shall meet the requirements of Section 4.4 (insulation levels, sealing materials and methods, etc.).

If the ducts are part of a single zone constant volume system serving less than 5,000 ft² and more than 25 percent of the ducts are outdoors or in unconditioned area including attic spaces and above insulated ceilings, then the duct system shall be sealed and tested for air leakage by the contractor. In most nonresidential buildings this requirement will not apply because the roof is insulated so that almost all of the duct length is running through directly or indirectly conditioned space.

If the ducts are in unconditioned space and have to be sealed, they must also be tested to leak no greater than 6 percent if the entire duct system is new or less than 15 percent if the duct system is added to a pre-existing duct system. The description of the test method can be found in Section 2.1.4.2 of Reference Nonresidential Appendix NA2. The air distribution acceptance test associated with this can be found in Reference Nonresidential Appendix NA7. This and all acceptance tests are described in Chapter 13 of this manual.

If the new ducts form an entirely new duct system directly connected to an existing or new air handler, the measured duct leakage shall be less than 6 percent of fan flow; or

If the new ducts are an extension of an existing duct system, the combined new and existing duct system shall meet one of the following requirements:

1. The measured duct leakage shall be less than 15 percent of fan flow; or
2. If it is not possible to meet the duct sealing requirements of §141.0(b)2Dii, all accessible leaks shall be sealed and verified through a visual inspection and smoke test performed by a certified HERS Rater utilizing the methods specified in Reference Nonresidential Appendix NA 2.1.4.2.2.

Exception: Existing duct systems that are extended, which are constructed, insulated or sealed with asbestos.

Once the ducts have been sealed and tested to leak less than the above amounts, a HERS rater will be contacted by the contractor to validate the accuracy of the duct sealing measurement on a sample of the systems repaired as described in Reference Nonresidential Appendix NA1.

4.9.4.3 **Prescriptive Requirements – Space-Conditioning Systems Alterations**

§141.0(b)2E

Similar requirements apply to ducts upon replacement of small (serving less than 5,000 ft²) constant volume HVAC units or their components (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil). Again the duct sealing requirements are for those systems where over 25 percent of the duct area is outdoors or in unconditioned areas including attic spaces and above insulated ceilings.

One can avoid sealing the ducts by insulating the roof and sealing the attic vents as part of a larger remodel, thereby creating a conditioned space within which the ducts are located, and no longer meets the criteria of §140.4(l).

When a space conditioning system is altered by the installation or replacement of space conditioning equipment (including replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil), the duct system that is connected to the new or replaced space conditioning equipment, if the duct system meets the criteria of §140.4(l)1, 2, and 3, shall be sealed, as confirmed through field verification and diagnostic testing in accordance with procedures for duct sealing of existing duct systems as specified in the Reference Nonresidential Appendix NA1, to one of the requirements of §141.0(b)2D; and the system shall include a setback thermostat that meets requirements of Reference Joint Appendix JA5.

There are three exceptions to this requirement:

1. Buildings altered so that the duct system no longer meets the criteria of §140.4(l)1, 2, and 3.

   Ducts would no longer have to be sealed if the roof deck was insulated and attic ventilation openings sealed.

2. Duct systems that are documented to have been previously sealed as confirmed through field verification and diagnostic testing in accordance with procedures in Reference Nonresidential Appendix NA2.

3. Existing duct systems constructed, insulated or sealed with asbestos.

For all altered unitary single zone, air conditioners, heat pumps, and furnaces where the existing thermostat does not comply with Reference Joint Appendix JA5, the existing thermostat must be replaced with a thermostat that complies with Reference Joint Appendix JA5. All newly installed space-conditioning systems requiring a thermostat shall be equipped with a thermostat that complies with Reference Joint Appendix JA5. A JA5 compliant is also known as the Occupant Controlled Smart Thermostat (OSCT), which is capable of responding to demand response signals in the event of grid congestion and shortages during high electrical demand periods.

4.9.4.4 **Performance Approach**

When using the performance approach for alterations, see §141.0(b)3.

4.9.4.5 **Acceptance Tests**

Acceptance tests must be conducted on the new equipment or systems when installed in new additions. For more detailed information, see Chapter 13.

Example 4-52

Question

A maintenance contractor comes twice a year to change the filters and check out the rooftop packaged equipment that serves our office. Do the Energy Standards apply to this type of work?

Answer

In general, the Energy Standards do not apply to general maintenance such as replacing filters, belts or other components; however if the rooftop unit wears out and needs to be replaced, then the new unit would have to meet the equipment efficiency requirements of §110.2 as well as the mandatory requirements of §120.1-§120.4 and the prescriptive requirements of §140.4.

Example 4-53

Question

Our building is being renovated and the old heating system is being entirely removed and replaced with a new system that provides both heating and cooling. How do the Energy Standards apply?

Answer

All of the requirements of the Energy Standards apply in the same way they would if the system were in a new building.

Example 4-54

Question

A 10,000 ft² addition is being added to a 25,000 ft² building. The addition has its own rooftop HVAC system. The system serving the existing building is not being modified. How do the Energy Standards apply?

Answer

The addition is treated as a separate building and all the requirements of the Energy Standards apply to the addition. None of the requirements apply to the existing system or existing building since it is not being modified.

Example 4-55

Question

A 3,000 ft² addition is being added to a 50,000 ft² office. The existing packaged variable air volume (PVAV) system has unused capacity and will be used to serve the addition as well as the existing building. This system has direct digital controls at the zone level and an air side economizer.

Ductwork will be extended from an existing trunk line and two additional VAV boxes will be installed with hot water reheat. Piping for reheat will be extended from existing branch lines. How do the Energy Standards apply?

Answer

The general rule is that the Energy Standards apply to new construction and not to existing systems that are not being modified. In this case, the Energy Standards would not apply to the existing PVAV. However, the ductwork serving the addition would have to be sealed and insulated according to the requirements of §120.4, the hot water piping would have to be insulated according to the requirements of §120.3, The new thermostats would have to meet the requirements of §120.2 (a), (b), and (h), ventilation would have to be provided per §120.1, fractional fan motors in the new space would have to comply with §140.4(c)4, and the new VAV boxes would have to meet the requirements of 140.4(d).

Example 4-56

Question

In the previous example (3,000 ft² addition is added to a 50,000 ft² office), how do the outside air ventilation requirements of §120.1 apply?

Answer

The outside air ventilation rates specified in §120.1 apply at the air handler. When existing air handlers are extended to serve additional space, it is necessary to reconfigure the air handler to assure that the outside air requirements of §120.1 are satisfied for all the spaces served. In addition, the acceptance requirements for outside air ventilation are also triggered (see Chapter 12). It would be necessary to evaluate the occupancies both in the addition and the existing building to determine the minimum outside air needed to meet the requirements of §120.1. The existing air handler would have to be controlled to assure that the minimum outside air is delivered to the spaces served by the air handler for all positions of the VAV boxes. (See Section 4.3 for details on how this is achieved. Additional controls may need to be installed at the air handler to meet this requirement.)

Example 4-57

Question

In the previous example, the 3,000 ft² addition contains a large 400 ft² conference room. What additional requirements are triggered in this instance?

Answer

In this case, the demand control requirements of §140.4(c) would apply to the conference room, since it has an occupant density greater than 25 persons per 1,000 ft² and the PVAV system serving the building has an air side economizer and direct digital controls (DDC) at the zone level. If the existing system did not have an outside air economizer or if it did not have DDC controls at the zone level, then the demand control requirements would not apply. A separate sensor would need to be provided in the conference room to meet this requirement. The programming on the OSA damper would have to be modified to increase OSA if the zone ventilation wasn't satisfied.

Example 4-58

Question

An existing building has floor-by-floor VAV systems with no air side economizers. The VAV boxes also have electric reheat. Outside air is ducted to the air handlers on each floor which is adequate to meet the ventilation requirements of §120.1, but not large enough to bring in 100 percent outside air which would be needed for economizer operation. A tenant space encompassing the whole floor is being renovated and new ductwork and new VAV boxes are being installed. Does the economizer requirement of §140.4(e) apply? Does the restriction on electric resistance heat of §140.4(g) apply?

Answer

Since the air handler is not being replaced, the economizer requirement of §140.4(e) does not apply. If in the future the air handler were to be replaced, the economizer requirement would need to be satisfied; however for systems such as this a water side economizer is often installed instead of an air side economizer. The electric resistance restriction of §140.4(g) does however apply, unless the *Exception* 2 to §149(a) applies. This exception permits electric resistance to be used for the additional VAV boxes as long as the total capacity of the electric resistance system does not increase by more than 150 percent.

Example 4-59

Question

In the previous example, the building owner has decided to replace the air handler on the floor where the tenant space is being renovated because the new tenant has electronic equipment that creates more heat than can be removed by the existing system. In this case, does the economizer requirement of §140.4(e) apply?

Answer

In this case, because the air handler is being replaced, the economizer requirement does apply. The designer would have a choice of using an air-side economizer or a water-side economizer. The air side economizer option would likely require additional or new ductwork to bring in the necessary volume of outside air. The feasibility of a water economizer will depend on the configuration of the building. Often a cooling tower is on the roof and chillers are in the basement with chilled water and condenser water lines running in a common shaft. In this case, it may be possible to tap into the condenser water lines and install a water economizer, however, pressure controls would need to be installed at the take offs at each floor and at the chiller.

Example 4-60

Question

400 tons of capacity is being added to an existing 800 ton chilled water plant. The existing plant is air cooled (two 400 ton air cooled chillers). Can the new chillers also be air cooled?

Answer

No. The requirements of §140.4(j) apply in this case and a maximum of 300 tons of air-cooled chillers has been reached (and exceeded) at this plant. The remainder has to be water cooled. They would not have to retrofit the plant to replace either of the existing air-cooled chillers with water cooled. If one of the existing air-cooled chillers failed in the future they would have to replace it with a water-cooled chiller. If both air-cooled chillers failed they could only provide 300 tons of air cooled capacity.

4.10 Glossary/Reference

Terms used in this chapter are defined in Reference Joint Appendix JA1. Definitions that appear below are either not included within Reference Joint Appendix JA1 or expand on the definitions.

4.10.1 Definitions of Efficiency

§110.1 and §110.2 mandate minimum efficiency requirements that regulated appliances and other equipment must meet. The following describes the various measurements of efficiency used in the Energy Standards.

The purpose of space-conditioning and water-heating equipment is to convert energy from one form to another, and to regulate the flow of that energy. Efficiency is a measure of how effectively the energy is converted or regulated. It is expressed as the ratio:

Equation 4-9

$$Efficiency = \frac{Output}{Input}$$

The units of measure in which the input and output energy are expressed may be either the same or different, and vary according to the type of equipment. The Energy Standards use several different measures of efficiency.

Combustion Efficiency is defined in the Appliance Efficiency Regulations as follows:

Combustion efficiency of a space heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated or lost as jacket loss, as determined using the applicable test method in Section 1604(e).

Boiler means a space heater that is a self-contained appliance for supplying steam or hot water primarily intended for space-heating. Boiler does not include hot water supply boilers.

Where boilers used for space heating are considered to be a form of space heater.

Thermal efficiency is used as the efficiency measurement for gas and oil boilers with rated input greater than or equal to 300,000 Btu/hr. It is a measure of the percent of energy transfer from the fuel to the heat exchanger (HX). Input and output energy are expressed in the same units so that the result has non-dimensional units:

Equation 4-10

$$\%\text{ Combustion Eff} = \frac{(\text{Energy to HX})\text{ x }100}{\text{Total Fuel Energy Input}}$$

Note: Combustion efficiency does not include losses from the boiler jacket. It is strictly a measure of the energy transferred from the products of combustion.

Fan Power Index is the power consumption of the fan system per unit of air moved per minute (W/cfm) at design conditions.

Thermal Efficiency is defined in the Appliance Efficiency Regulations as a measure of the percentage of heat from the combustion of gas, which is transferred to the space or water being heated as measured under test conditions specified. The definitions from the Appliance Efficiency Regulations are:

1. Thermal Efficiency of a space heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated, or in the case of a boiler, to the hot water or steam, as determined using the applicable test methods in Section 1604(e).
2. Thermal Efficiency of a water heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the water, as determined using the applicable test method in Section 1604(f).
3. Thermal Efficiency of a pool heater means a measure of the percentage of heat from the input that is transferred to the water, as determined using the applicable test method in Section 1604(g).

Equation 4-11

$$\%\ Thermal\ Efficiency\ = \frac{(Energy\ Transferred\ to\ Medium)}{(Total\ Fuel\ Input)}$$

4.10.2 Definitions of Spaces and Systems

The concepts of spaces, zones, and space-conditioning systems are discussed in this subsection.

Fan System is a fan or collection of fans that are used in the scope of the Prescriptive requirement for fan-power limitations §140.4(c). §140.4(c) defines fan-systems as all fans in the system that are required to operate at design conditions in order to supply air from the heating or cooling source to the conditioned space, and to return it back to the source or to exhaust it to the outdoors. For cooling systems this includes supply fans, return fans, relief fans, fan coils, series-style fan powered boxes, parallel-style fan powered boxes and exhaust fans. For systems without cooling this includes supply fans, return fans, relief fans, fan coils, series-style fan powered boxes, parallel-style fan powered boxes and exhaust fans. Parallel-style fan-powered boxes are often not included in a terminal unit where there is no need for heating as the fans are only needed for heating.

Space is not formally defined in the Energy Standards, but is considered to be an area that is physically separated from other areas by walls or other barriers. From a mechanical perspective, the barriers act to inhibit the free exchange of air with other spaces. The term “space” may be used interchangeably with “room.”

Space Conditioning zone is a space or group of spaces within a building with sufficiently similar comfort conditioning requirements so that comfort conditions, as specified in

§140.4(b)3, as applicable, can be maintained throughout the zone by a single controlling device. It is the designer's responsibility to determine the zoning; in most cases each building exposure will consist of at least one zone. Interior spaces that are not affected by outside weather conditions usually can be treated as a single zone.

A building will generally have more than one zone. For example, a facility having 10 spaces with similar conditioning that are heated and cooled by a single space-conditioning unit using one thermostat is one zone. However, if a second thermostat and control damper, or an additional mechanical system, is added to separately control the temperature within any of the 10 spaces, then the building has two zones.

Space-Conditioning System is used to define the scope of the requirements of the Energy Standards. It is a catch-all term for mechanical equipment and distribution systems that provide either collectively or individually- heating, ventilating, or cooling within or associated with conditioned spaces in a building. HVAC equipment is considered part of a space-conditioning system if it does not exclusively serve a process within the building. Space conditioning systems include general and toilet exhaust systems.

Space-conditioning systems may encompass a single HVAC unit and distribution system (such as a package HVAC unit) or include equipment that services multiple HVAC units (such as a central outdoor air supply system, chilled water plant equipment or central hot water system).

4.10.3 Types of Air

Exhaust Air is air being removed from any space or piece of equipment and conveyed directly to the atmosphere by means of openings or ducts. The exhaust may serve specific areas, such as toilet rooms, or may be for a general building relief, such as an economizer.

Make-up Air is air provided to replace air being exhausted.

Mixed Air is a combination of supply air from multiple air streams. The term mixed air is used in the Energy Standards in an exception to the prescriptive requirement for space conditioning zone controls §140.4(d). In this manual the term mixed air is also used to describe a combination of outdoor and return air in the mixing plenum of an air handling unit.

Outdoor Air is air taken from outdoors and not previously circulated in the building. For the purposes of ventilation, outdoor air is used to flush out pollutants produced by the building materials, occupants and processes. To ensure that all spaces are adequately ventilated with outdoor air, the Energy Standards require that each space be adequately ventilated (See Section 4.3).

Return Air is air from the conditioned area that is returned to the conditioning equipment either for reconditioning or exhaust. The air may return to the system through a series of ducts, or through plenums and airshafts.

Supply Air is air being conveyed to a conditioned area through ducts or plenums from a space-conditioning system. Depending on space requirements, the supply may be heated, cooled, or neutral.

Transfer Air is air that is transferred directly from either one space to another or from a return plenum to a space. Transfer air is a way of meeting the ventilation requirements at the space level and is an acceptable method of ventilation per §120.1. It works by transferring air with a low level of pollutants from an over ventilated space) to a space with a higher level of pollutants (See Section 4.3).

4.10.4 Air Delivery Systems

Space-conditioning systems can be grouped according to how the airflow is regulated as follows:

Constant Volume System is a space-conditioning system that delivers a fixed amount of air to each space. The volume of air is set during the system commissioning.

Variable Air Volume (VAV) System is a space conditioning system that maintains comfort levels by varying the volume of conditioned air to the zones served. This system delivers conditioned air to one or more zones. There are two styles of VAV systems, single-duct VAV where mechanically cooled air is typically supplied and reheated through a duct mounted coil, and dual-duct VAV systems where heated and cooled streams of air are blended at the zone level. In single-duct VAV systems the duct serving each zone is provided with a motorized damper that is modulated by a signal from the zone thermostat. The thermostat also controls the reheat coil. In dual-duct VAV systems the ducts serving each zone are provided with motorized dampers that blend the supply air based on a signal from the zone thermostat.

Pressure Dependent VAV Box has an air damper whose position is controlled directly by the zone thermostat. The actual airflow at any given damper position is a function of the air static pressure within the duct. Because airflow is not measured, this type of box cannot precisely control the airflow at any given moment: a pressure dependent box will vary in output as other boxes on the system modulate to control their zones.

Pressure Independent VAV Box has an air damper whose position is controlled on the basis of measured airflow. The setpoint of the airflow controller is, in turn, reset by a zone thermostat. A maximum and minimum airflow is set in the controller, and the box modulates between the two according to room temperature.

4.10.5 Return Plenums

Return Air Plenum is an plenum is an air compartment or chamber including uninhabited crawl spaces, areas above a ceiling or below a floor, including air spaces below raised floors of computer/data processing centers, or attic spaces, to which one or more ducts are connected and which forms part of either the supply air, return air or exhaust air system, other than the occupied space being conditioned. The return air temperature is usually within a few degrees of space temperature.

4.10.6 Zone Reheat, Recool and Air Mixing

When a space-conditioning system supplies air to one or more zones, different zones may be at different temperatures because of varying loads. Temperature regulation is normally accomplished by varying the conditioned air supply (variable volume), by varying the temperature of the air delivered, or by a combination of supply and temperature control. With multiple zone systems, the ventilation requirements or damper control limitations may cause the cold air supply to be higher than the zone load, this air is tempered through reheat or mixing with warmer supply air to satisfy the actual zone load. §140.4(c) limits the amount of energy used to simultaneously heat and cool the same zone as a basis of zone temperature control.

Zone Reheat is the heating of air that has been previously cooled by cooling equipment or systems or an economizer. A heating device, usually a hot water coil, is placed in the zone supply duct and is controlled via a zone thermostat. Electric reheat is sometimes used, but is severely restricted by the Energy Standards.

Zone Recool is the cooling of air that has been previously heated by space conditioning equipment or systems serving the same building. A chilled water or refrigerant coil is usually placed in the zone supply duct and is controlled via a zone thermostat. Re-cooling is less common than reheating.

Zone Air Mixing occurs when more than one stream of conditioned air is combined to serve a zone. This can occur at the HVAC system (e.g. multizone), in the ductwork (e.g. dual-duct system) or at the zone level (such as a zone served by a central cooling system and baseboard heating). In some multizone and dual duct systems an unconditioned supply is used to temper either the heating or cooling air through mixing. §140.4(c) only applies to systems that mix heated and cooled air.

4.10.7 Economizers

4.10.7.1 Air Economizers

An air economizer is a ducting arrangement and automatic control system that allows a cooling supply fan system to supply outside air to reduce or eliminate the need for mechanical cooling.

When the compliance path chosen for meeting the Energy Standards requires an economizer, the economizer must be integrated into the system so that it is capable of satisfying part of the cooling load while the rest of the load is satisfied by the refrigeration equipment. The Energy Standards also require that all new economizers meet the Acceptance Requirements for Code Compliance before a final occupancy permit may be granted. The operation of an integrated air economizer is diagrammed in Figure 4-32.

When outdoor air is sufficiently cold, the economizer satisfies all cooling demands on its own. As the outdoor temperature (or enthalpy) rises, or as system cooling load increases, a point may be reached where the economizer is no longer able to satisfy the entire cooling load. At this point the economizer is supplemented by mechanical refrigeration, and both operate concurrently. Once the outside drybulb temperature (for temperature controlled economizer) or enthalpy (for enthalpy economizers) exceeds that of the return air or a predetermined high limit, the outside air intake is reduced to the minimum required, and cooling is satisfied by mechanical refrigeration only.

Nonintegrated economizers cannot be used to meet the economizer requirements of the prescriptive compliance approach. In nonintegrated economizer systems, the economizer may be interlocked with the refrigeration system to prevent both from operating simultaneously. The operation of a nonintegrated air economizer is diagrammed in Figure 4-33. Nonintegrated economizers can only be used if they comply through the performance approach.

Figure 4-32: Integrated Air Economizer

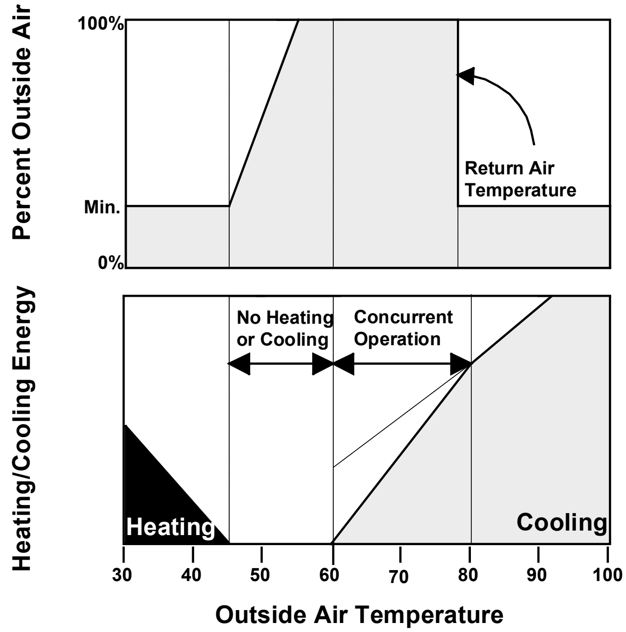
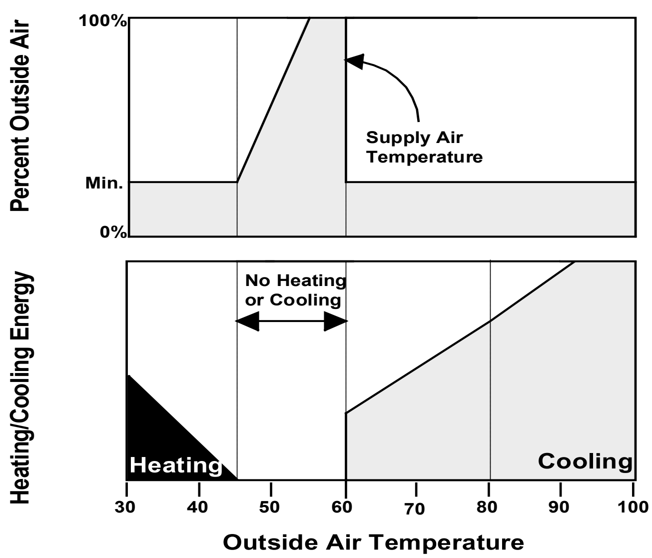


Figure 4-33: Nonintegrated Air Economizer



4.10.7.2 **Water Economizers**

A water economizer is a system by which the supply air of a cooling system is cooled directly or indirectly by evaporation of water, or other appropriate fluid, in order to reduce or eliminate the need for mechanical cooling.

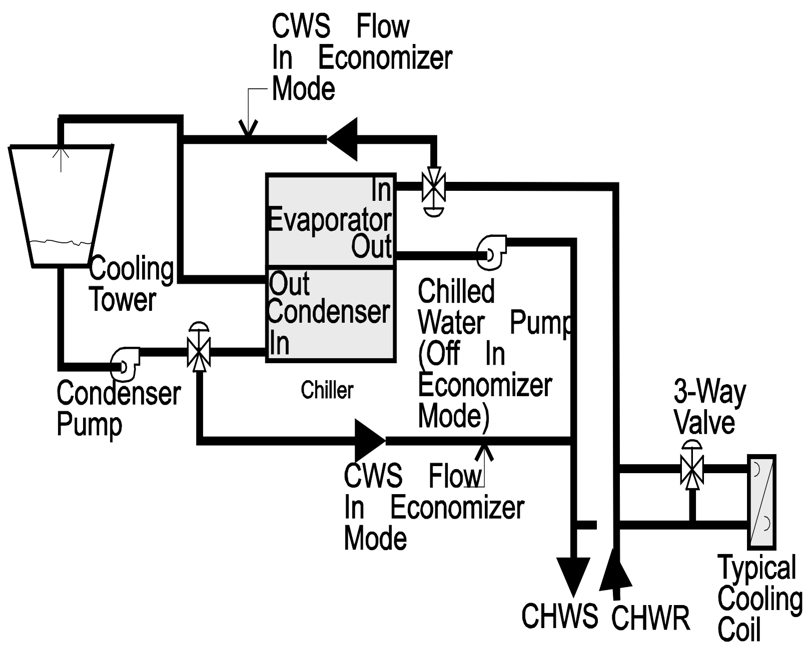
As with an air economizer, a water economizer must be integrated into the system so that the economizer can supply a portion of the cooling concurrently with the refrigeration system.

There are three common types of water-side economizers:

1. **Strainer-cycle or chiller-bypass water economizer**. This system, depicted in Figure 4-34 below, does *not* meet the prescriptive requirement as it cannot operate in parallel with the chiller. This system is applied to equipment with chilled water coils.
2. **Water-precooling economizer**. This system depicted in Figure 4-35 and Figure 4-36 below meets the prescriptive requirement if properly sized. This system is applied to equipment with chilled water coils.
3. **Air-precooling water economizer**. This system depicted in Figure 4-37 below *also meets* the prescriptive requirement if properly sized. The air-precooling water economizer is appropriate for water-source heat pumps and other water-cooled HVAC units.

To comply with the prescriptive requirements, the cooling tower serving a water-side economizer must be sized for 100 percent of the anticipated cooling load at the off-design outdoor-air condition of 50°F dry bulb/45°F wet bulb. This requires rerunning the cooling loads at this revised design condition and checking the selected tower to ensure that it has adequate capacity.

Figure 4-34: "Strainer-Cycle" Water Economizer



This system does not meet the prescriptive requirement as it cannot operate in parallel with the chiller

Figure 4-35: Water-Precooling Water Economizer with Three-Way Valves

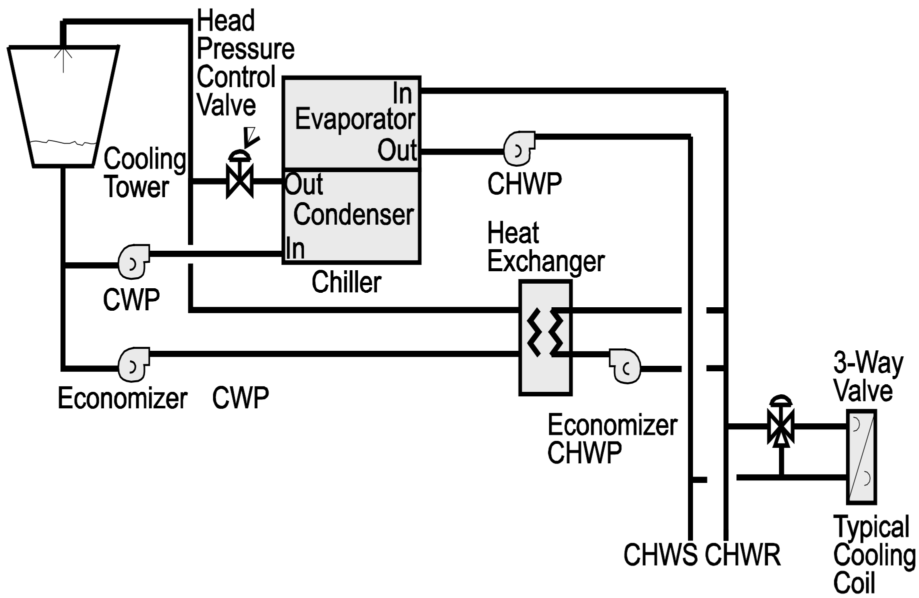


Figure 4-36: Water-Precooling Water Economizer with Two-Way Valves

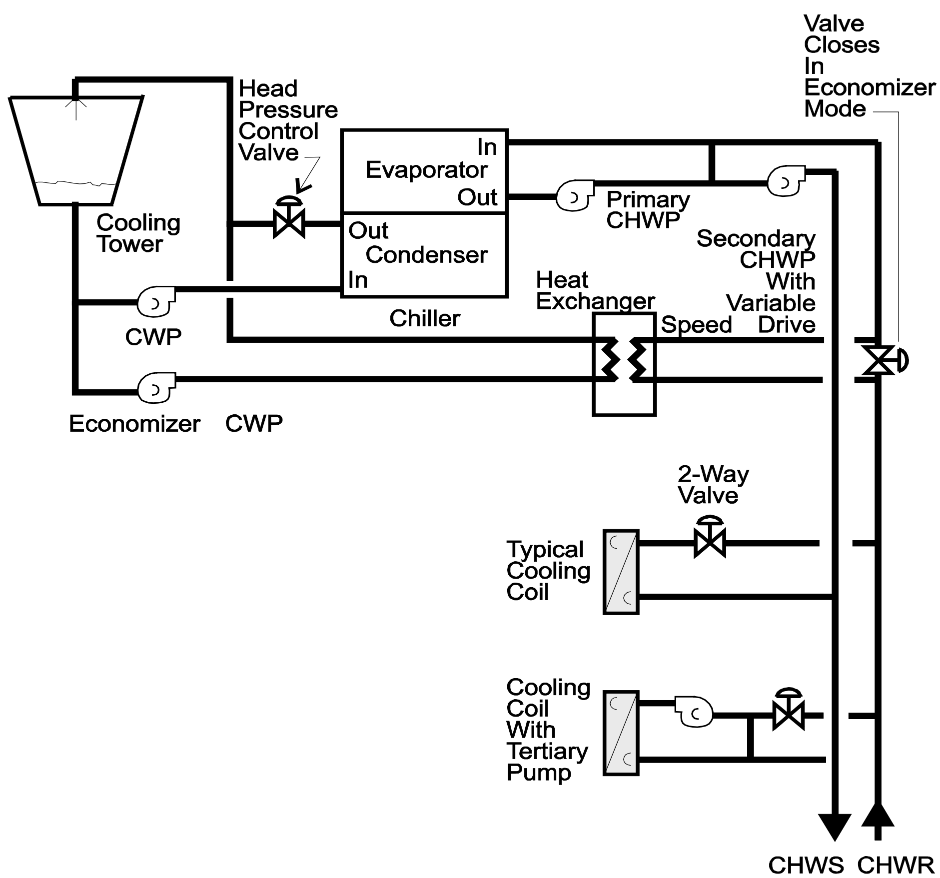
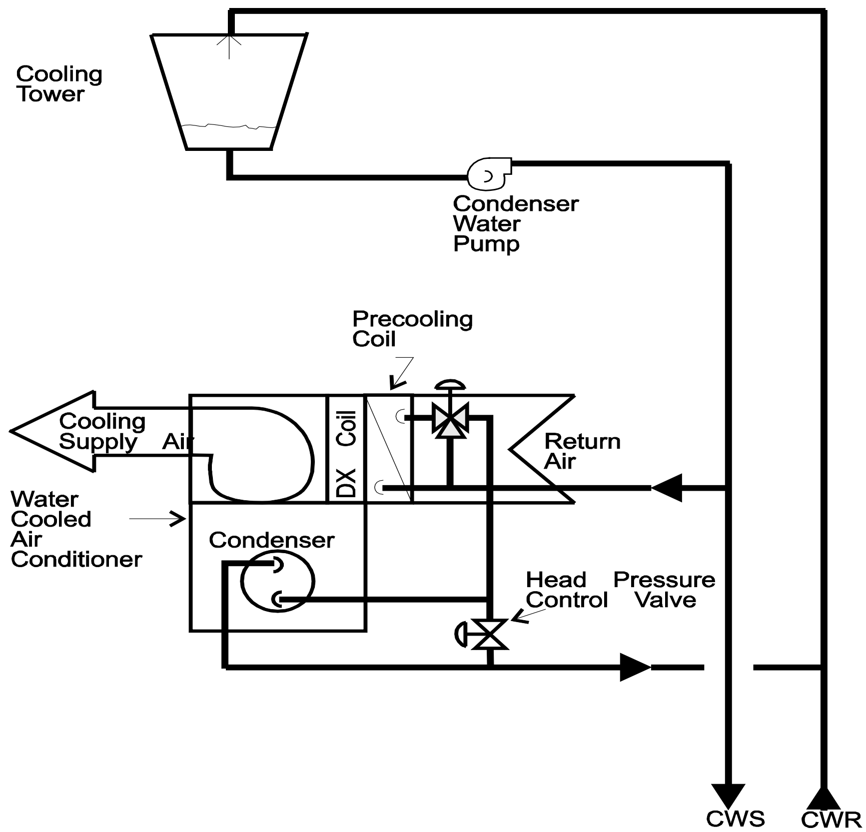


Figure 4-37: Air-Precooling Water Economizer



4.10.8 Unusual Sources of Contaminants

§120.1 address ventilation requirements for buildings and uses the term of "unusual sources of contamination." In this context, such contaminants are considered to be chemicals, materials, processes or equipment that produce pollutants which are considered harmful to humans, and are not typically found in most building spaces. Examples may include some cleaning products, blueprint machines, heavy concentrations of cigarette smoke and chemicals used in various processes.

The designation of such spaces is left to the designer's discretion, and may include considerations of toxicity, concentration and duration of exposure. For example, while photocopiers and laser printers are known to emit ozone, scattered throughout a large space it may not be of concern. A heavy concentration of such machines in a small space may merit special treatment (See Section 4.3).

4.10.9 Demand Controlled Ventilation

Demand controlled ventilation is required for use on systems that have an outdoor air economizer, and serve a space with a design occupant density, or maximum occupant load factor for egress purposes in the CBC, greater than or equal to 25 people per 1000 ft^2 (40 ft^2/ person) §120.1(c)3. Demand controlled ventilation is also allowed as an exception in the ventilation requirements for intermittently occupied systems §120.1(c)1, §120.1(c)3 and §120.1(c)4. It is a concept in which the amount of outdoor air used to purge one or more offending pollutants from a building is a function of the measured level of the pollutant(s).

§120.1 allows for demand controlled ventilation devices that employ a carbon dioxide (CO_2) sensor. Carbon dioxide sensors measure the level of carbon dioxide, which is used as a proxy for the amount of pollutant dilution in densely occupied spaces. CO_2 sensors have been on the market for many years and are available with integrated self-calibration devices that maintain a maximum guaranteed signal drift over a 5-year period. ASHRAE Standard 62 provides some guidelines on the application of demand controlled ventilation.

Demand controlled ventilation is available at either the system level (used to reset the minimum position on the outside air damper) and at the zone level (used to reset the minimum airflow to the zone). The zone level devices are sometimes integrated into the zone thermostat.

Occupant sensor ventilation control devises are required in multipurpose rooms less than 1000 ft^2, classrooms greater than 750 ft^2 and conference, convention, auditorium, and meeting center rooms greater than 750 ft^2 that do not generate dust, fumes, vapors, or gasses §120.1(c)5 and §120.2(e)3. Occupant sensor control devises are used to setup the operating cooling temperature, setback the operating heating temperature, and set minimum ventilation rate levels during unoccupied periods. Spaces with an area of less than 1,500 ft^2 are exempt from the demand control ventilation requirements specified in §120.1(c)3 if employing occupant sensor ventilation control devices in accordance with §120.1(c)5

4.10.10 Intermittently Occupied Spaces

The demand controlled ventilation devices discussed here are allowed and/or required only in spaces that are intermittently occupied. An intermittently occupied space is considered to be an area that is infrequently or irregularly occupied by people. Examples include auction rooms, movie theaters, auditoriums, gaming rooms, bars, restaurants, conference rooms and other assembly areas. Because the Energy Standards requires base ventilation requirement in office spaces that are very close to the actual required ventilation rate at 15 cfm per person, these controls may not save significant amounts of energy for these low-density applications. However, even in office applications, some building owners may install CO_2 sensors as a way to monitor ventilation conditions and alert to possible malfunctions in building air delivery systems.

4.11 Mechanical Plan Check Documents

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and recommended procedures documenting compliance with the mechanical requirements of the Energy Standards. It does not describe the details of the requirements; these are presented in Section 4.2. The following discussion is addressed to the designer preparing construction documents and compliance documentation, and to the enforcement agency plan checkers who are examining those documents for compliance with the Energy Standards.

4.11.1 Field Inspection Checklist

New for the compliance documents is the Field Inspection Energy Checklist. Prescriptively the Documentation Author is responsible for filling out the Field Inspection Energy Checklist. For the Performance Approach the fields will be automatically filled. A copy shall be made available to the Field Inspector during different stage inspection.

The Field Inspection Energy Checklist is designed to help Field Inspectors look at specifics features that are critical to envelope compliance. These features should match the building plans as indicated on the Mechanical Field Inspection Energy Checklist or NRCC-MCH-01-E. The Field Inspector must verify after the installation of each measure (e.g. HVAC Systems). The Field Inspector in addition must collect a signed MECH-INST (Installation Certificate) from the installer.

In the case of the Field Inspection Energy Checklist does not match exactly the building plans or the MECH-INST document, the field inspector must verify the features are meeting the minimum efficiency or better and if so no further compliance is required from the Architect or responsible party. In the case the features do not meet the efficiencies (worse) the field inspector shall require recompliance with the actual installed features.

4.11.1.1 **HVAC SYSTEM Details**

The Field Inspector need check the Pass or Fail check boxes only after the measures have been verified. If the Special Feature is checked, the enforcement agency should pay special attention to the items specified in the checklist. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation. See MECH-2C Pages 1-2-3 of 3.

4.11.1.2 **Special Features Inspection Checklist**

The local enforcement agency should pay special attention to the items specified in this checklist. These items require special written justification and documentation, and special verification. The local enforcement agency determines the adequacy of the justification, and may reject a building or design that otherwise complies based on the adequacy of the special justification and documentation submitted. See MECH-1C Pages 2-3 of 3.

4.11.1.3 **Discrepancies**

If any of the Fail boxes are checked off, the field inspector shall indicate appropriate action of correction(s). See Field Inspection Energy Checklist on Page 2 of MECH-1C.

The use of each document is briefly described. The information and format of these may be included in the equipment schedule:

NRCC-MCH-01-E: Certificate of Compliance

Required for every job, and it is required to part on the plans.

NRCC-MCH-02-E: Air, Water Side, and Service Hot Water & Pool System Requirements

Summarizes the major components of the heating and cooling systems, and service hot water and pool systems, and documents the location on the plans and in the specifications where the details about the requirements appear.

NRCC-MCH-03-E: Mechanical Ventilation and Reheat

Documents the calculations used as the basis for the outdoor air ventilation rates. For VAV systems, it is also used to show compliance with the reduced airflow rates necessary before reheating, re-cooling or mixing of conditioned airstreams.

NRCC-MCH-07-E: Fan Power Consumption

This document is used, following the prescriptive approach, to calculate total system fan power consumption for fan systems exceeding 25 brake horsepower. The "total system" includes supply, exhaust and return fans used for space conditioning.

NRCC-PLB-01-E: Certificate of Compliance – Water Heating System General Information

Required for every job and required to part on the plans.

NRCI-PLB-01-E: Water Heating System

This installation document is used for all hot water system

NRCI-PLB-02-E: High Rise Residential, Hotel/Motel Single Dwelling Unit Hot Water Systems Distribution

Used when individual water heating system is installed in each dwelling units in High Rise Residential, Hotel/Motel

NRCI-PLB-03-E: High Rise Residential, Hotel/Motel Central Hot Water Systems Distribution

This installation document is used when central water heating system is installed that service multiple dwelling units in High Rise Residential, Hotel/Motel

NRCI-PLB-04-E: Nonresidential Single Dwelling Unit Hot Water Systems Distribution

Used when individual water heating system is installed in each dwelling units in High Rise Residential, Hotel/Motel

NRCI-PLB-05-E: Nonresidential Central Hot Water Systems Distribution Water Heating System

This installation document is used when central water heating system is installed that service multiple dwelling units in High Rise Residential, Hotel/Motel

4.11.2 Mechanical Inspection

The mechanical building inspection process for energy compliance is carried out along with the other building inspections performed by the enforcement agency. The inspector relies upon the plans and upon the NRCC-MCH-01-E Certificate of Compliance document printed on the plans.

4.11.3 Acceptance Requirements

Acceptance requirements can effectively improve code compliance and help determine whether mechanical equipment meets operational goals and whether it should be adjusted to increase efficiency and effectiveness.

Acceptance tests are described in detail in Chapter 13.

4.11.3.1 Process

The process for meeting the acceptance requirements includes:

1. Document plans showing thermostat and sensor locations, control devices, control sequences and notes,
2. Review the installation, perform acceptance tests and document results, and
3. Document the operating and maintenance information, complete installation certificate and indicate test results on the Certificate of Acceptance, and submit the Certificate to the enforcement agency prior to receiving a final occupancy permit.

4.11.3.2 Administration

The administrative requirements contained in the Energy Standards require the mechanical plans and specifications to contain:

Requirements for acceptance testing for mechanical systems and equipment shown in the table below:

Table 4-24: Mechanical Acceptance Tests

Variable Air Volume Systems
Constant Volume Systems
Package Systems
Air Distribution Systems
Economizers
Demand Control Ventilation Systems
Ventilation Systems
Variable Frequency Drive Fan Systems
Hydronic Control Systems
Hydronic Pump Isolation Controls and Devices
Supply Water Reset Controls
Water Loop Heat Pump Control
Variable Frequency Drive Pump Systems

1. Within 90 days of receiving a final occupancy permit, record drawings be provided to the building owners.
2. Operating and maintenance information be provided to the building owner.
3. For the issuance of installation certificates for mechanical equipment.

For example, the plans and specifications would require an economizer. A construction inspection would verify the economizer is installed and properly wired. Acceptance tests would verify economizer operation and that the relief air system is properly functioning. Owners' manuals and maintenance information would be prepared for delivery to the building owner. Finally, record drawing information, including economizer controller set points, must be submitted to the building owner within 90 days of the issuance of a final occupancy permit.

4.11.3.3 Plan Review

Although acceptance testing does not require that the construction team perform any plan review, they should review the construction drawings and specifications to understand the scope of the acceptance tests and raise critical issues that might affect the success of the acceptance tests prior to starting construction. Any construction issues associated with the mechanical system should be forwarded to the design team so that necessary modifications can be made prior to equipment procurement and installation.

4.11.3.4 Testing

The construction inspection is the first step in performing the acceptance tests. In general, this inspection should identify:

1. Mechanical equipment and devices are properly located, identified, calibrated and set points and schedules established.
2. Documentation is available to identify settings and programs for each device, and
3. For air distribution systems, this may include select tests to verify acceptable leakage rates while access is available.

Testing is to be performed on the following devices:

- Variable air volume systems
- Constant volume systems
- Package systems
- Air distribution systems
- Economizers
- Demand control ventilation systems
- Variable frequency drive fan systems
- Hydronic control systems
- Hydronic pump isolation controls and devices
- Supply water reset controls
- Water loop heat pump control
- Variable frequency drive pump systems
- System programming
- Time clocks

Chapter 13 contains information on how to complete the acceptance documents. Example test procedures are also available in Chapter 13.

4.11.3.5 Roles and Responsibilities

The installing contractor, engineer of record or owners agent shall be responsible for documenting the results of the acceptance test requirement procedures including paper and electronic copies of all measurement and monitoring results. They shall be responsible for performing data analysis, calculation of performance indices and crosschecking results with the requirements of the Energy Standards. They shall be responsible for issuing a Certificate of Acceptance. Enforcement agencies shall not release a final Certificate of

Occupancy until a Certificate of Acceptance is submitted that demonstrates that the specified systems and equipment have been shown to be performing in accordance with the Energy Standards. The installing contractor, engineer of record or owners agent upon completion of undertaking all required acceptance requirement procedures shall record their State of California Contractor's License number or their State of California Professional Registration License Number on each Certificate of Acceptance that they issue.

4.11.3.6 **Contract Changes**

The acceptance testing process may require the design team to be involved in project construction inspection and testing. Although acceptance test procedures do not require that a contractor be involved with a constructability review during design-phase, this task may be included on individual projects per the owner's request. Therefore, design professionals and contractors should review the contract provided by the owner to make sure it covers the scope of the acceptance testing procedures as well as any additional tasks.

Table of Contents

5. Nonresidential Indoor Lighting

This chapter covers the Title 24 California Code of Regulations, Part 6 (the Energy Standards), requirements for indoor lighting design and installation, including controls, for both conditioned and unconditioned nonresidential buildings. It is addressed primarily to lighting designers, electrical engineers, and enforcement agency personnel responsible for lighting design, installation, plan check, and inspection.

Chapter 6 addresses nonresidential outdoor lighting requirements.

Chapter 7 addresses sign lighting requirements.

5.1 Overview

The primary mechanism for regulating nonresidential indoor lighting energy under the Energy Standards is to limit the allowed lighting power in watts installed in the building. Other mechanisms require basic equipment efficiency and that the lighting be controlled automatically for efficient operation.

5.1.1 Significant Changes in the 2016 Energy Standards

- Reductions to some Lighting Power Density (LPD) values in Tables 140.6-B and 140.6-C.
- Reduction to LPD values in Table 140.6-G for applying specific Illuminating Energy Society of North America (IES) design criteria with the Tailored Method.
- New requirements for partial-ON occupancy controls in some spaces including private offices, conference rooms, multipurpose rooms, and classrooms.
- Removal of three Power Adjustment Factors (PAFs):
  - Partial-ON Occupant Sensing Control
  - Manual Dimming and Multi-scene Programmable Dimming for Hotels/motels, Restaurants, Auditoriums, and Theaters
  - Combined Manual Dimming plus Partial-ON Occupant Sensing Control
- Addition of two new Power Adjustment Factors (PAFs):
  - Institutional Tuning
  - Daylight Dimming plus OFF Control

5.1.2 Scope and Application

- The Energy Standards, nonresidential indoor lighting requirements and supporting definitions are contained in §100, §110.9, §120.8, §130.0, 1§30.1, §130.4, §140.3, §140.0, §140.1, §140.6, and §141.0.
- The nonresidential indoor lighting requirements apply to nonresidential buildings, high-rise residential buildings (except dwelling units), and hotel/motel occupancies (including guest rooms) as defined in §100.1.
- The nonresidential indoor lighting requirements are the same for unconditioned spaces as for conditioned spaces, as defined in §100.1, except that Performance Approach trade-offs are not allowed between unconditioned and conditioned spaces.

- Some function areas within buildings classified as low-rise residential are required to comply with the nonresidential indoor lighting requirements (for example, §150.0(k)6B places additional lighting requirements on the common area in a low-rise multi-family residential building when there is greater than 20 percent common area in the building).
- Some function areas in nonresidential, high-rise residential, and hotel/motel occupancies are required to comply with low-rise residential lighting requirements. The low-rise residential lighting requirements are covered in chapter 6 of the 2016 Residential Compliance Manual.
- Hotel/motel guest rooms are covered by portions of both the nonresidential indoor lighting requirements and the residential indoor lighting requirements. The residential indoor lighting requirements are covered in the Residential Compliance Manual.
- Qualified historic buildings are not covered by the Energy Standards, as stated in exception 1 to §100.0(a). Historic buildings are regulated by the California Historical Building Code (Title 24 California Code of Regulations, Part 8 or Part 2, Volume 2, Chapter 34). However, non-historical components of the buildings, such as new or replacement mechanical, plumbing, and electrical (including lighting) equipment, additions and alterations to historic buildings, and new appliances in historic buildings may need to comply with the Energy Standards and the Appliance Efficiency Regulations, as well as other codes. For more information about energy compliance requirements for Historic Buildings, see Section 1.7.2 of this manual.
- All section (§) and Table references in this Chapter refer to sections and Tables contained in Title 24 California Code of Regulations, Part 6, also known as the Energy Standards or California Energy Code.

5.1.3 Mandatory Measures

§130.0 through §130.4

Some requirements in the nonresidential lighting Standards are classified as "Mandatory Measures," because they are required to be met regardless of the compliance approach used. There are no alternate options for the Mandatory Measures. All projects must comply with all Mandatory Measures.

5.1.4 Lighting Power Allotments

Lighting Power Allotments are the established maximum lighting power (typically watts per square foot) that can be installed based upon the compliance approach used, the building type, and the type of primary function area. Lighting Power Allotments for an application are determined by one of the following four compliance approaches:

A. **Prescriptive Approach – Complete Building Method**: applicable when the entire building's lighting system is designed and permitted at one time, and when at least 90 percent of the building is one primary nonresidential building type of use, as defined in §100.1. In some cases, the complete building method may be used for an entire nonresidential building type tenant space in a multi-tenant building. A single Lighting Power Density Allotment value governs the entire building §140.6(c)1.

B. **Prescriptive Approach – Area Category Method**: applicable for any permit situation, including tenant improvements. Lighting power values are assigned to each of the primary function areas of a building (offices, lobbies, corridors, etc., as defined in §100.1). This approach provides some flexibility to accommodate special tasks by providing an additional power allowance under some circumstances.

C. **Prescriptive Approach – Tailored Method:** applicable for a limited number of defined primary function areas when additional flexibility is needed to accommodate special task lighting needs. Several layers of lighting power allotments may be allowed depending on the space and tasks. Lighting power allotments are determined room-by-room and task-by-task. When using the Tailored Method, the Area Category Method shall be used for the remainder of the interior lighting in the building.

D. **Performance Approach:** applicable when the designer uses an Energy Commission-certified compliance software program to demonstrate that the proposed building's energy consumption, including indoor lighting power, meets the energy budget. The performance approach incorporates one or more of the three previous methods which set the appropriate Lighting Power Allotment used in calculating the building's custom energy budget.

   The Performance Approach allows energy allotments to be traded between space conditioning, mechanical ventilation, indoor lighting, service water heating, envelope, and covered process loads. Such trade-offs can only be made when permit applications are sought for those systems involved. For example, under the performance approach, a building with an indoor lighting or mechanical ventilation system that is more efficient than the prescriptive efficiency requirements may be able to meet the energy budget for a standard designed building with more lighting power than allowed under the three prescriptive lighting approaches.

   No additional lighting power allotment is gained by using the Performance Method unless it is traded from the space conditioning, mechanical ventilation, service water heating, envelope, or covered process systems. Therefore, the Performance Approach is not applicable to lighting compliance alone. The Performance Approach may only be used to model the performance of indoor lighting systems that are covered under the building permit application.

5.1.5 Forms, Plan Check, Inspection, Installation, and Acceptance Tests

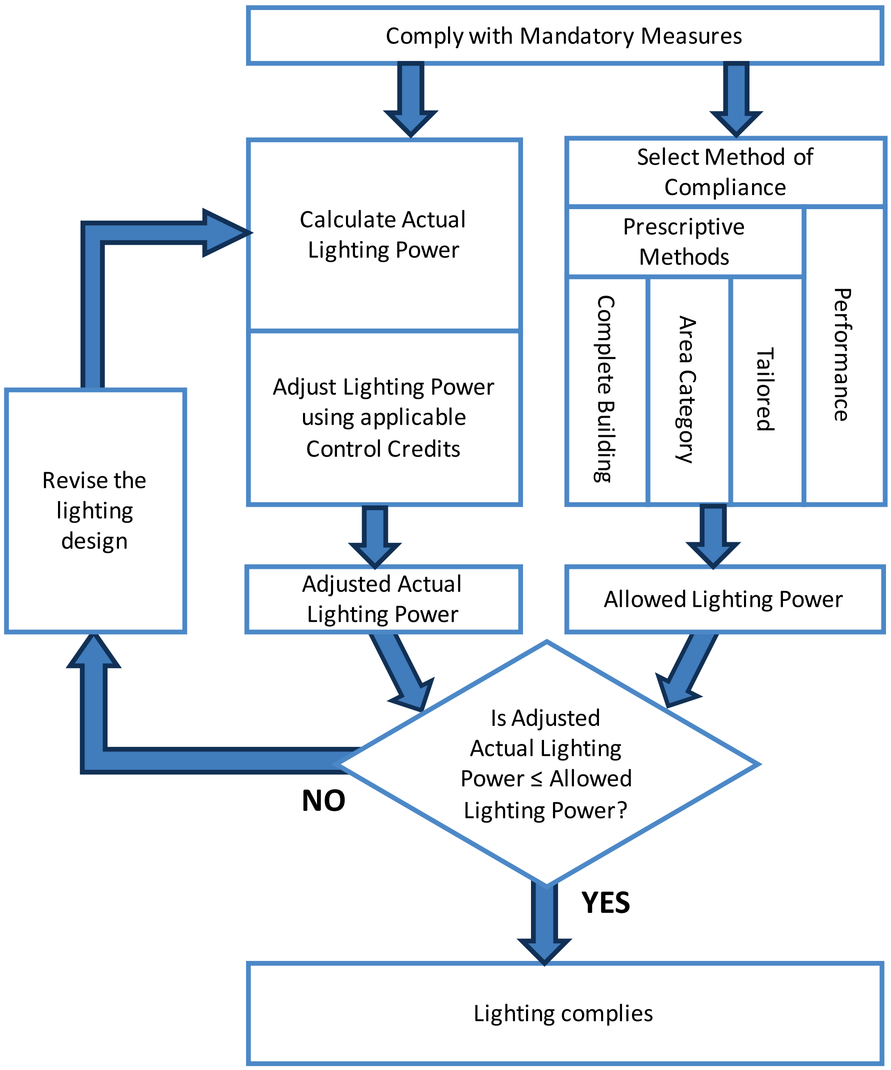
In summary, the compliance process begins with the builder submitting Certificates of Compliance, which provide all design information necessary to show that the proposed project will comply with the Energy Standards, to the responsible code enforcement agency. Construction may not begin until all Certificates of Compliance are reviewed and approved by the agency. As construction proceeds, builders must submit Certificates of Installation certifying that installed equipment and systems meet or exceed the design criteria specified in the approved Certificates of Compliance. Code enforcement officials may conduct field inspections to verify information submitted by builders. At the end of construction, acceptance tests must be performed by qualified contractors on all specified systems to ensure they are installed correctly and function adequately.

If inspections or acceptance tests identify noncompliant or nonfunctional systems, these defects must be fixed before the building can be approved. Once the code enforcement agency determines the project complies with all building code requirements, including the energy code, the building will receive a Certificates of Occupancy, which certify that the building is in compliance with the Energy Standards.

5.1.6 The Lighting Compliance Process

Figure 5-1 below, shows the process for complying with the nonresidential indoor lighting requirements.

Figure 5-1: Lighting Compliance Flowchart



A. First, following the right side of Figure 5-1:

The Mandatory Measures are required regardless of the compliance method selected.

Select one of the four possible methods for complying with the nonresidential indoor lighting requirements of the Energy Standards. There are three Prescriptive compliance methods: Complete Building Method, Area Category Method, and Tailored Method; and one Performance Method where compliance is demonstrated using one of the software programs that have been approved by the Energy Commission.

This process will result in the permitted lighting power for the building.

B. Second, following the left side of Figure 5-1:

Calculate the actual lighting power installed by totaling all of the lighting proposed in the building design.

For any of the the three Prescriptive Methods (Complete Building, Area Category, and Tailored), subtract lighting control credits. The result is the adjusted actual watts of lighting power for the proposed building design.

For the Performance approach, adjusted actual watts of lighting power can be calculated automatically by the compliance software based on the modelling approach. Refer to the compliance software documentation for details.

C. Conclusion

If the adjusted actual watts are less than the permitted lighting power, then the lighting in the building complies with the Energy Standards. If the adjusted actual watts are equal to or greater than the permitted lighting power than the lighting in the building does not comply with the Energy Standards and either the lighting power must be reduced, or additional lighting credits must be acquired from improved efficiency in other systems.

5.2 General Requirements for Mandatory Measures

Some requirements in the nonresidential lighting Standards are classified as “Mandatory Measures” because they are required regardless of the compliance approach used. All projects must comply with all Mandatory Measures.

It is the responsibility of the designer to specify products that meet these requirements. It is the responsibility of the installer to comply with all of the mandatory requirements, even if the plans mistakenly do not. It is the responsibility of code enforcement officials, in turn, to check that the mandatory features and specified devices are installed.

The mandatory measures for nonresidential indoor lighting include the following:

- Some functional areas in nonresidential buildings are required to comply with the low-rise residential lighting Energy Standards (§130.0(b)).
- Manufactured lighting equipment, products, and devices must be appropriately certified (§110.0(b) and §110.1).
- Requirements for how luminaires shall be classified according to technology and how installed lighting power shall be determined (§110.9).
- Required indoor lighting controls (Section 5.4).
- Lighting control acceptance testing (Section 5.4.6).
- Lighting control Certificates of Installation (Section 5.4.7).
- Although not related exclusively to lighting, the Energy Standards impose mandatory measures for electrical power distribution systems. See Chapter 8 of this manual for additional information about mandatory measures for electrical power distribution systems.

5.2.1 Residential Function Areas in Nonresidential Buildings

The following function areas in nonresidential, high-rise residential, and hotel/motel occupancies are required to comply with the low-rise residential lighting Standards (§130.0(b)):

1. High-rise residential dwelling units.
2. Outdoor lighting attached to a high-rise residential or hotel/motel building and separately controlled from inside a dwelling unit or guest room.
3. Fire station dwelling units.
4. Hotel and motel guest rooms. Note that hotel and motel guest rooms are also required to comply with the nonresidential lighting requirements in §130.1(c)8, which require captive card key controls, occupant sensing controls, or automatic controls. In addition, hotel and motel guest rooms shall meet the controlled receptacle requirements of §130.5(d)4.
5. Dormitory and senior housing dwelling units.

All other function areas in nonresidential, high-rise residential, and hotel/motel occupancies, such as common areas, shall comply with the applicable nonresidential lighting Standards.

5.2.2 Certification Requirements for Manufactured Lighting Equipment, Products, and Devices

§110.0(b) and §110.1

For lighting products that are subject to State or federal appliance regulations, installation shall be limited to those products that have been certified to the Energy Commission by their manufacturer, pursuant to the provisions of the Appliance Efficiency Regulations (Title 20 California Code of Regulations, §1606).

Once a device is certified, it will be listed in the Appliance Efficiency Database, which is available from: http://www.energy.ca.gov/appliances/database/

Call the Energy Hotline at 1-800-772-3300 to obtain more information.

If a device is certified to the Energy Commission, the Energy Standards do not require a builder, designer, owner, operator, or enforcing agency to independently test it to confirm its compliance with the Appliance Efficiency Regulations.

5.2.3 Requirements for Lighting Control Devices and Systems, Ballasts, and Luminaires

§110.9

For the purposes of the Energy Standards, lighting controls are separated into two categories:

- Self-Contained Lighting Controls are unitary lighting control modules that do not require any additional components to be fully functional.
- Lighting Control Systems require two or more components to be installed in the building to provide all of the functionality required to make up a fully functional and compliant lighting control.

Both categories of lighting controls must meet specified performance and certification requirements.

The Energy Standards also cover lighting controls which are not covered by the Title 20 Appliance Efficiency Regulations, such as field assembled lighting control systems, line-voltage track lighting integral current limiters, supplementary overcurrent protection panels for use with track lighting, ballasts for residential recessed compact fluorescent luminaires, and qualifications for residential high efficacy LED luminaires.

The requirements in §110.9 for ballasts used in residential recessed compact fluorescent luminaires, and for residential high efficacy LED luminaires, do not apply to most nonresidential lighting function areas, except for inside dwelling units of high-rise residential, hotel/motel, fire stations, and dormitory/senior housing.

5.2.3.1 General Lighting Control Requirements

The following lighting controls systems must comply with the applicable part of the Title 20 Appliance Efficiency Regulations and must include the specific functionality listed below (§110.9(b)). In addition, all components of the systems considered together as installed shall meet all applicable requirements for the application for which they are installed, as required in §130.0 through 130.5, §140.6 through 140.8, §141.0, and §150.0(k).

A. Time-Switch Lighting Controls

- Automatic Time-Switch Controls
- Astronomical Time-Switch Controls
- Multi-Level Astronomical Time-Switch Controls
- Outdoor Astronomical Time-Switch Controls

B. Daylighting Controls

- Automatic Daylight Controls
- Photo Controls

C. Dimmers

D. Occupant Sensing Controls

- Occupant Sensors
- Motion Sensors
- Vacancy Sensors
- Partial-ON Sensors
- Partial-OFF Sensors

5.2.3.2 Self-Contained Lighting Control Devices

A Self-Contained Lighting Control is defined in §100.1 as a unitary lighting control module that requires no additional components to be a fully functional lighting control. Self-Contained Lighting Controls are required by §110.9(a)3 to be certified by the manufacturer according to the Title 20 Appliance Efficiency Regulations. Lighting controls regulated by the Energy Standards, but not regulated by the Title 20 Appliance Efficiency Regulations, shall meet the following requirements:

A. Part-Night Outdoor Lighting Control (§110.9(b)5)

Part-Night outdoor lighting controls do not apply to nonresidential indoor lighting requirements (see Section 6.3.4 for additional information).

A Part Night Outdoor Lighting Control is defined by §100.1 as a time or occupancy-based lighting control device or system that is programmed to reduce or turn off the lighting power to an outdoor luminaire for a portion of the night. (Note that this lighting control does not apply to nonresidential indoor lighting Standards).

B. Track lighting integral current limiter (§110.9(c))

A track lighting current limiter is used to limit the rated power that can go through a section of track lighting. Without the current limiter, the “installed” wattage of a long section of track could be excessive and use up all of the allotted lighting power for a space. With track lighting and a current limiter, one can space the track heads far apart and use high efficacy sources in the track heads so it is possible to stay below the rated wattage of the current limiter. If the wattage served by the current limiter exceeds the rated wattage of the current limiter, the current limiter turns off the current to the controlled lighting.

A track lighting integral current limiter shall be recognized for compliance with the Energy Standards only for line-voltage track lighting systems and only if it meets all of the following requirements:

1. Shall be certified to the Energy Commission by the manufacturer in accordance with the requirements in §110.9(c).
2. Before a Line-Voltage Track Lighting Integral Current Limiter will be recognized for compliance with the lighting requirements, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.
    a. If any of the requirements in the Certificate of Installation are not met, the Line-Voltage Track Lighting Integral Current Limiter shall not be recognized for compliance with the Energy Standards.
3. Shall be manufactured so that the current limiter housing is used exclusively on the same manufacturer's track for which it is designed.
4. Shall be designed so that the current limiter housing is permanently attached to the track so that the system will be irreparably damaged if the current limiter housing were to be removed after installation into the track. Methods of attachment may include but are not limited to one-way barbs, rivets, and one-way screws.
5. Shall employ tamper resistant fasteners for the cover to the wiring compartment.
6. Shall have the identical volt-ampere (VA) rating of the current limiter, as the system is installed and rated for compliance with the Energy Standards clearly marked on all of the following places:
    a. So that it is visible for the building officials’ field inspection without opening coverplates, fixtures, or panels.
    b. Permanently marked on the circuit breaker.
    c. On a factory-printed label that is permanently affixed to a non-removable base-plate inside the wiring compartment.
7. Shall have a conspicuous factory installed label permanently affixed to the inside of the wiring compartment warning against removing, tampering with, rewiring, or bypassing the device.

8. Each electrical panel from which track lighting integral current limiters are energized shall have a factory printed label permanently affixed and prominently located, stating the following:

   "NOTICE: Current limiting devices installed in track lighting integral current limiters connected to this panel shall only be replaced with the same or lower amperage. Adding track or replacement of existing current limiters with higher continuous ampere rating will void the track lighting integral current limiter certification, and will require re-submittal of compliance documentation to the enforcement agency responsible for compliance with the California Title 24, Part 6 Building Energy Efficiency Standards."

C. Track Lighting Supplementary Overcurrent Protection Panel (§110.9(d))

A Track Lighting Supplementary Overcurrent Protection Panel is a subpanel that contains current limiters for use with multiple track lighting circuits only.

A Track Lighting Supplementary Overcurrent Protection Panel shall be used only for line-voltage track lighting and shall be recognized for compliance with the Energy Standards only if it meets all of the following requirements:

1. Before a Track Lighting Supplementary Overcurrent Protection Panel will be recognized for compliance with the lighting requirements in the Energy Standards, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.
   a. If any of the requirements in the Certificate of Installation are not met, the Track Lighting Supplementary Overcurrent Protection Panel shall not be recognized for compliance with the Energy Standards.
2. Shall be listed in accordance with Article 100 of the California Electric Code.
3. Shall be used only for line voltage track lighting. No other lighting or building power shall be used in a Supplementary Overcurrent Protection Panel, and no other lighting or building power shall be recognized for compliance with the Energy Standards by using a Supplementary Overcurrent Protection Panel.
4. Be permanently installed in an electrical equipment room, or permanently installed adjacent to the lighting panel board providing supplementary overcurrent protection for the track lighting circuits served by the supplementary over current protection pane.
5. Shall have a permanently installed label that is prominently located stating the following:

   "NOTE: This Panel for Track Lighting Energy Code Compliance Only. The overcurrent protection devices in this panel shall only be replaced with the same or lower amperage. No other overcurrent protective device shall be added to this panel. Adding to, or replacement of existing overcurrent protective device(s) with higher continuous ampere rating, will void the panel listing and require re-submittal of compliance documentation to the enforcement agency responsible for compliance with the California Title 24, Part 6 Building Energy Efficiency Standards."

5.2.3.3 **Requirements for Lighting Control Systems**

Lighting Control Systems are defined by §100.1 as requiring two or more components to be installed in the building to provide all of the functionality required to make up a fully functional and compliant lighting control. Lighting control systems may be installed for compliance with lighting control requirements in the Energy Standards providing they meet all of the following requirements:

1. A lighting control system shall comply with all requirements listed below; and all components of the system considered together as installed shall meet all applicable requirements for the lighting control application for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150(k).
2. Before a Lighting Control System (including an EMCS) can be recognized for compliance with the lighting control requirements in the Energy Standards, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

   If any of the requirements in the Certificate of Installation are not met, the Lighting Control System (or EMCS) shall be considered noncompliant.
3. If there are indicator lights that are integral to a lighting control system, they shall consume no more than one watt of power per indicator light.
4. A lighting control system shall meet all of the functional requirements in the Title 20 Appliance Efficiency Regulations for the comparable self-contained lighting control devices.

   For example, if a lighting control system is installed to comply with the Energy Standards for an occupancy sensor, then the lighting control system shall comply with all of the requirements for an occupancy sensor in Title 20. If that same lighting control system is also installed to comply with the Energy Standards for a daylighting control, then it shall also comply with all of the requirements for a daylighting control in Title 20. Each of these functions shall be documented in the Certificate of Installation (see item 2 above).
5. If the system is installed to function as a partial-on or partial-off occupant sensor, the installation may be made up of a combination of single or multi-level Occupant, Motion, or Vacancy Sensor Controls, provided that the components installed to comply with manual-on requirements shall not be capable of conversion by the user from manual-on to automatic-on functionality.

Figure 5-2: Functional Diagram for Partial-ON Occupant Sensor

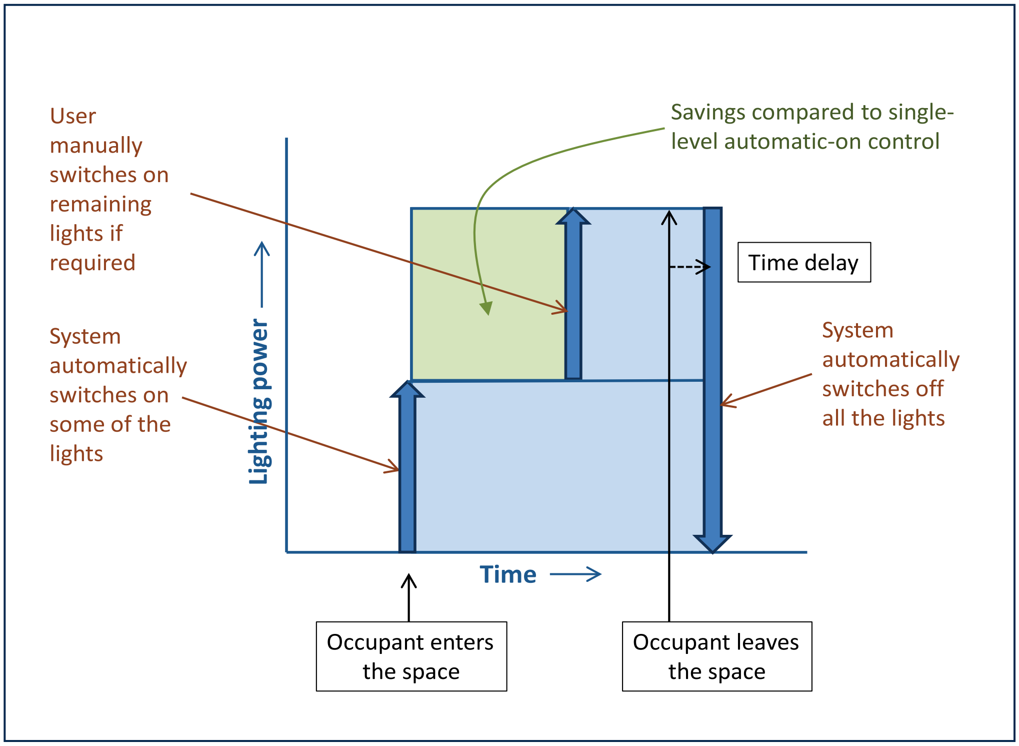
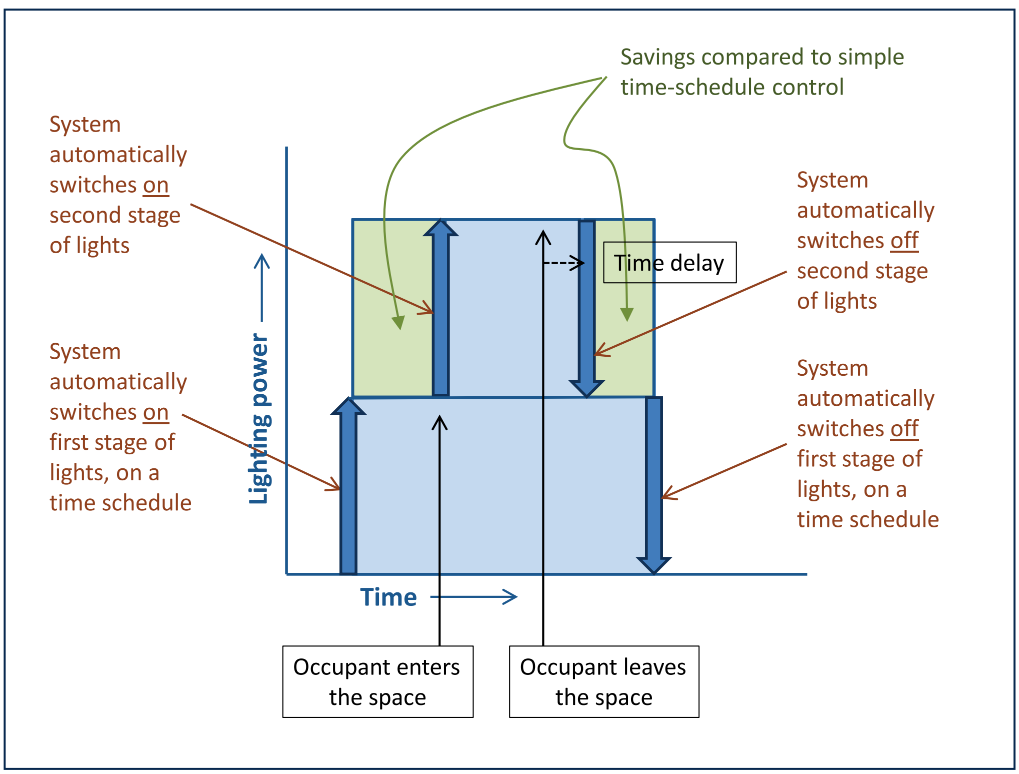


Figure 5-3: Functional Diagram for Partial-OFF Occupant Sensor



5.2.3.4 **Requirements for Residential Luminaires**

The following requirements apply only to residential lighting installations:

1. The requirements for residential lighting only apply when installed in specifically defined residential function areas that are within a nonresidential building. (See Section 5.2.1)

2. There are no requirements for certifying nonresidential luminaires in accordance with the Energy Standards. However, there are some luminaires and light sources that are designed to be installed in either residential or nonresidential applications.

   If the luminaires are designed to be installed in residential lighting applications as specified in §150.0(k) and the luminaires are classified as JA8 high efficacy luminaires in accordance with Table 150.0-A, the luminaires shall be certified to the Energy Commission according to the requirements in Reference Joint Appendix JA8 as a JA8 High Efficacy Light Source.

3. Residential High Efficacy Luminaires. Certain types of light sources are automatically classified as high efficacy, unless they are in recessed downlight luminaires. (Recessed downlight luminaires in ceilings have specific requirements, outlined in Residential Compliance Manual Chapter 6.)

   Luminaires with the following light sources are automatically classified as high efficacy:

   - Pin-based linear fluorescent luminaires using electronic ballasts
   - Pin-based compact fluorescent luminaires using electronic ballasts
   - Pulse-start metal halide luminaires
   - High pressure sodium luminaires
   - Luminaires with GU-24 sockets other than LEDs
   - Luminaires with hardwired high frequency generator and induction lamp
   - Inseparable SSL luminaires installed outdoors
   - Inseparable SSL luminaries with colored light sources for decorative lighting purpose

   The luminaire types listed here are the only types that are automatically classified as high efficacy for residential lighting application. All other luminaire types must have a light source or lamp that meets the requirements of Reference Joint Appendix JA8.

4. Ballasts for Residential Recessed Luminaires. To qualify as high efficacy for compliance with the residential lighting in §150.0(k), any compact fluorescent lamp ballast in a residential recessed luminaire shall meet all of the following conditions, in accordance with §110.9(f):

   - Be rated by the ballast manufacturer to have a minimum rated life of 30,000 hours when operated at or below a specified maximum case temperature. This maximum ballast case temperature specified by the ballast manufacturer shall not be exceeded when tested in accordance to UL 1598 Section 19.15.
   - Have a ballast factor of no less than 0.90 for non-dimming ballasts and a ballast factor of no less than 0.85 for dimming ballasts.

5.3 Mandatory Requirements for Luminaire Labeling, Classification, and Determination of Luminaire Power

§130.0(c); NA8

The requirements for maximum rated wattage labeling, classifying the type of lighting technology used, and determining how many watts of power are used in luminaires is contained in §130.0(c). While all residential luminaires are required to be high efficacy, there are no similar requirements for nonresidential luminaires.

A. Manufacturer labeling of luminaires.

1. The maximum relamping rated wattage of a luminaire shall be listed on a permanent, pre-printed, factory-installed label, as specified by UL 1574, 1598, 2108, or 8750, as applicable.
2. Peel-off and peel-down labels that allow the maximum labeled wattage to be changed are prohibited, except for luminaires meeting ALL of the following requirements:
   a. It can accommodate a range of lamp wattages without changing the luminaire housing, ballast, transformer or wiring.
   b. It has a single lamp.
   c. It has an integrated ballast or transformer.
   d. Peel-down labels are layered such that the rated wattage reduces as successive layers are removed.
   e. Qualifies as one of the following three types of luminaires:
      i. High intensity discharge luminaires, having an integral electronic ballast, with a maximum relamping rated wattage of 150 watts.
      ii. Low-voltage luminaires (this shall not apply to low voltage track systems), ≤ 24 volts, with a maximum relamping rated wattage of 50 watts.
      iii. Compact fluorescent luminaires, having an integral electronic ballast, with a maximum relamping rated wattage of 42 watts.

B. Luminaires with line voltage lamp holders not containing permanently installed ballasts are always classified as incandescent luminaires. The wattage of such luminaires shall be determined as follows:

1. The maximum relamping rated wattage of the luminaire.
2. For recessed luminaires with line-voltage medium screw base sockets, wattage shall not be less than 50 watts per socket.

For example, if a recessed luminaire has a relamping rated wattage on a permanent, pre-printed, factory-installed label of 30 watts, it shall be counted as 50 watts; if a recessed luminaire has a relamping rated wattage of 90 watts, it shall be counted as 90 watts.

Peel-down labels are never recognized for any type of incandescent luminaire.

C. Luminaires and luminaire housings designed to accommodate a variety of trims or modular components that allow the conversion between incandescent and any other lighting technology without changing the luminaire housing or wiring shall be classified as incandescent.

D. Screw-based adaptors shall not be used to convert an incandescent luminaire to any type of non-incandescent technology. Screw-based adaptors, including screw-base adaptors classified as permanent by the manufacturer, shall not be recognized for compliance with the Energy Standards.

E. Luminaires and luminaire housings manufactured with incandescent screw base sockets shall be classified only as incandescent. Field modifications, including hard wiring of an LED module, shall not be recognized as converting an incandescent luminaire or luminaire housing to a non-incandescent technology for compliance with the Energy Standards unless such sockets are removed.

F. The wattage of luminaires with permanently installed or remotely installed ballasts or drivers shall be determined as follows:

   1. The operating input wattage of the rated lamp/ballast combination published in ballast manufacturer's catalogs based on independent testing lab reports as specified by UL 1598.

   2. The maximum input wattage of the rated driver published in driver's manufacturer catalogs based on independent testing lab reports as specified by UL 8750 or LM-79-08.

G. The wattage of line-voltage lighting track and plug-in busway which allows the addition or relocation of luminaires without altering the wiring of the system shall be determined by one of the following methods:

   1. There is only one option for line voltage busway and track rated for more than 20 amperes. Wattage shall be the total volt-ampere rating of the branch circuit feeding the busway and track.

   2. There are four options for determining the wattage of line voltage busway and track rated for 20 amperes or less, as follows:

      a. The volt-ampere rating of the branch circuit feeding the track or busway.

      b. The higher of:

         i. The rated wattage of all of the luminaires included in the system, where luminaire classification and wattage is determined according to the applicable provisions in §130.0(c).

         ii. 45 watts per linear foot.

      c. When using a Line-Voltage Track Lighting Integral Current Limiter, the higher of:

         i. The volt-ampere rating of an integral current limiter controlling the track or busway.

         ii. 12.5 watts per linear foot of track or busway.

      An integral current limiter shall be certified to the Energy Commission in accordance with §110.9, and shall comply with the Lighting Control Installation Requirements.

Before a Line-Voltage Track Lighting Integral Current Limiter will be recognized for compliance with the lighting requirements in the Energy Standards, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

If any of the requirements in the Certificate of Installation are not met, the Line-Voltage Track Lighting Integral Current Limiter shall not be recognized for compliance with the Energy Standards.

d. When using a dedicated track lighting supplementary overcurrent protection panel, the sum of the ampere (A) rating of all of the overcurrent protection devices times the branch circuit voltages.

Track lighting supplementary overcurrent protection panels shall comply with the applicable requirements in §110.9, and shall comply with the Lighting Control Installation Requirements.

Before a dedicated track lighting supplementary overcurrent protection panel will be recognized for compliance with the lighting requirements, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

If any of the requirements in the Certificate of Installation are not met, the track lighting supplementary overcurrent protection panel shall not be recognized for compliance with the Energy Standards.

H. Luminaires and lighting systems with permanently installed or remotely installed transformers. The wattage of such luminaires shall be determined as follows:

1. For low-voltage luminaires that do not allow the addition of lamps, lamp holders, or luminaires without rewiring, the wattage shall be the rated wattage of the lamp/transformer combination.
2. For low-voltage lighting systems, including low voltage tracks and other low-voltage lighting systems which allow the addition of lamps, lamp holders, or luminaires without rewiring, the wattage shall be the maximum rated input wattage of the transformer, labeled in accordance with item 1, or the maximum rated wattage published in transformer manufacturer’s catalogs, as specified by UL 2108.

I. Light emitting diode (LED) Luminaires, and LED Light Engine for nonresidential applications are not required to be certified to the Energy Commission. An LED light engine is a an integrated assembly comprised of LED packages (components) or LED arrays (modules), LED driver, and other optical, thermal, mechanical and electrical components. The light engine is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed and does not use an ANSI standard (screw) base. LED luminaires and light engines for residential applications shall be certified to the Energy Commission in order to be classified as high efficacy. See Chapter 6 in the 2016 Residential Compliance Manual for information on classifying residential LED luminaires as high efficacy.

1. The wattage of such luminaires shall be the maximum rated input wattage of the system when tested in accordance with IES LM-79-08.
2. The maximum rated input wattage shall be labeled on the luminaire, light engine, or luminaire housing in accordance with §130.0(c)1. Labels only on the power supply are not sufficient for compliance with this requirement.
3. An LED lamp, integrated or non-integrated type in accordance with the definition in ANSI/IES RP-16-2010, shall not be classified as a LED lighting system for compliance with the Energy Standards. LED modules having screw-bases including but not limited to screw based pig-tails, screw-based sockets, or screw-based adaptors shall not be recognized as an LED lighting system for compliance with the Energy Standards. The intent of this requirement is to not give credit for screw based LED lamps. An ANSI/IES RP-16-2010 integrated or non-integrated LED lamp is one with a screw base. The governing wattage of a luminaire with a screw based lamp is the rated luminaire wattage and not the LED lamp. If one wants to take credit for the lower wattage afforded by a LED lamp then the luminaire must have a **GU-24 socket** or be a hard wired LED luminaire (i.e. contain a LED light engine) that is rated according to IES LM-79-08.
4. Luminaires manufactured or rated for use with low-voltage incandescent lamps, into which have been installed LED modules or LED lamps, shall not be recognized as a LED lighting system for compliance with the Energy Standards.
5. For LED lighting systems which allow the addition of luminaires or light engines without rewiring, the wattage of such luminaires shall be the maximum rated input wattage of the power supply, labeled in accordance with §130.0(c)1 or published in the power supply manufacturer's catalog.

J. The wattage of all other miscellaneous lighting equipment shall be the maximum rated wattage of the lighting equipment, or operating input wattage of the system, labeled in accordance with §130.0(c)1, or published in manufacturer's catalogs, based on independent testing lab reports as specified by UL 1574 or UL 1598.

5.3.1 Summary of Installed Luminaire Wattage

The installed wattage of indoor lighting luminaires are calculated as follows for the various type of systems:

A. Line voltage screw based luminaires (not including track lighting):

- The maximum rated wattage of the luminaire, regardless of the wattage of the lamp that is installed.
  - Additional requirements for recessed luminaires: The wattage of recessed luminaires shall not be less than 50 watts

B. Luminaires containing a hardwired ballasts:

- The rated input wattage of the lamp/ballast

C. Line voltage track lighting one of the following:

1. The larger of the rated wattage of luminaires installed on the track or 45 Watts per linear foot.
2. The volt-amps of the circuit serving the track.

3. The larger of the volt-amps of the integral current limiter serving the track or 12.5 Watts per linear foot of track.
4. The volt amps of the dedicated overcurrent protection in track lighting supplementary overcurrent protection panel.

D. Low voltage luminaires with hardwired or remotely installed transformers:

- If the lamps cannot be replaced without rewiring, the rated wattage of lamp/transformer combination.
- If the lamps can be replaced without rewiring (i.e. the lamps fit into a socket), the maximum rated input wattage of the transformer.

E. Light emitting diode (LED) luminaires and LED light engines:

- The maximum rated input wattage of the system when tested in accordance with IES LM-79-08, or

F. Screw-in LED or CFL lamps or screw-in assemblies are not recognized for their lower wattages, the rating for luminaires with screw-in lamps or assemblies is the labeled rating of the luminaire itself.

Note: The Energy Standards Nonresidential Appendix NA8 provides an alternate option for determining how many watts of power is used per luminaire. NA8 provides tables that contain a limited list of lamp and ballast combinations. These tables in NA8 provide an alternate voluntary option to the provision in §130.0(c) for determining luminaire power for any lamp and ballast combination specifically listed in NA8. Appendix NA8 is not intended to list all possible lamp and ballast combinations, and shall not to be used to determine luminaire power for any lighting system not specifically listed in NA8.

When using NA8 to determine luminaire power, luminaire classification shall still be determined in accordance with §130.0(c).

Lamp ballast combinations included in Appendix NA8 are:

- Fluorescent U-Tubes
- Fluorescent Linear Lamps T5
- Fluorescent Rapid Start T-8
- Fluorescent Eight foot T-8 High Output (HO) with Rapid Start Ballasts
- High Intensity Discharge (Metal Halide and High Pressure Sodium)
- 12 Volt Tungsten Halogen Lamps Including MR16, Bi-pin, AR70, AR111, PAR36

Example 5-1 Luminaire power

Question

I’m considering replacing tubular fluorescent lamps with tubular LED lamps as part of a larger lighting system alteration. What method can I use to determine the luminaire power for these luminaires?

Answer

Complying with §130.0(c)6: Reference Nonresidential Appendix NA8 can be used to determine luminaire power where fluorescent ballasts are used with tubular LED lamps. Simply find the matching ballast and type/length of linear or U-shaped fluorescent lamp, and use the value given in that table. If more than one value applies, use the smallest appropriate value.

5.4 Mandatory Lighting Controls

§130.1

This section contains information about lighting controls that must be installed, regardless of the method used to comply with the lighting power requirements.

All lighting controls and equipment must comply with the applicable requirements in §110.9, and must be installed in accordance with the manufacturer's instructions (§130.0(d)).

Mandatory nonresidential indoor lighting controls include the following:

1. Area Controls. Manual controls separately controlling lighting in each area.
2. Multi-Level Controls. Providing occupants with the ability to use all of the light, some of the light, or none of the light in an area.
3. Shutoff Controls. Automatically shutting off or reducing light output of lighting when the space is vacant.
4. Automatic Daylighting Controls. Separately controlling some or all of the lights in the daylight area from the lights that are not in the daylight area.
5. Demand Responsive Lighting Controls. Installing controls that are capable of receiving and automatically responding to a demand response signal.

5.4.1 Area Lighting Controls

§130.1(a)

All luminaires in each area enclosed by ceiling-height partitions shall be independently controlled from luminaires in other areas, with fully functional manual ON and OFF lighting controls.

EXCEPTION: The exception to the mandatory area lighting control requirements is that up to 0.2 watts per square foot of lighting in any area within a building may be continuously illuminated during occupied times to allow for means of egress, provided that the following conditions are met:

1. The area is designated for means of egress on the building plans and specifications submitted to the enforcement agency under §10-103(a)2 of Part 1.
2. The controls for the egress lighting are not accessible to unauthorized personnel.

5.4.1.1 **Requirements for ON and OFF Controls**

The ON and OFF lighting controls shall meet the following requirements:

1. Be readily accessible to occupants, and
2. Be operated with a manual control that is located in the same room or area with the lighting that is being controlled by that lighting control.

EXCEPTIONS: There are two exceptions to the requirements for these controls to be readily accessible and located in the same room:

1. In malls and atria, auditorium areas, retail merchandise sales areas, wholesale showroom areas, commercial and industrial storage areas, general commercial and industrial work areas, convention centers, and arenas, the lighting control shall be located so that a person using the lighting control can see the lights or area controlled by that lighting control, or so that the area being lit is annunciated.

Annunciated is defined in §100.1 as a type of visual signaling device that indicates the on, off, or other status of a load.

2. Public restrooms having two or more stalls, parking areas, stairwells, and corridors may use a manual control that is not accessible to unauthorized personnel. However, note that all other lighting controls in accordance with §130.1 are still required.

5.4.1.2 **Interaction of Manual ON and OFF Controls with Other Lighting Controls**

In addition to the manual area lighting controls, other lighting controls may be installed provided they do not override the functionality of controls installed in accordance with §130.1(a)1 (functionally controlled with a manual ON and OFF lighting control), §130.1(a)2 (readily accessible), or §130.1(a)4 (separately controlled lighting systems).

5.4.1.3 **Separately Controlled Lighting System**

In addition to the requirements in §130.1(a)1, 2, and 3:

1. General lighting shall be separately controlled from all other lighting systems in an area.
2. Floor and wall display, window display, case display, ornamental, and special effects lighting shall each be separately controlled on circuits that are 20 amps or less.
3. When track lighting is used, general, display, ornamental, and special effects lighting shall each be separately controlled.

5.4.2 Multi-Level Lighting Controls

§130.1(b) & Table 130.1-A

The multi-level lighting control requirements allow a room to be occupied with all of the lights turned on, part of the lights turned on, and none of the lights turned on, whether the room is occupied or vacant. The number of required lighting control steps varies, depending on the type of lighting technology in each installed luminaire, in accordance with Table 5-1 (Table 130.1-A of the Energy Standards). The uniformity requirements in Table 5-1 require that multi-level control occur per luminaire so one cannot meet this requirement by controlling alternate luminaires or alternate rows of luminaires. Note that switching alternate lamps in each luminaire for certain luminaire types, is permitted per Table 5-1 for meeting the illuminance uniformity requirement.

This requirement applies to enclosed spaces larger than 100 square feet and with a connected general lighting load greater than 0.5 W/ square foot. General lighting does not include task lights, display, or ornamental lighting.

These spaces also must comply with the following:

1. Lighting shall have the required number of control steps and meet the uniformity requirements in accordance with Table 130.1-A.
2. Multi-level lighting controls shall not override the functionally of other lighting controls required for compliance with §130.1(a) area controls, (c) automatic shut-off controls (d) daylighting controls. and (e) demand responsive controls.
3. Dimmable luminaires shall be controlled by a dimmer control that is capable of controlling lighting through all required lighting control steps and that allows the manual ON and OFF functionality required by §130.1(a).

5.4.2.1 **Exceptions to multi-level lighting controls**

The following applications are not required to comply with the requirements in Table 130.1-A of the Energy Standards (Table 5-1).

1. Classrooms with a connected general lighting load of 0.7 watts per square feet or less and public restrooms shall have at least one control step between 30-70 percent of full rated power.
2. An area enclosed by ceiling height partitions that has only one luminaire with no more than two lamps.
3. Areas specified in §130.1(b). These areas include:
   - Aisle ways and open areas in warehouses
   - Library book stack aisles 10 feet or longer that are accessible from only one end and library book stack aisles 20 feet or longer that are accessible from both ends
   - Corridors and stairwells
   - Parking garages, parking areas, and loading and unloading areas
4. The area specified in §130.1(c)6 and 7 are also not required to meet the requirements of §130.1(b).

Table 5-1: Multi-Level Lighting Controls and Uniformity Requirements

Luminaire Type	**Minimum Required Control Steps (percent of full rated power[1])**	**Uniform level of illuminance shall be achieved by:**
Line-voltage sockets except GU-24	Continuous dimming 10-100%	
Low-voltage incandescent systems		
LED luminaires and LED source systems		
GU-24 rated for LED		
GU-24 sockets rated for fluorescent > 20 watts	Continuous dimming 20-100%	
Pin-based compact fluorescent > 20 watts[2]		
GU-24 sockets rated for fluorescent ≤ 20 watts	Minimum one step between 30-70%	Stepped dimming; or Continuous dimming; or Switching alternate lamps in a luminaire
Pin-based compact fluorescent ≤ 20 watts[2]		
Linear fluorescent and U-bent fluorescent ≤ 13 watts		

Linear fluorescent and U-bent fluorescent > 13 watts	Minimum one step in each range:				Stepped dimming; or Continuous dimming; or Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire~~,~~ illuminating the same area and in the same manner
	20-40%	50-70%	75-85%	100%	
Track Lighting	Minimum one step between 30 – 70%				Step dimming; or Continuous dimming; or Separately switching circuits in multi-circuit track with a minimum of two circuits.
HID > 20 watts	Minimum one step between 50 – 70%				Stepped dimming; or
Induction > 25 watts					Continuous dimming; or
Other light sources					Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner.

1. Full rated input power of ballast and lamp, corresponding to maximum ballast factor
2. Includes only pin based lamps: twin tube, multiple twin tube, and spiral lamps

Table 130.1-A of the Energy Standards

5.4.3 Automatic Shut-OFF Controls

§130.1(c)

In addition to lighting controls installed to comply with §130.1(a)(manual ON and OFF controls located in each area); §130.1(b)(multi-level lighting controls); §130.1(d)(automatic daylighting controls); and §130.1(e)(demand responsive controls) - all installed indoor lighting shall be equipped with shut-OFF controls that meet the following requirements (§130.1(c)1):

A. Shall be controlled with one or more of the following automatic shut-OFF controls:
   1. Occupant sensing control.
   2. Automatic time-switch control.
   3. Other control capable of automatically shutting OFF all of the lights when the space is typically unoccupied.

B. Separate controls for lighting on each floor, other than lighting in stairwells.

C. Separate controls for lighting in each room (enclosed space); spaces larger than 5,000 square feet will have more than one separately controlled zone where each zone does not exceed 5,000 square feet.

EXCEPTION: Only in the following function areas, the separately controlled space may exceed 5,000 square feet, but may not exceed 20,000 square feet per separately controlled space, and separately controls the lighting on each floor:

a. Mall
b. Auditorium
c. Single tenant retail
d. Industrial
e. Convention center
f. Arena

D. Separate controls for general, display, ornamental, and display case lighting.

5.4.3.1 **General Exceptions to §130.1(c)1:**

The following applications are exempted from the automatic shut-OFF requirements of §130.1(c)1:

1. Where the lighting is serving an area that is in continuous use, 24 hours per day/365 days per year.
2. Lighting complying with §130.1(c)5 instead of §130.1(c)1. This exception applies to those areas where occupant sensing controls are required to shut OFF all lighting. These areas include offices 250 square feet or smaller, multipurpose rooms of less than 1,000 square feet, classrooms of any size, or conference rooms of any size, in accordance with §130.1(c)5.
3. Lighting complying with §130.1(c)6 in addition to §130.1(c)1. This exception applies only to those areas where full or partial OFF occupant sensing controls are required in addition to the requirements in §130.1(c)1. These areas include aisle ways and open areas in warehouses, library book stack aisles 10 feet or longer that are accessible from only one end, library book stack aisles 20 feet or longer that are accessible from both ends, and corridors and stairwells (§130.1(c)6).
4. Lighting complying with §130.1(c)7 instead of §130.1(c)1. This exception applies to those areas where partial OFF occupant sensing controls are required. These areas include stairwells and common area corridors that provide access to guestrooms and dwelling units, in accordance with §130.1(c)7A; or parking garages, parking areas and loading and unloading areas, in accordance with §130.1(c)7B.
5. Up to 0.1 watts per square foot of lighting may be continuously illuminated, provided that the area is designated for means of egress on the plans and specifications submitted to the enforcement agency under §10-103(a)2 of Part 1.

   Note that the above exception is a change from the previous code version. All building types are permitted up to 0.1 watts per square foot for egress lighting.
6. Electrical equipment rooms subject to Article 110.26(D) of the California Electric Code.
7. Lighting that is designated as emergency lighting, connected to an emergency power source or battery supply, and is intended to function in emergency mode only when normal power is absent.

5.4.3.2 **Use of Countdown Timer Switches**

Countdown timer switches shall not be used to comply with the automatic shut-OFF control requirements in §130.1(c)1.

EXCEPTIONS: Only the following three function areas may use a countdown timer switch to comply with the automatic shut-OFF control requirements:

1. Single-stall bathrooms smaller than 70 square feet may use countdown timer switches with a maximum setting capability of ten minutes.
2. Closets smaller than 70 square feet may use countdown timer switches with a maximum setting capability of ten minutes.
3. Lighting in a Server Aisle in a Server Room may use countdown timer switches with a maximum setting capability of 30 minutes.
    a. A Server Aisle is defined by §100.1 as an aisle of racks of Information Technology (IT) server equipment in a Server Room. While networking equipment may also be housed on these racks, it is largely a room to manage server equipment.
    b. A Server Room is defined by §100.1 as a room smaller than 500 square feet, within a larger building, in which networking equipment and Information Technology (IT) server equipment is housed, and a minimum of five IT severs are installed in frame racks.

5.4.3.3 **Requirements for Automatic Time-Switch Control**

A. Override Lighting Controls

When an occupant sensing control is used to comply with the automatic shut-OFF requirements, lighting is automatically controlled in response to the presence or absence of occupants.

However, when an automatic time-switch control is used to comply with the automatic shut-OFF requirements, such a control is not responsive to the presence or absence of occupants. Therefore, when any control other than an occupant sensing control is used (i.e. automatic time-switch control, signal from another building system, or other control capable of automatically shutting OFF all of the lights), the lighting control system shall incorporate an override lighting control that:

1. Complies with §130.1(a) (Manual ON/OFF control located in each room).
2. Allows the lighting to remain ON for no more than 2 hours when an override is initiated.

EXCEPTIONS: In the following function areas, if a captive-key override is utilized, the override time may exceed 2 hours:

a. Malls
b. Auditoriums
c. Single tenant retail
d. Industrial
e. Arenas

B. Holiday “Shut-OFF” Feature

If an automatic time-switch controls installed to comply with §130.1(c)1, it shall incorporate an automatic holiday "shut-OFF" feature that turns OFF all loads for at least 24 hours, and then resumes the normally scheduled operation.

EXCEPTIONS: In only the following function areas, the automatic time-switch control is not required to incorporate an automatic holiday shut-OFF feature:

a. Retail stores and associated malls
b. Restaurants
c. Grocery stores
d. Churches
e. Theaters

5.4.3.4 Areas where Occupant Sensing Controls are required to shut OFF ALL Lighting

§130.1(c)5

Lighting in the following function areas shall be controlled with occupant sensing controls to automatically shut OFF all of the lighting when the room is unoccupied. In addition, controls shall be provided that allow the lights to be manually shut-OFF in accordance with §130.1(a) regardless of the sensor status:

a. Offices 250 square feet or smaller
b. Multipurpose rooms of less than 1,000 square feet
c. Classrooms of any size
d. Conference rooms of any size

In areas required by §130.1(b) to have multi-level lighting controls, the occupant sensing controls shall function either as a:

a. Partial-ON Occupant Sensor capable of automatically activating between 50-70 percent of controlled lighting power.
b. Vacancy Sensor that automatically turns lights OFF after an area is vacated of occupants but requires lights to be turned ON manually.

In areas not required by §130.1(b) to have multi-level lighting controls, the occupant sensing controls may function as either as a:

a. Normal occupant sensor.
b. Partial-ON occupancy sensor.
c. Vacancy sensor.

Note that multipurpose rooms less than 1,000 square feet, classrooms greater than 750 square feet and conference rooms greater than 750 square feet are required to be equipped with an occupancy sensor that controls the HVAC thermostat setup and setback and ventilation (§120.2(e)3). As a result, the occupancy sensor or lighting control system in the space must be capable of triggering the HVAC without fully triggering the lighting load.

The same occupancy sensor used to control the lighting can also control the HVAC system. Besides the cost benefit, the benefit of using the lighting occupancy sensor to control the HVAC unit is that it is immediately apparent that the occupancy sensor has failed when it is controlling the lighting and it may be less apparent that the sensor has failed if it is controlling only the HVAC system.

This method of controlling cooling, ventilation and lighting satisfies the requirements of §120.2(e)3 and §130.1(c), so no additional shutoff controls are required in these spaces, except in cases of lighting associated with the egress path, which may remain energized until the building is scheduled to normally be unoccupied.

5.4.3.5 Areas where full or partial OFF occupant sensing controls are required in addition to complying with §130.1(c)1

§130.1(c)6

In addition to the basic shutoff requirements in §130.1(c)1, §130.1(c)6 requires a shutoff device (typically a timeswitch) for the lighting system, which may be done in a building-wide manner. Lighting in the listed spaces (warehouses, library book stack aisles, and stairwells and corridors) must have the capability to reduce lighting power by at least 50 percent when they are unoccupied.

Egress lighting equipment is exempted, and may remain at full power until the building is beyond the “normally occupied” schedule, at which time it may be placed on occupancy sensors and turned OFF completely.

A. In aisle ways and open areas in warehouses, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls must have independent zoning for each aisle, and the aisle zones must not extend beyond the aisle into the open area of the warehouse.

   EXCEPTIONS: The following conditions exempt the lighting system from this requirement, but they must meet the additional listed requirements:

   1. In aisle ways and open areas in warehouses in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce lighting power by at least 40 percent (instead of the 50 percent required above).
   2. When metal halide lighting or high pressure sodium lighting is installed in warehouses, occupant sensing controls shall reduce lighting power by at least 40 percent (instead of the 50 percent required above). This is a limitation of the dimming or bi-level ballast technology for HID light sources.

   Note that even if the exemptions apply, these only result in a lighting power reduction associated with aisles and open areas during “normally occupied” periods. These spaces are still required to comply with the applicable automatic shut-OFF controls in §130.1(c), which will produce deeper savings during the “after hours” periods.

B. In library book stack aisles meeting the following criteria, lighting shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied:

   1. Library book stack aisles 10 feet or longer that are accessible from only one end.
   2. Library book stack aisles 20 feet or longer that are accessible from both ends.

   The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the aisle way being controlled by the sensor.

Note: This lighting is required to comply with the applicable automatic shut-OFF controls in §130.1(c).

C. Lighting installed in corridors and stairwells shall be controlled by occupant sensing controls that separately reduce the lighting power in each space by at least 50 percent when the space is unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.

Note: These subsections indicate that the lighting must turn off the lights *at least* 50 percent, but the decision to turn off the lights fully may be made by the designer. There is no limit on the maximum the lights may be turned off, as there is in some other portions of the code.

The lighting in this section must also comply with the other portions of §130.1(c) that requires a full shutoff capability, which in the case of a partial-OFF sensor, would probably be triggered by a timeswitch.

5.4.3.6 **Areas where partial OFF occupant sensing controls are required instead of complying with §130.1(c)1**

§130.1(c)7

The listed areas are required to have a Partial-OFF lighting control system INSTEAD of meeting the shutoff requirements of §130.1(c), however, that does not mean that they are not permitted to also meet those basic shutoff requirements, only that they are not required. This means that lighting in stairwells and corridors of hotels/motels and parking garages may operate on a full-time basis at the minimum setback level, and are not required to be shut OFF in the “after hours” periods as the majority of building lighting is required to be.

A. Lighting in stairwells and common area corridors which provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels shall be controlled with occupant sensing controls that automatically reduce lighting power by at least 50 percent when the areas are unoccupied. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress. This permits the lights to remain ON at a setback level continuously. Note that the zoning of the controls require careful consideration of paths of egress to ensure that the sensor coverage in the zone is adequate.

EXCEPTION: In common area corridors and stairwells in which the installed lighting power is 80 percent or less of the value allowed under the Area Category Method, occupant sensing controls shall reduce power by at least 40 percent (instead of the 50 percent required above).

B. In parking garages, parking areas and loading and unloading areas, the general lighting shall be controlled as follows:

1. By occupant sensing controls having at least one control step between 20 percent and 50 percent of design lighting power.
2. No more than 500 watts of rated lighting power shall be controlled together as a single zone.
3. A reasonably uniform level of illuminance shall be achieved in accordance with the applicable requirements in Table 5-1 (Table 130.1-A of the Energy Standards).

4. The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in each separately controlled space.
5. The occupant sensing controls shall be automatically activated from all designed paths of egress.

This states that the lighting power must be reduced by at least 50 percent of the original lighting power, and that the lighting must be reduced while maintaining similar levels of uniformity to the full power conditions. Note that the zoning of the controls require careful consideration of paths of egress to ensure that the sensor coverage in the zone is adequate, and the wattage limits per zone will typically not permit entire floors of a garage to be on a single zone.

EXCEPTION: Metal halide luminaires meeting the following criteria shall be controlled by occupant sensing controls having at least one control step between 20 percent and 60 percent of design lighting power:

- Have a metal halide lamp plus ballast mean system efficacy of greater than 75 lumens per watt, (the lamp/ballast mean system efficacy is the rated mean lamp lumens at 40 percent of lamp life[1] divided by the ballast rated input watts) and
- Are used for general lighting in parking garages, parking areas and loading and unloading areas.

The requirement for metal halide luminaires to have a control step between 20 percent and 60 percent is a limitation of the dimming or bi-level ballast technology for HID light sources.

Note that interior areas of parking garages are classified as indoor lighting for compliance with §130.1(c)7B.

The parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in §130.2. These controls provisions in §130.1(c)7B do not apply to open rooftop parking.

§130.1(c)7 indicates that the lighting must turn off the lights by at least 50 percent, but the decision to turn the lights off fully may be made by the designer.

The spaces listed in these sections are not required to meet the other requirements in §130.1(c) for full shutoff capability (these do not need to be connected through a timeswitch for unoccupied hours shutoff).

5.4.3.7 **Requirements for Hotel and Motel Guest Rooms**

§130.1(c)8

In addition to complying with the low-rise residential lighting Standards in accordance with §130.0(b), hotel and motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that, no longer than 30 minutes after the guest room has been vacated, lighting power is switched off.

[1] Illuminating Engineering Society. Section 13.3 “Life and Lumen Maintenance” in The Lighting Handbook: 10th Edition Reference and Application. 2011. New York..

EXCEPTION: A luminaire in a hotel or motel guest room meeting all of the following criteria is not required to have captive card key controls, occupancy sensing controls, or automatic controls under the following conditions:

- Applies to one high efficacy luminaire (where high efficacy is defined in §150.0(k) and Table 150.0-A), and
- That is switched separately from the other lighting in the room, and
- The switch for that luminaire is located within 6 feet of the entry door.

This one high efficacy luminaire is exempted so a person can turn on a light switch to find the captive card control.

5.4.4 Automatic Daylighting Controls

§130.1(d)

Daylighting can be used as an effective strategy to reduce electric lighting energy use by reducing electric lighting power in response to available daylight. §130.1(d) addresses mandatory requirements for daylighting.

Additional lighting controls are required in daylit zones to automatically shut off lighting when sufficient daylight is available.

Prescriptive daylighting controls are covered in subchapter 5.5 of this chapter.

5.4.4.1 Description of Terms

The following terms are used to describe the daylighting requirements in §130.1(d).

A. General Lighting - Electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting, and also known as ambient light.

Typical luminaires used for general lighting are troffers (prismatic, parabolic, or indirect diffusers), pendants (direct, indirect, or direct/indirect), high bay, low bay, and “aisle-lighter” fixtures. General lighting does not include display lighting (typically using directional MR, PAR, flood, spot, or wall washers) or ornamental lighting (such as drum fixtures, chandeliers, or projection lighting.)

B. Window Head Height - The vertical distance from the finished floor level to the top of a window

C. Daylit Zones - A region of space considered to be close to a source of daylight such as window, clerestory, roof monitor or skylight, where luminaires can be dimmed or switched in response to available daylight.

5.4.4.2 Definitions of Daylit Zones

Areas having skylights and windows are classified according to daylit zones. The three different types of daylit zones are defined as follows:

A. Skylit Daylit Zone is the rough area in plan view under each skylight, plus 0.7 times the average ceiling height in each direction from the edge of the rough opening of the skylight, minus any area on a plan beyond a permanent obstruction that is taller than the following:

- A permanent obstruction that is taller than one-half the distance from the floor to the bottom of the skylight.

The bottom of the skylight is measured from the bottom of the skylight well for skylights having wells, or the bottom of the skylight if no skylight well exists.

For the purpose of determining the Skylit Daylit Zone, the geometric shape of the Skylit Daylit Zone shall be identical to the plan view geometric shape of the rough opening of the skylight; for example, for a rectangular skylight the Skylit Daylit Zone plan area shall be rectangular, and for a circular skylight the Skylit Daylit Zone plan area shall be circular.

Note: Modular furniture walls shall not be considered a permanent obstruction.

Figure 5-4: Skylit Daylit Zone Diagram

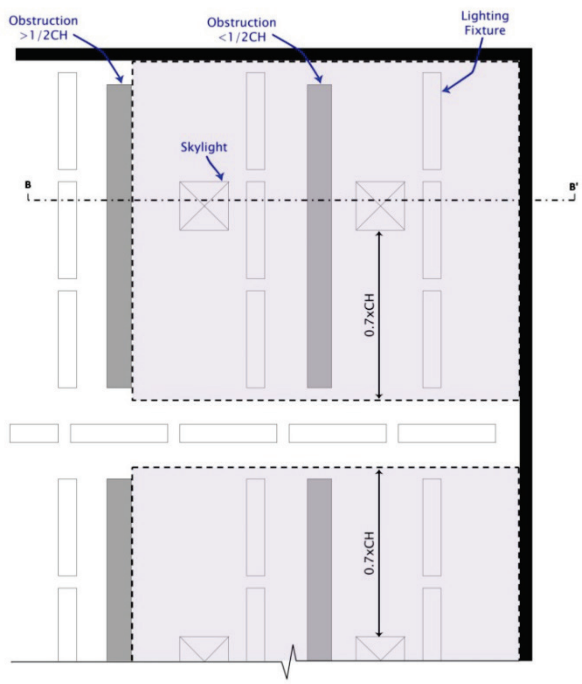
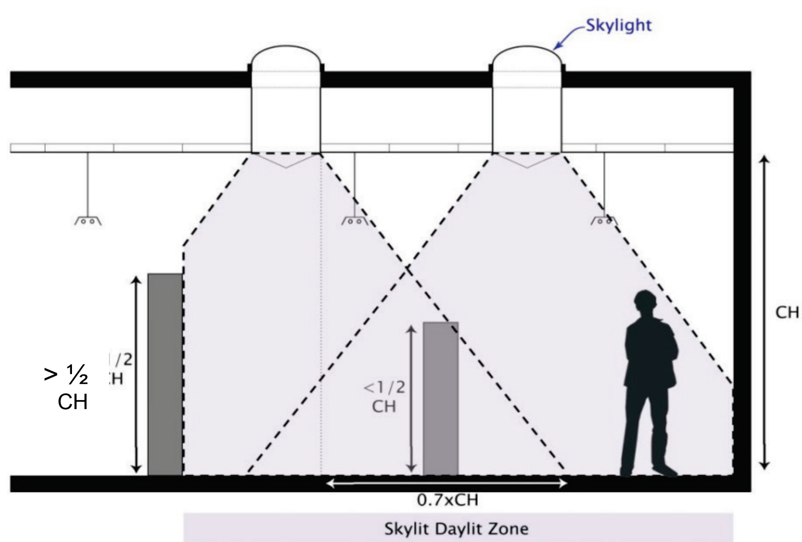


Figure 5-5: Skylit Daylit Zone Diagram 2



B. **PRIMARY SIDELIT DAYLIT ZONE** is the area in plan view and is directly adjacent to each vertical glazing, one window head height deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

Note: Modular furniture walls shall not be considered a permanent obstruction.

Figure 5-6: Primary Sidelit Daylit Zone Diagram 1

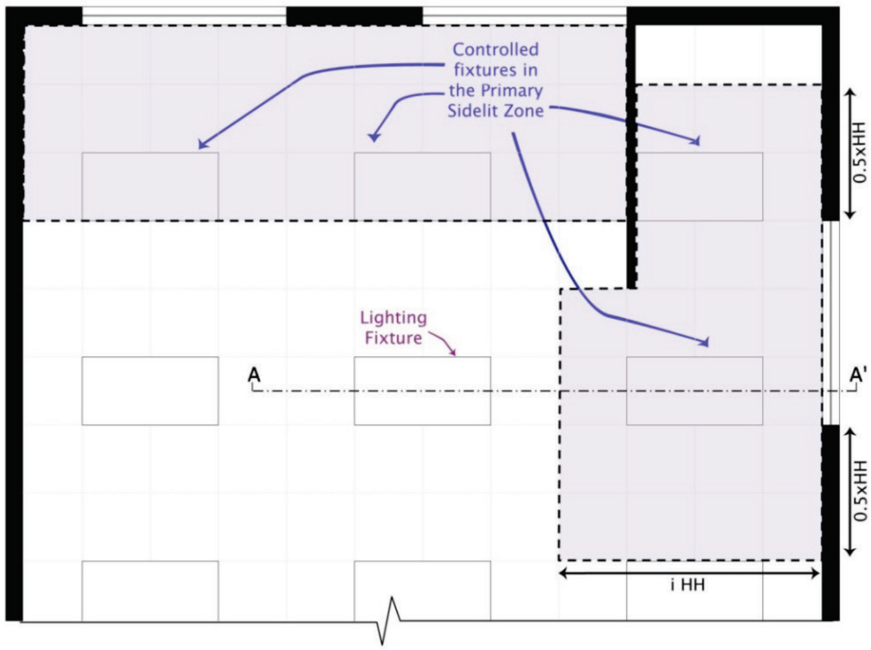
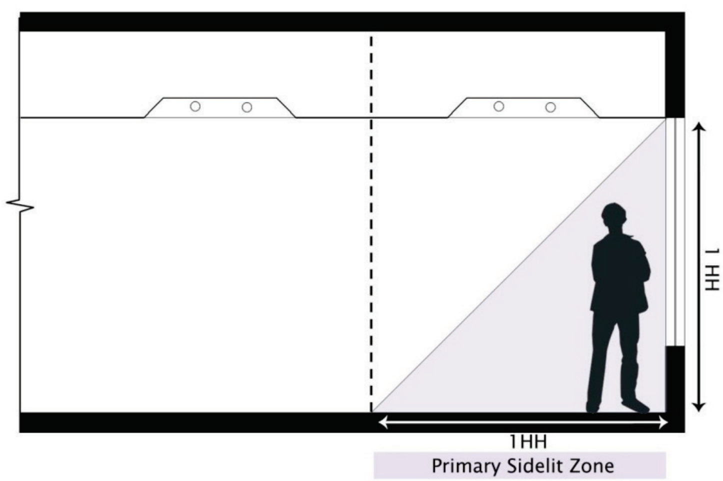


Figure 5-7: Primary Sidelit Daylit Zone Diagram 2



C. **SECONDARY SIDELIT DAYLIT ZONE** is the area in plan view and is directly adjacent to each vertical glazing, two window head heights deep into the area, and window width plus 0.5 times window head height wide on each side of the rough opening of the window, minus any area on a plan beyond a permanent obstruction that is 6 feet or taller as measured from the floor.

Note: Modular furniture walls shall not be considered a permanent obstruction.

The daylighting controls in the Skylit Daylit Zone and the Primary Sidelit Daylit Zone are mandatory; they cannot be traded away for other efficiency measures when using the performance (whole building energy simulation) approach. The daylighting controls requirements in the Secondary Sidelit Daylit Zone is prescriptive and thus can be traded away for other efficiency measures in the performance approach. If code compliance is accomplished with the prescriptive approach then daylighting controls will be required in both the Primary and Secondary Sidelit Daylit Zones and these two zones must be controlled separately from each other.

Figure 5-8: Secondary Sidelit Daylit Zone Diagram 1

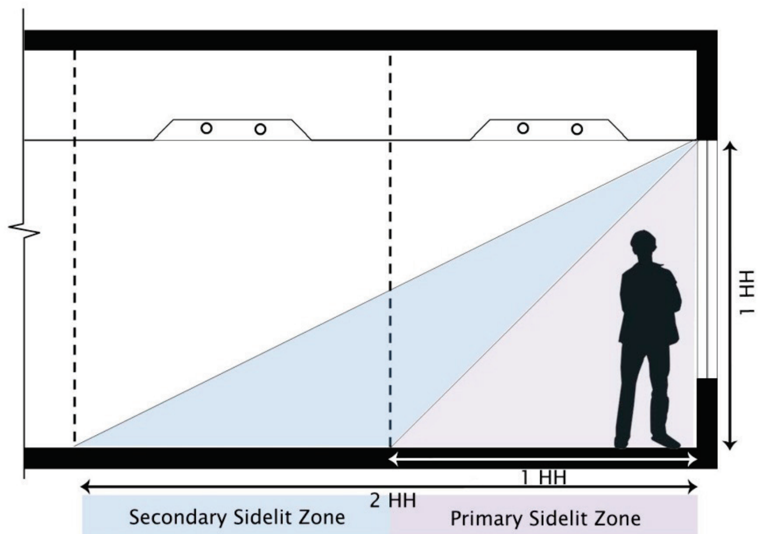
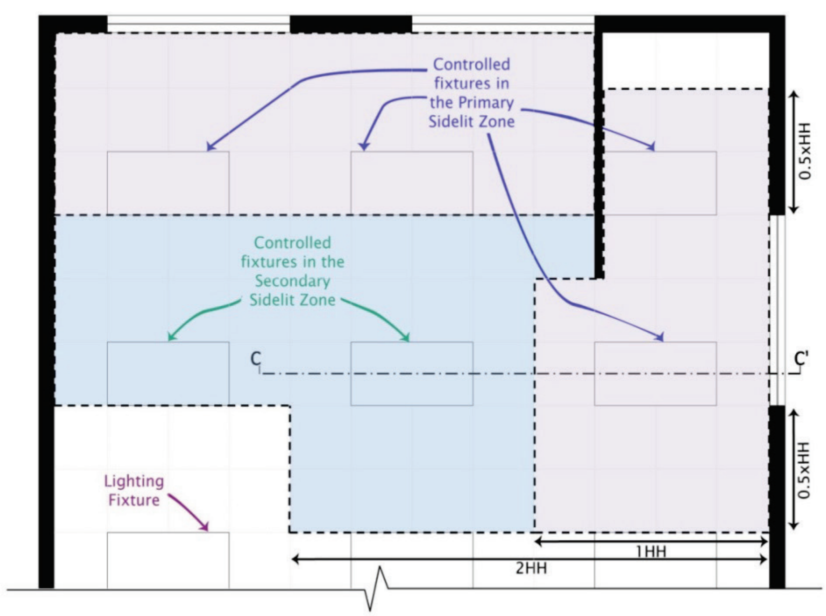


Figure 5-9: Secondary Sidelit Daylit Zone Diagram 2



5.4.4.3 **Controlling Lighting in Daylit Zones**

Mandatory daylighting controls for lighting in Skylit Daylit Zones and Primary Sidelit Daylit Zones are covered in this subchapter.

There are also prescriptive controls required for lighting in Secondary Sidelit Daylit Zones. The prescriptive daylighting controls are covered in Section 5.5 of this chapter.

Mandatory daylighting controls are required in the following daylit zones:

A. Luminaires providing general lighting that are in, or at least 50 percent in, the Skylit Daylit Zones or the Primary Sidelit Daylit Zones shall be controlled independently by fully functional automatic daylighting controls that meet the applicable device requirements in §110.9, and meet the applicable requirements below:

   1. All Skylit Daylit Zones and Primary Sidelit Daylit Zones shall be shown on the building plans.

   2. Luminaires in the Skylit Daylit Zone shall be controlled separately from those in the Primary Sidelit Daylit Zones.

   3. Luminaires that fall in both a Skylit and Primary Sidelit Daylit Zone shall be controlled as part of the Skylit Daylit Zone.

There are also prescriptive daylighting control requirements, which are covered in Section 5.5 of this chapter.

5.4.4.4 **Automatic Daylighting Control Installation and Operation**

For luminaires in Skylit Daylit Zones and Primary Sidelit Daylit Zones, automatic daylighting controls shall be installed and configured to operate according to all of the following requirements:

1. Photosensors shall be located so that they are not readily accessible to unauthorized personnel. The location where calibration adjustments are made to automatic daylighting controls shall be readily accessible to authorized personnel and may be inside a locked case or under a cover which requires a tool for access. Access to controls can be limited by placing locks or screws on enclosures or under a cover plate so a tool or key is needed to gain access. Though not required, commissioning and retro-commissioning of the control is simplified if the calibration adjustments are readily accessible to authorized personnel so that a lift or a ladder is not required to access the location where calibration adjustment are made.

   Some controls have wireless remotes for adjusting settings; this is convenient as one person can be located at the edge of the daylit zone with a light meter and the wireless calibration tool and make the calibration adjustments without having to run back and forth between taking the measurement and making the adjustment.

2. Automatic daylighting controls shall provide functional multi-level lighting levels having at least the number of control steps specified in Table 5-1 (Table 130.1-A of the Energy Standards).

   EXCEPTION: Multi-level lighting controls are not required if the controlled lighting has a lighting power density less than 0.3 W/ft^{2}.

   Note that when the requirements of §130.1(d) are triggered by the addition of skylights to an existing building and the lighting system is not recircuited, the daylighting control need not meet the multi-level requirements in §130.1(d). This is in accordance with §141.0(b)2G for alterations.

3. For each space, the combined illuminance from the controlled lighting and daylight shall not be less than the illuminance from controlled lighting when no daylight is available.

   In the darkest portion of the daylit zone (furthest away from windows or skylights) the control should not over-dim the lights; this portion of the daylit area should not get darker as daylight levels increase, due to incorrect calibration of the controls.

4. In areas served by lighting that is daylight controlled, when the daylight illuminance is greater than 150 percent of the design illuminance received from the general lighting system at full power, the general lighting power in that daylight zone shall be reduced by a minimum of 65 percent.

   The best control would fully dim the system when daylight levels in the darkest portion of the daylit zone are at 100 percent of design illuminance, but the 150 percent /65 percent requirement allows some tolerance for error while obtaining most of the energy savings.

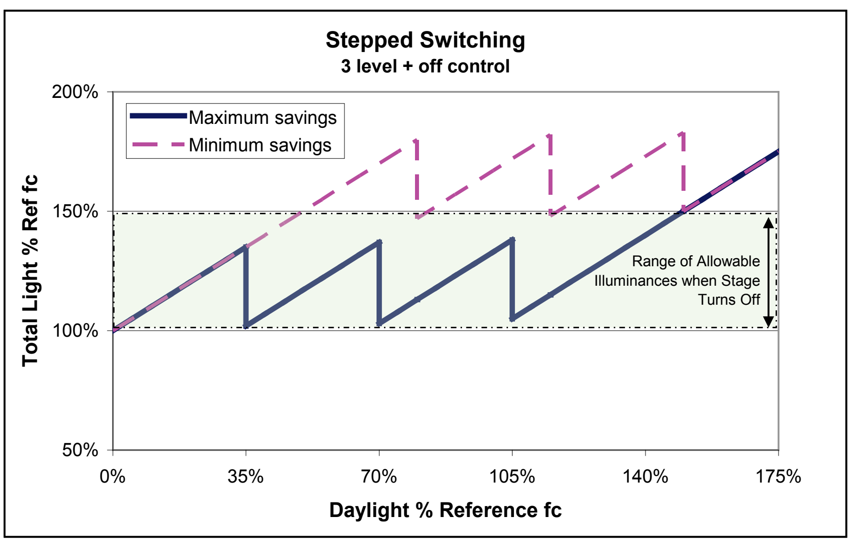
   EXCEPTIONS: Automatic daylighting controls are not required for any of the following conditions:

   - Rooms in which the combined total installed general lighting power in the Skylit Daylit Zone and Primary Sidelit Daylit Zone is less than 120 Watts.
   - Rooms which have a total glazing area of less than 24 square feet.
   - Parking garages complying with §130.1(d)3.

Figure 5-10 and Figure 5-11 plot the performance of switching and dimming automatic daylighting controls (photo controls). The performance is indicated in terms of lighting at the darkest point of the zone served by the controlled lighting.

The total lighting as plotted on the y-axis made up of both daylit and electric lighting contribution to total foot-candles (fc) at this darkest location in the zone served by the controlled lighting. Daylight plotted on the x-axis is just the daylight available at this darkest location.

Figure 5-10: Stepped Switching



In Figure 5-10, the light levels are given as a fraction of the reference or design foot-candles (fc). The bottom points of both controls indicate the total illuminance just after a stage of lighting has switched off. Both controls are compliant because the total illuminance at the darkest location in the zone served by controlled lighting just after switching off a stage of lighting is between 100 and 150 percent of the reference illuminance. The reference illuminance is the illuminance at this same location when there is no daylight (night time).

Figure 5-11: Dimming Controls

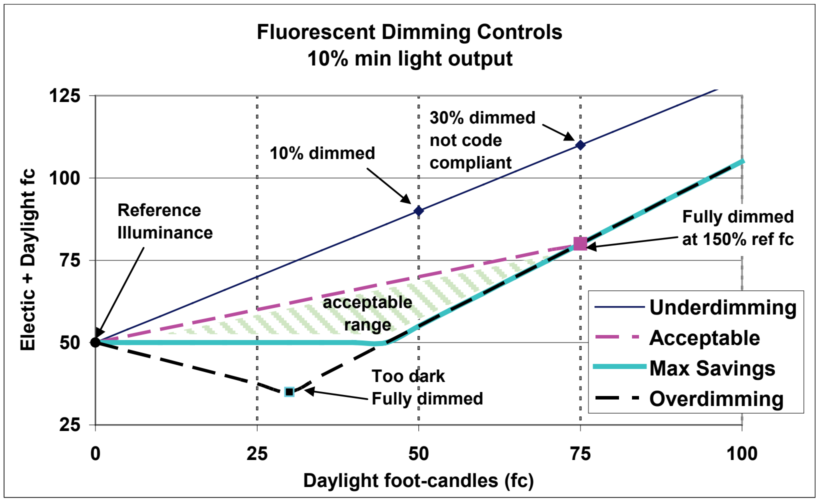


Figure 5-11 plots the performance of complying ("Acceptable" and "Max Savings") and non-complying ("Under-dimming" and "Over-dimming") controls. By fully dimming when daylight is 150 percent of the reference illuminance and also assuring that the total illuminance never falls below the reference illuminance (50 fc), the "Acceptable" control is minimally complaint with the requirements of §130.1(d)2D. Even greater savings are possible with the "Max Savings" control that maintains the 50 fc reference under all partially daylit conditions and is fully dimmed at 150 percent of the reference illuminance.

The "Under-dimming" control is only 30 percent dimmed when the daylight in the darkest portion of the zone served by the controlled lighting is at 150 percent of the reference illuminance (75 fc). The "Under-dimming" control does not save enough energy and thus is not code compliant. The "Over-dimming" condition reduces the electric lighting by more than the amount of daylight that enters the space. As a result, it actually is darker in portions of the space under partial daylight conditions than it is at night. In the short term, the "Over-dimming" control may save the most energy.

However, over the long term it is likely that the occupants may disable the control and the control would save no energy. As a result the "Over-dimming" control is not code compliant.

These performance metrics of complying and non-complying control systems are the basis of the functional performance tests for the Automatic Daylighting Controls acceptance test. This test is described in detail in Chapter 10 – Acceptance Testing.

5.4.4.5 **Parking Garage Daylighting Requirements**

In a parking garage area having a combined total of 36 square feet or more of glazing or opening, luminaires providing general lighting that are in the combined Primary and Secondary Sidelit Daylit Zones shall be controlled independently from other lighting in the parking garage by automatic daylighting controls, and shall meet the following requirements as applicable:

A. All Primary and Secondary Sidelit Daylit Zones shall be shown on the building plans.

B. Automatic Daylighting Control Installation and Operation.

Automatic daylighting control shall be installed and configured to operate according to all of the following requirements:

1. Automatic daylighting controls shall have photosensors that are located so that they are not readily accessible to unauthorized personnel. The location where calibration adjustments are made to the automatic daylighting controls shall be readily accessible to authorized personnel but may be inside a locked case or under a cover which requires a tool for access.
2. Automatic daylighting controls shall be multi-level, continuous dimming or ON/OFF.
3. The combined illuminance from the controlled lighting and daylight shall not be less than the illuminance from controlled lighting when no daylight is available.
4. When illuminance levels measured at the farthest edge of the Secondary Sidelit Zone away from the glazing of opening are greater than 150 percent of the illuminance provided by the controlled lighting when no daylight is available, the controlled lighting power consumption shall be zero.

EXCEPTIONS:

1. Luminaires located in the daylight transition zone and luminaires for dedicated ramps. Daylight transition zone and dedicated ramps are defined in §100.1.
2. When the total combined general lighting power in the Primary Sidelit Daylight Zones is less than 60 watts.

The primary differences between the automatic daylight control requirements in parking garages and the rest of interior lighting spaces are:

- Primary and Secondary Zone are controlled together in parking garages whereas they must be separately controlled in other spaces. However, it is permissible that in either space type, a single sensor is used if the control system is capable of making the appropriate light level adjustments in each individual zone.
- Daylighting controls in parking garages are permitted to use an ON/OFF control strategy, whereas for all other interior spaces the control must be step switching or dimming
- When sufficient daylight is present, controlled lighting in parking garages must be OFF whereas in other interior spaces the lighting power must be reduced by 65 percent. Egress lighting for the parking garage may be controlled, but the controls must employ a failsafe mechanism that ensures that the egress lighting is functioning and stays ON if the photocell fails.

Examples for complying with the mandatory daylighting controls requirements, and the prescriptive daylighting requirements are covered in Section 5.5 of this chapter.

5.4.5 Demand Responsive Controls

§130.1(e)

DEMAND RESPONSE is defined in §100.1 as short-term changes in electricity usage by end-use customers, from their normal consumption patterns. Demand response may be in response to:

1. Changes in the price of electricity.
2. Participation in programs or services designed to modify electricity use in response to wholesale market prices or when system reliability is jeopardized.

A. Buildings larger than 10,000 square feet, excluding spaces with a lighting power density of 0.5 W/ft^2 or less, shall be capable of automatically reducing lighting power in response to a Demand Responsive Signal; so that the total lighting power of the non-excluded spaces can be lowered by a minimum of 15 percent below the total installed lighting power when a Demand Response Signal is received. Lighting shall be reduced in a manner consistent with uniform level of illumination requirements in Table 5-1 (Table 130.1-A of the Energy Standards).

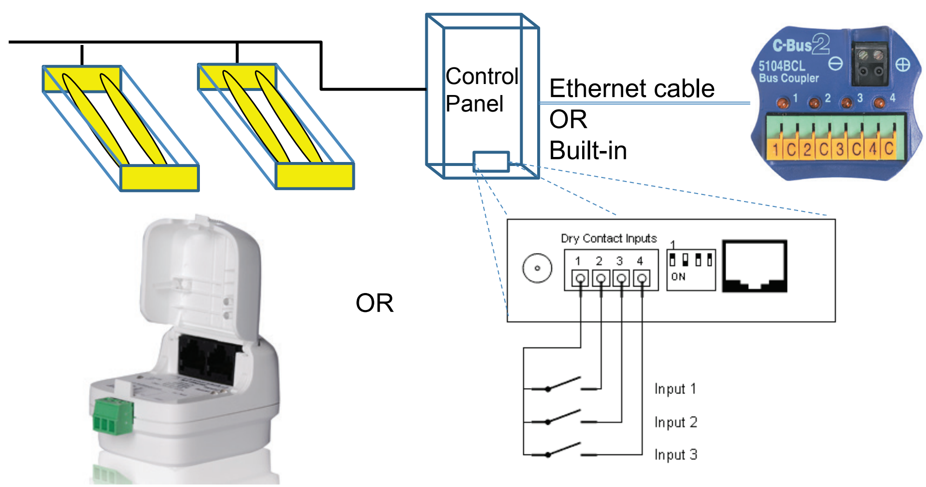
EXCEPTION: Lighting not permitted by a health or life safety statute, ordinance, or regulation to be reduced shall not be counted toward the total lighting power.

B. Demand responsive controls and equipment shall be capable of receiving and automatically responding to at least one standards-based messaging protocol by enabling demand response after receiving a demand response signal.

Example 5-2 Compliance Method 1 – using Centralized Powerline Dimming Control

This method requires the use of luminaires with dimmable ballasts or LED drivers, compatible with powerline controls, and the use of a lighting control panel downstream of the breaker panel. The lighting circuit relays are replaced by circuit controllers, which can send the dimming signal via line voltage wires. The panel could have several dry contact inputs that provide dedicated levels of load shed depending upon the demand response signal received. Different channels can be assigned to have different levels of dimming as part of the demand response. Local controls can be provided by either line voltage or low voltage controls.

Figure 5-12: Potential inputs to receive Demand Response signal



Network adapter for zone based system

Figure 5-12 illustrates example inputs that could be used to receive demand response signals. The inclusion of one of these types of control inputs, along with the proper design of the lighting system, will result in a lighting system that complies with the requirements of §130.1(e).There are several ways in which the lighting can be designed to meet the demand responsive requirements; outlined below are three specific compliance scenarios.

Example 5-3 Compliance Method 2 – using Addressable Lighting System

The addressable lighting system is similar in design to that of a centralized control panel, but with additional granularity of control. With an addressable system, each fixture can be addressed individually, whereas a centralized control panel is limited to an entire channel, or circuit, being controlled in unison. The cost of enabling demand response on a system with a centralized control panel is less dependent on building size or number of rooms than an addressable zone based system.

Enabling demand response for the addressable lighting system entails making a dry contact input available to receive an electronic signal. This is a feature that is included in the base model of most lighting control panels. Some smaller scale addressable lighting systems may have a limited number of inputs dedicated for alternative uses, such as a time clock. If this is the case, an I/O input device can be added to the network to provide an additional closed contact input.

Example 5-4 Demand Response for Select Zones

Enabling demand response for a zoned system would entail adding a network adapter to each room to be controlled for purposes of demand response. The network adapter allows for each room to be monitored and controlled by an energy management control system (EMCS). These types of systems are commonly used for HVAC systems, and to respond to demand response signals. The assumption is that if the building is installing an EMCS, the preference would be to add the lighting network to that existing demand response system. There is additional functionality that results from adding the lighting system to an EMCS. In addition to being able to control the lighting for demand response, the status of the lighting system can then be monitored by the EMCS. For example, occupancy sensors would be able to be used as triggers for the HVAC system, turning A/C on and off when people entered and leave the room. Therefore the potential for savings from this type of system is higher than the value of the lighting load shed for demand response.

5.4.6 Lighting Control Acceptance Requirements (§130.4)

Before an occupancy permit shall be granted for a newly constructed building or area, or a new lighting system serving a building, area, or site is operated for normal use, indoor and outdoor lighting controls serving the building, area, or site shall be certified as meeting the Acceptance Requirements for Code Compliance.

A Certificate of Acceptance shall be submitted to the enforcement agency under §10-103(a) of Part 1 and §130.4(a), that:

1. Certifies that all of the lighting acceptance testing necessary to meet the requirements of Part 6 is completed
2. Certifies that the applicable procedures in Reference Nonresidential Appendix NA7.6 and NA7.8 have been followed
3. Certifies that automatic daylight controls comply with §130.1(d) and Reference Nonresidential Appendix NA7.6.1
4. Certifies that lighting shut-OFF controls comply with §130.1(c) and Reference Nonresidential Appendix NA7.6.2
5. Certifies that demand responsive controls comply with §130.1(e) and Reference Nonresidential Appendix NA7.6.3
6. Certifies that outdoor lighting controls comply with the applicable requirements of §130.2(c) and Reference Nonresidential Appendix NA7.8
7. Certifies that lighting systems receiving the Institutional Power Adjustment Factor comply with §140.6(a)2J and Reference Nonresidential Appendix NA7.7.6.2

5.4.7 Lighting Certificate of Installation Requirements

Before any of the following applications will be recognized for compliance with the lighting requirements, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation for installation of the following items:

1. Lighting Control System
2. Energy Management Control System
3. Track lighting integral current limiter
4. Track lighting supplementary overcurrent protection panel
5. Interlocked lighting systems service a single space
6. Lighting controls installed to earn a lighting Power Adjustment Factor (PAF)
7. Additional lighting wattage available for a videoconference studio

If any of the requirements in the Certificate of Installation fail the installation requirements, that application shall not be recognized for compliance with the Energy Standards.

5.4.8 Summary of Mandatory Controls

Table 5-2: Summary of Mandatory Nonresidential Lighting Control Requirements

Bldg/Space Type	Application	LPD	Control	Additional Exception
All except industrial and arenas	All except sales floors, auditoriums, malls with remote controls in view of lighting or annunciated.	------	Manual light switch in each enclosed space separately controlling general, display ornamental and special effects lighting.	1
All	Enclosed spaces > 100 square foot and > 1 luminaire with > 2 lamps	> 0.5 W/ square foot	Multi-level control of each luminaire	2
All except parking garage	All except hotel/motel high-rise res common area corridors and stairwells	All	Automatic full shut off controls (timeclock and timed override switch or occupancy sensor)	3
All	Offices < 250 square foot, multi-purpose rooms < 1,000 square foot, classrooms, conference rooms	All	Automatic full shut off occupancy sensors that also must operate as either partial-ON sensors or vacancy sensors	------
Warehouse	Aisles and open areas	All	Occupant sensor per aisle and for open areas, reduce power by at least 50 percent	4
Library	Single ended stacks > 10 ft or double ended stacks > 20 ft	All	Occupant sensor per aisle, reduce power by at least 50 percent	------
All except hotel/motel, high rise residential	Corridors and stairwells	All	Occupant sensor per space, reduce power by at least 50 percent, turn lights on from all paths of egress	------
Hotel/motel, high rise residential	Corridors and stairwells	All	Occupant sensor per space, reduce power by at least 50 percent. No additional shut-off controls are required	5
Parking garages	------	All	Partial off occupancy sensor with one sensor per 500 W of lighting and with control step between 20 percent and 50 percent or rated power.	6
Hotel/motel	Guest room	All	Captive card key or occupancy sensing on/off control	7
All except parking garage	> 24 square foot of glazing per room and more than 120 W in skylit and primary sidelit daylight zones	> 0.3 W square foot	Multi-level daylighting controls separately controlling skylit, primary sidelit and secondary sidelit daylight zones	8
All except parking garage	> 24 square foot of glazing per room and more than 120 W in skylit and primary sidelit daylight zones	< 0.3 W square foot	Multi-level or On/off daylighting controls separately controlling skylit, primary sidelit and secondary sidelit daylight zones	8
Parking garage	> 36 square foot of opening or glazing, > 60 watts in combined primary and sidelit daylight zone		Multi-level or On/off daylighting controls controlling combined primary and secondary sidelit daylight zones.	9
All bldg > 10,000 square foot	Habitable spaces	> 0.5 W/ square foot	Demand responsive control to lower building lighting power by 15 percent	------

1. Egress lighting up to 0.2 W/ square foot. Switch accessible to authorized personnel for multi-stall bathrooms.
2. Classrooms <0.7 W/ square foot and bi-level lighting with step between 30 percent and 70 percent of rated power.
3. Continuously occupied areas or egress lighting < 0.05 W/ square foot.
4. If HID or LPD < 80 percent of area category LPD, reduce power by at least 40 percent.
5. LPD < 80 percent of area category LPD, reduce power by at least 40 percent.
6. HID lighting with mean efficacy > 75 lm/W, control step between 20 percent and 60 percent of rated power.
7. One high efficacy luminaire controlled by a switch and within 6 ft of entry door.
8. Skylights added to existing lighting system, ON/OFF control acceptable.
9. Luminaires located in the daylight transition zone or dedicated ramps.

Most spaces will have more than one overlapping control system controlling the lighting. Examples include:

- **Small offices** will have a switch by the door and a Partial-ON occupancy sensor or Vacancy Sensor. If there is more than one luminaire in the office it will be required to be multi-level – most easily accomplished by a dimming luminaire. Typically these small offices will not have more than 120 Watts within one head height of the windows and thus often will not be required to have daylighting controls. For those offices within buildings greater than 10,000 square feet, an added demand control will also be required.
- **Large open plan offices** are not required to use occupancy sensors to provide automatic off control. These spaces are required to have light switches (or manual dimmer) by the entrances and could either use occupancy sensors or a time switch with a timed override manual switch. Because the general lighting power density is likely greater than 0.5 W/ square foot, the lighting must be multi-level and likely dimming ballasts will be used. In large office spaces with perimeter windows it is likely that there will be more than 120 Watts of lighting in the primary Sidelit zone and thus the lights in the Primary Sidelit zone (within 1 head height of the windows) must be separately controlled by a daylighting control. If the building complies prescriptively the lighting in the Secondary Sidelit zone (between 1 and 2 window head heights from the perimeter windows) must also be controlled separately with daylighting controls. For those offices in buildings greater than 10,000 square feet, an added demand control will also be required.
- **Classrooms** are required to have a manual switch by the entry and a Partial-ON occupancy sensor or Vacancy Sensor to automatically turn off lights when the space is unoccupied. Classrooms that have lighting power densities less than 0.7 W per square foot can meet the multi-level control requirements with a bi-level control. However, the lights that are within the Primary Sidelit zone must be controlled as in Table 130.1-A which requires at least 4 step of control for fluorescent luminaires. If the school is complying prescriptively, the lights in the Secondary Sidelit Zone are also required to control lighting as pre Table 130.1-A. In addition this space must have demand response controls which also be controlled according to Table 130.1-A. As a result, many classroom lighting systems will comply with dimming ballasts controlled by a daylighting and demand response signal in the Sidelit Zones and by a manual dimming and demand response signal in the rest of the classroom. All of the lights will be controlled to turn off by an occupancy sensor when the room is vacated.
- **Warehouses** that prescriptively comply with the standards will have enough skylights so that the at least 75 percent of the floor area will be in the skylight daylight zone before accounting for partitions and other obstructions that reduce the fraction of general lighting that is controlled. If the LPD of the warehouse lighting system is less than 0.5 W per square foot, the multi-level control and the demand responsive control requirements do not apply. However the lighting in the skylit daylight Zone must be controlled by a multi-level daylighting control. If the lighting is HID (metal halide or high pressure sodium) the multi-level daylighting controls are only required to be 2 level (high and low) plus off. In addition, open area and aisle lighting must be controlled by occupancy sensors that reduce lighting power by at least 50 percent (or 40 percent if the lighting is HID). The multi-level control can be accomplished with step dimming or continuous dimming ballasts though it is possible to accomplish the control with a 2 lamp HID luminaire or a 4 or more lamp fluorescent luminaire.

- **Retail spaces** typically will have the area switches in a location that is not accessible to the general public. General lighting, display lighting and ornamental lighting are required to be separately switched. Automatic shut-off controls will typically be time switch based with local timed override switches. With the prescriptive daylighting requirements applying to large open spaces with floor areas greater than 5,000 square feet and ceiling heights greater than 15 feet, many retail spaces are prescriptively required to daylight at last 75 percent of the space. Only the general lighting is required to be controlled with automatic daylighting controls; display lighting and ornamental lighting are allowed to be fully on regardless of how much daylight is entering the space.

5.5 Prescriptive Daylighting Requirements

This section contains information about the prescriptive nonresidential indoor daylighting control requirements in the Secondary Sidelit Daylit Zone, and the prescriptive requirements for minimum daylight area in large enclosed spaces directly under a roof.

The prescriptive daylighting requirements are in addition to the mandatory daylighting controls, which are covered in Section 5.4 of this chapter.

The end of this subchapter also has examples for complying with the mandatory daylighting requirements.

5.5.1 Automatic Daylighting Control Requirements – in Secondary Daylit Zones

§140.6(d)

All luminaires providing general lighting that is in, or at least 50 percent in, a Secondary Sidelit Daylit Zone as defined in §130.1(d)1C (see Section 5.4.4.2C of this chapter), and that is not in a Primary Sidelit Daylit Zone shall comply with the following:

1. The general lighting shall be controlled independently from all other luminaires (including those in the Primary Sidelit Zone, the Daylit Zone under skylights and lights that are not in Daylit Zones) by automatic daylighting controls that meet the applicable requirements of §110.9.
2. The general lighting shall be controlled in accordance with the applicable requirements in §130.1(d)2 (see Section 5.4.2 of this chapter).
3. All Secondary Sidelit Daylit Zones shall be shown on the plans submitted to the enforcing agency.

   EXCEPTIONS:

   1. Luminaires in Secondary Sidelit Daylit Zone(s) in areas where the total wattage of general lighting is less than 120 Watts.
   2. Luminaires in parking garages complying with §130.1(d)3.

5.5.2 Minimum Daylighting Requirements – for Large Enclosed Spaces

§140.3(c)

§140.3 has prescriptive requirements for building envelopes, including minimum daylighting for large enclosed spaces directly under roofs. Lighting installed in spaces complying with these prescriptive envelope measures are also required to comply with all lighting control requirements, including the mandatory and prescriptive lighting control requirements.

The mandatory daylighting control requirements are covered in Section 5.4.4 of this chapter.

Thus if one prescriptively complies by installing daylight openings in large enclosed spaces directly under roofs, the daylit areas could have electric lighting systems with high enough lighting power to trigger the mandatory requirements for daylighting controls. However if one complies using the performance approach it is possible to displace the daylighting openings and daylighting controls with other building efficiency options

5.5.2.1 **Large Enclosed Spaces Requiring Minimum Daylighting – Qualifying Criteria**

The minimum prescriptive daylighting requirements for large enclosed spaces apply to both conditioned and unconditioned nonresidential spaces that meet the following qualifying criteria:

1. Space is directly under a roof.
2. Is located in climate zones 2 through 15.
3. Has a floor area greater than 5,000 ft².
4. Has a ceiling height greater than 15 ft.

   EXCEPTIONS:

   1. Auditoriums, churches, movie theaters, museums, or refrigerated warehouses.
   2. Enclosed spaces having a designed general lighting system with a lighting power density less than 0.5 W/ft^2.
   3. In buildings with unfinished interiors, future enclosed spaces in which there are plans to have one of the following:
      a. A floor area of less than or equal to 5,000 ft^2.
      b. Ceiling heights less than or equal to 15 feet. This exception shall not be used for S-1 or S-2 (storage) or F-1 or F-2 (factory) occupancies.
   4. Enclosed spaces where it is documented that permanent architectural features of the building, existing structures or natural objects block direct beam sunlight on at least half of the roof over the enclosed space for more than 1,500 daytime hours per year between 8 a.m. and 4 p.m.

5.5.2.2 **Prescriptive Daylighting Requirements**

In Climate Zones 2 thru 15, enclosed spaces larger than 5000 square feet shall have at least 75 percent of spaces in daylit zones and the 75 percent spaces shall be within Primary Sidelit Daylit Zone or Skylit Daylit Zone.

For large enclosed spaces that are required to comply, following are details of the minimum prescriptive daylighting requirements:

1. A combined total of at least 75 percent of the floor area, as shown on the plans, shall be within the Skylit Daylit Zone or Primary Sidelit Daylit Zone. The calculation of the

Daylit Zone area to show compliance with this minimum daylighting requirement does not need to account for the presence of partitions, stacks or racks other than those that are ceiling high partitions. The design of the envelope may be developed before there is any knowledge of the location of the partial height partitions or shelves as is often the case for core and shell buildings. Thus the architectural daylit zone requirement of 75 percent of the area of the enclosed space indicates the possibility of the architectural space being mostly daylit.

The daylit zone and controls specification in §130.1(d) describe which luminaires are controlled. The obstructing effects of tall racks, shelves and partitions must be taken into consideration while determining the specifications. There is a greater likelihood that the electrical design will occur later than the architectural design and thus greater planning for these obstructions can be built in to the lighting circuiting design. With addressable luminaires, the opportunity is available to the contractor to incorporate the latest as built modifications into the daylight control grouping of luminaires according to unobstructed access to daylight.

2. The total skylight area is at least 3 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of the skylights; or the product of the total skylight area and the average skylight visible transmittance is no less than 1.5 percent of the total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of skylights.

   The above two requirements can be translated and represented by the following equations.

$$\frac{Skylight\ Area}{Daylit\ Zone\ under\ skylights} \geq 3\ percent \qquad (Equation\ 5-1)$$

$$Skylight\ Area \times VT \geq 1.5\ percent\ \times Daylit\ Zone\ under\ skylights \quad (Equation\ 5-2)$$

   Definitions of the above equation terms:

   Skylight Area = total skylight area on the roof

   Daylit Zone under skylights = total floor area in the space within a horizontal distance of 0.7 times the average ceiling height from the edge of the rough opening of skylights

   VT = Visible Transmittance

3. General lighting in daylit zones shall be controlled in accordance with §130.1(d).

4. Skylights shall have a glazing material or diffuser that has a measured haze value greater than 90 percent, tested according to ASTM D1003, or a Commission approved test method.

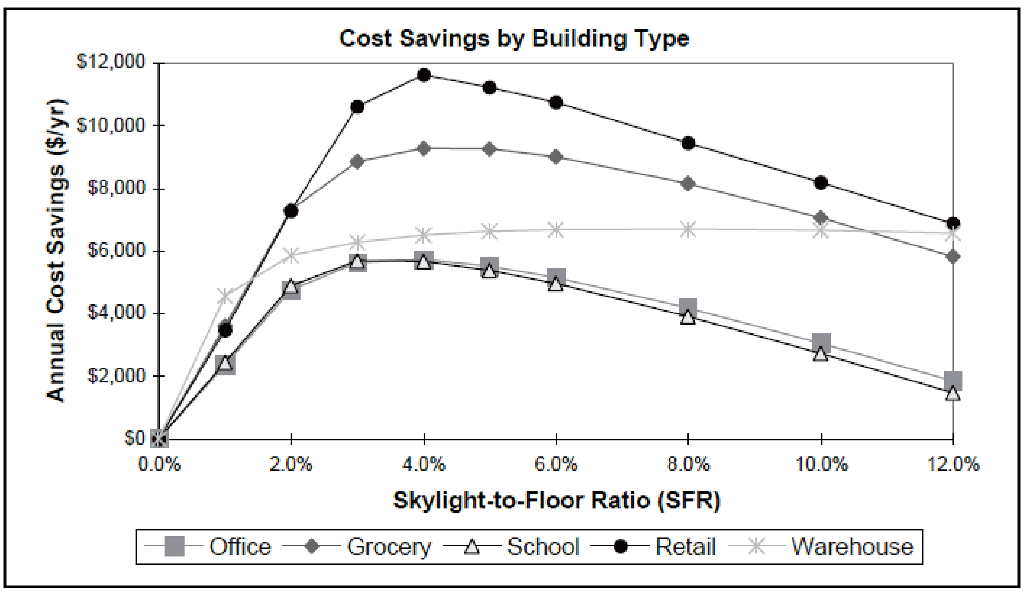
   Skylights must also meet the maximum glazing area, thermal transmittance (U-factor), solar heat gain coefficient (SHGC), and visible transmittance (VT) requirements of §140.3(a). Plastic skylights are required to have a VT of 0.64 and glass skylights are required to have a VT of 0.49. Currently plastics are not accompanied by low emissivity films which transmit light but block most of the rest of the solar spectrum. As a result, there is not maximum SHGC for plastic skylights. Glass skylights are required to have a maximum SHGC of 0.25. With a minimum VT of 0.49 and a maximum SHGC of 0.25, glass skylights must utilize low emissivity films or coatings that have a high light to solar gain ratio.

5. All Skylit Daylit Zones and Primary Sidelit Daylit Zones shall be shown on building plans.

In large buildings which must meet the minimum daylighting requirement, the core zone of many of these spaces will be daylit with skylights. Skylighting 75 percent of the floor area is achieved by evenly spacing skylights across the roof of the zone. A space can be fully skylit by having skylights spaced so that the edges of the skylights are not further apart than 1.4 times the ceiling height. Thus in a space having a ceiling height of 20 feet, the space will be fully skylit if the skylights are spaced so the there is no more than 28 feet of opaque ceiling between the skylights.

The total skylight area on the roof a building is prescriptively limited to a maximum of 5 percent of the gross roof area (§140.3(a)). A number of simulation studies have identified that the optimal skylight area that balances heat gain, heat loss and lighting energy cost savings. These studies have found that savings can be optimized if the product of the VT of the skylight and the skylight to daylit area ratio is greater than 2 percent (this figure accounts for a light well factor of 75 percent and a skylight dirt depreciation factor of 85 percent).[2] If one fully daylights the space with skylights and the skylights meet the prescriptive requirements of 64 percent visible light transmittance, a minimum skylight area of at least 3 percent of the roof area is needed to optimize energy cost savings (see Figure 5-13).

Figure 5-13: Skylighting Savings by Skylight to Floor Ratio and Building Type in San Bernardino, CA (Climate Zone 10)



[2] Energy Design Resources *Skylighting Guidelines*. 1999. http://www.energydesignresources.com/resources/publications/design-guidelines/design-guidelines-skylighting-guidelines.aspx

Example 5-5

Warehouse 40,000 square feet area and 30 foot tall ceiling (roof deck)

Maximum skylight spacing distance and recommended range of skylight area

The maximum spacing of skylights that results in the space being fully skylit is:

Maximum skylight spacing = 1.4 x Ceiling Height + Skylight width

Spacing skylights closer together results in more lighting uniformity and thus better lighting quality – but costs more as more skylights are needed. However as a first approximation one can space the skylights 1.4 times the ceiling height. For this example skylights can be spaced 1.4 x 30 = 42 feet. In general the design will also be dictated by the size of roof decking materials (such as 4' by 8' plywood decking) and the spacing of roof purlins so the edge of the skylights line up with roof purlins. For this example we assume that roof deck material is 4' by 8' and skylights are spaced on 40 foot centers.

Each skylight is serving a 40 foot by 40 foot area of 1,600 square foot. A standard skylight size for warehouses is often 4' by 8' (so it displaces one piece of roof decking). The ratio of skylight area to daylit area is 2 percent (32/1600 = 0.02). Assuming this is a plastic skylight and it has a minimally compliant visible light transmittance of 0.65 the product of skylight transmittance and skylight area to daylit area ratio is;

(0.65)(32/1,600) = 0.013 = 1.3 percent

This is shy of the 2 percent rule of thumb described earlier for the product of skylight transmittance and skylight area to daylit area ratio. If one installed an 8 ft by 8 ft skylight (two 4 ft by 8 ft skylights) on a 40 foot spacing would yield a 2.6 percent product of skylight transmittance and skylight area to daylit area ratio. With 64 square feet of skylight area for each 1,600 square feet of roof area, the skylight to roof area ratio (SRR) is 4 percent which is less than the maximum SRR of 5 percent allowed by §140.3(a).

An alternate approach would be to space 4 ft by 8 ft skylights closer together which would provide more uniform daylight distribution in the space and could more closely approach the desired minimum VT skylight area product. By taking the product of the skylight VT and the skylight area and dividing by 0.02 (the desired ratio) yields the approximate area the skylight should serve. In this case with a VT of 0.65 and a skylight area of 32 square feet, each skylight should serve around (0.65*32 /0.02) = 1,040 square feet. A 32 foot center to center spacing of skylights results in (32*32) = 1,024 square feet of daylit area per skylight.

For the minimally compliant 4 ft by 8 ft plastic skylight with a visible light transmittance of 0.65 the product of skylight transmittance and skylight area to daylit area ratio is;

(0.65)(32/1,024) = 0.0203 = 2.03 percent

Example 5-6

Methods for complying with the mandatory daylight control requirements for a space with linear fluorescent luminaires

The Energy Standards require that automatic daylighting controls shall provide functional multi-level lighting levels having at least the number of control steps specified in Table 130.1-A. A minimum of 4 control steps are needed. These steps are identified as:

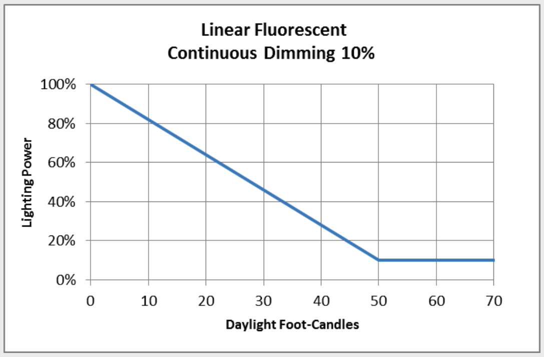
1 - 20-40 percent; 2 - 50-70 percent; 3 - 80-85 percent; 4 - 100 percent

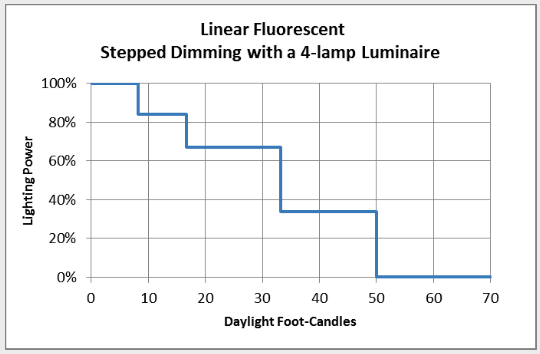
This can be achieved in one of three ways, using:

1. Continuous dimming - Here the photocontrol gradually dims all luminaires in the daylit zone in response to the available daylight.
2. Stepped dimming with a 4-lamp luminaire - The required control steps can be achieved using a 4-lamp fixture and with two lamps powered by an ON/OFF

Stage	On/Off Switching Ballast - power level	2-Stepped Dimming Ballast - power level	**Result**
1 - Full ON	100%	100%	**100%**
2	100%	67%	**84%**
3	100%	33%	**67%**
4	0%	67%	**34%**
5 - Full OFF	0%	0%	**0%**

3. Switching alternate lamps in each luminaire, having a minimum of 4 lamps per luminaire. Here the lamps may be tandem-wired such that power to each of the 4 lamps can be controlled separately by the photocontrol based on available daylight.





Example 5-7

Methods for complying with the mandatory daylight control requirements for a space with HID lighting

The Standards require that automatic daylighting controls shall provide functional multi-level lighting levels having at least the number of control steps specified in Table 130.1-A.

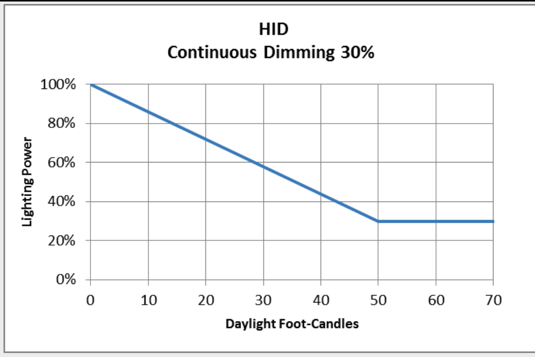
A space with HID lamps that are greater than 20 Watts installed power per lamp, shall have a minimum of 1-step between 50 percent and 70 percent.

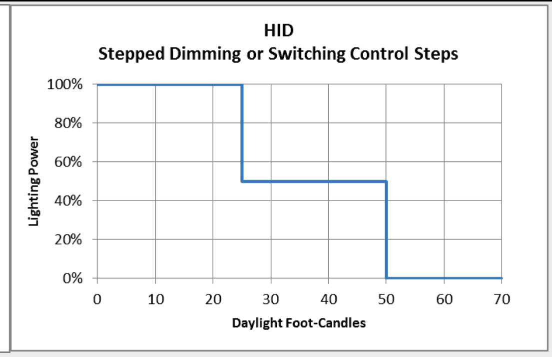
This can be achieved in one of three ways, using:

A. Continuous dimming - Here the photocontrol gradually dims all luminaires in the daylit zone in response to the available daylight.

B. Stepped dimming - Here the photocontrol signals the stepped dimming ballast to reduce power in incremental steps such there is one control step between 50 percent and 70 percent as noted above.

C. Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire. Here the lamps may be tandem-wired such that power to each lamp in the luminaire can be controlled separately by the photocontrol based on available daylight.





Example 5-8

Complying with the 150 percent of the design illuminance daylighting requirement

When the illuminance received from the daylight is greater than 150 percent of the design illuminance (or nighttime electric lighting illuminance), the general lighting power in the daylight zone must reduce by a minimum of 65 percent.

For example, a space has 500 Watts of installed lighting power in daylit zones. The design illuminance for the space is 50 foot-candle (fc). When the available daylight in the space reaches 75 fc (i.e. 150 percent of 50 fc), then the power consumed by the general lighting in the daylit zones should be 175 Watts or lower.

Without checking all points in the daylit zone served by controlled lighting, verifying that the requirements are met at a worst case location far away from windows or skylights is sufficient. This location is called the "Reference Location"

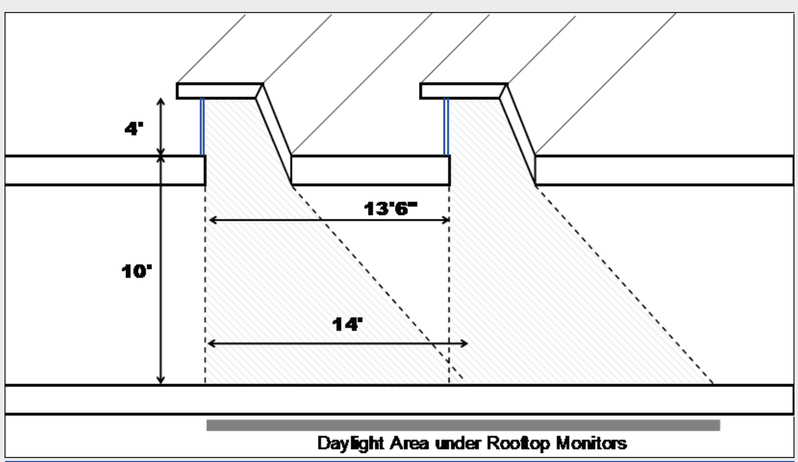
Example 5-9

Question

Draw the daylit zone for two roof top monitors with four 4 foot long windows projecting over a 10 ft tall roof. The two monitors are 13.5 ft apart.

Answer

Standards currently define skylights as glazing having a slope less than 60 degrees from the horizontal with conditioned or unconditioned space below. Because rooftop monitors have a slope greater than 60 degrees, they are therefore considered to be windows.



5.6 General Requirements for Prescriptive Lighting

See Section 5.5 of this chapter for the prescriptive daylighting requirements.

5.6.1 Requirements for a Compliant Building

A building complies with §140.6 if:

1. The Calculation of Actual Indoor Lighting Power of all proposed building areas combined, when calculated in accordance with §140.6(a) is no greater than the Calculation of Allowed Indoor Lighting Power, Specific Methodologies calculated under §140.6(c).
2. The Calculation of Allowed Indoor Lighting Power, General Rules comply with §140.6(b).
3. General lighting complies with the Automatic Daylighting Controls in Secondary Daylit Zone requirements in §140.6(d).

5.6.2 Calculation of Actual Indoor Lighting Power

The actual indoor Lighting Power of all building areas is the total watts of all planned permanent and portable lighting systems in all areas of the proposed building.

Some adjustments are available to reduce the actual indoor lighting power that must be reported. These adjustments are discussed in Section 5.6.5.

5.6.3 Portable Office Lighting

The Energy Standards (§140.6(a)) require that all planned portable lighting be counted toward the building's lighting energy use, regardless of the function area in which it is planned for.

Because office furniture is typically not installed until after the building inspection is complete, there are special provisions for portable lighting in office areas. Up to 0.3 watts per square foot of portable lighting for office areas shall not be required to be included in the calculation of actual indoor Lighting Power. However, if more than 0.3 watts per square foot of portable lighting is installed in office areas, any portable lighting wattage above 0.3 watts per square foot shall be required to be included in the calculation of actual indoor Lighting Power.

The Energy Standards define portable lighting as lighting with plug-in connections for electric power, that is: table and freestanding floor lamps; attached to modular furniture; workstation task luminaires; luminaires attached to workstation panels; attached to movable displays; or attached to other personal property.

5.6.4 Two interlocked lighting systems

A. Within the following five function areas, as defined in §100.1, two different interlocking lighting systems may be installed. All other function areas are permitted to install only one lighting system.

   1. Auditorium
   2. Convention center
   3. Conference room
   4. Multipurpose room
   5. Theater

B. No more than two lighting systems may be used for these five specifically defined function areas, and if there are two lighting systems, they must be interlocked.

C. Where there are two interlocked lighting systems, the watts of the lower wattage system may be excluded from determining the actual indoor Lighting Power if:

1. Before two interlocked lighting systems will be recognized for compliance with the lighting requirements in Part 6 of Title 24, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

   If any of the requirements in the Certificate of Installation fail the installation tests, the two interlocked lighting systems shall not be recognized for compliance with the lighting Standards.

2. The two lighting systems shall be interlocked with a Nonprogrammable Double-Throw Switch to prevent simultaneous operation of both systems.

3. For compliance with the Energy Standards a Nonprogrammable Double-Throw Switch is an electrical switch commonly called a "single pole double throw" or "three-way" switch that is wired as a selector switch allowing one of two loads to be enabled. It can be a line voltage switch or a low voltage switch selecting between two relays. It cannot be overridden or changed in any manner that would permit both loads to operate simultaneously.

5.6.5 Power Adjustment Factors (PAFs)

The Energy Standards provide an option for a lighting power reduction credit when specific lighting controls are installed, provided those lighting controls are not required.

A Power Adjustment Factor (PAF) is an adjustment to the installed lighting power in an area so that some of the installed lighting power is not counted toward the building's total installed lighting load.

In calculating actual installed indoor Lighting Power, the installed watts of a luminaire providing general lighting in a function area listed in Table 140.6-C may be reduced by multiplying the number of watts controlled by the applicable Power Adjustment Factor (PAF), per Table 140.6-A.

To qualify for a PAF, the following conditions are required to be met:

1. Before a Power Adjustment Factor will be allowed for compliance with §140.6, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

   If any of the requirements in this Certificate of Installation fail the Power Adjustment Factor installation tests, the installation shall not be eligible for using the PAF.

2. Luminaires and controls meet the applicable requirements of §110.9, and §130.0 through §130.5.

3. The controlled lighting is permanently installed general lighting systems and the controls are permanently installed nonresidential-rated lighting controls. (Thus, for example, portable lighting, portable lighting controls, and residential rated lighting controls shall not qualify for PAFs.)

There are furniture mounted lighting systems that are installed to provide general lighting. When used for determining PAFs for general lighting in offices, furniture mounted luminaires that comply with all of the following conditions shall qualify as permanently installed general lighting systems:

a. The furniture mounted luminaires shall be permanently installed no later than the time of building permit inspection.
b. The furniture mounted luminaires shall be permanently hardwired.
c. The furniture mounted lighting system shall be designed to provide indirect general lighting. It may also have elements that provide direct task lighting.
d. Before multiplying the installed watts of the furniture mounted luminaire by the applicable PAF, 0.3 watts per square foot of the area illuminated by the furniture mounted luminaires shall be subtracted from installed watts of the furniture mounted luminaires to account for portable lighting.
e. The lighting control for the furniture mounted luminaire complies with all other applicable requirements in §140.6(a)2.

4. At least 50 percent of the light output of the controlled luminaire is within the applicable area listed in Table 140.6-A. Luminaires on lighting tracks shall be within the applicable area in order to qualify for a PAF.
5. Only one PAF from Table 140.6-A may be used for each qualifying luminaire. PAFs shall not be added together unless specifically allowed in Table 140.6-A.
6. Only lighting wattage directly controlled in accordance with §140.6(a)2 shall be used to reduce the calculated actual indoor Lighting Power as allowed by §140.6(a)2. If only a portion of the wattage in a luminaire is controlled in accordance with §140.6(a)2, then only that portion of controlled wattage may be reduced in calculating actual indoor Lighting Power.
7. Lighting controls used to qualify for a PAF shall be designed and installed in addition to manual, multi-level, and automatic lighting controls required in §130.1, and in addition to any other lighting controls required by the Energy Standards.
8. To qualify for the PAF for daylight dimming plus OFF control, the following requirements must be met:
   a. The lighting controls system shall meet all of the requirements of §130.1(d)
   b. The lighting control system shall turn lights completely OFF when the daylight available in the daylit zone is greater than 150 percent of the illuminance received from the general lighting system at full power.
   c. The lighting equipment must be included in the Skylit Daylit or Primary Sidelit Daylit lighting zones only.
   d. This PAF shall not be available for atria or any other areas that operate with a photocell ON/OFF control that does not include intermediate steps.
   e. The OFF step must be demonstrated in the acceptance testing of the daylight zone controls.
9. To qualify for the PAF for an occupant sensing control controlling the general lighting in large open plan office areas above workstations, in accordance with Table 140.6-A, the following requirements shall be met:

a. The total open plan office area shall be greater than 250 square feet.

b. This PAF shall be available only in office areas which contain workstations.

c. Controlled luminaires shall only be those which provide general lighting directly above the controlled area, or furniture mounted luminaires that comply with §140.6(a)2 and provide general lighting directly above the controlled area.

d. Qualifying luminaires shall be controlled by occupant sensing controls that meet all of the following requirements, as applicable:

i. Infrared sensors shall be equipped by the manufacturer, or fitted in the field by the installer, with lenses or shrouds to prevent them from being triggered by movement outside of the controlled area.

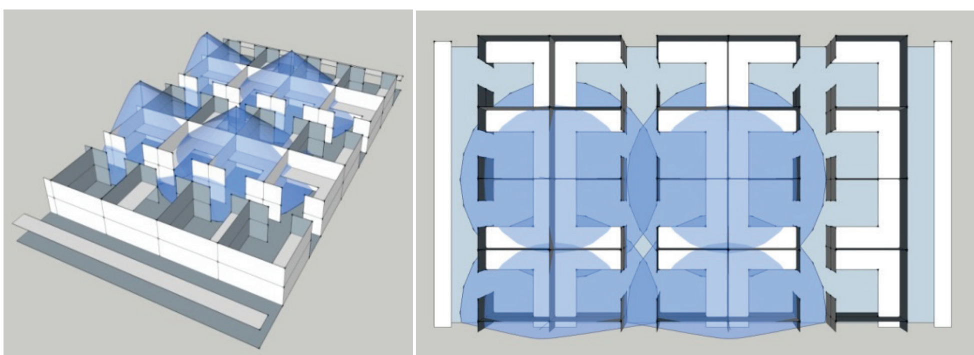
ii. Ultrasonic sensors shall be tuned to reduce their sensitivity to prevent them from being triggered by movements outside of the controlled area.

iii. All other sensors shall be installed and adjusted as necessary to prevent them from being triggered by movements outside of the controlled area.

e. The PAF shall be applied only to the portion of the installed lighting power that is controlled by the occupant sensors, not to the total installed lighting power.

f. The value of the PAF (0.2, 0.3 or 0.4) depends on how many workstations are controlled together by the same occupant sensor.

Figure 5-14: To Qualify for the PAF for Occupancy Sensing Controls in Open-Plan Offices, Sensors Must be Tuned to the Controlled Area



10. To qualify for the PAF for Institutional Tuning, the following requirements must be met:

a. The lighting controls shall limit the maximum output or maximum power draw of the controlled lighting to 85 percent or less of full light output or full power draw.

b. The means of setting the limit is accessible only to authorized personnel.

c. The setting of the limit is verified by the acceptance test required by §130.4(a)7.

d. The construction documents specify which lighting systems shall have their maximum light output or maximum power draw set to no greater than 85 percent of full light output or full power draw.

11. To qualify for the PAF for a Demand Responsive Control in Table 140.6-A, a Demand Responsive Control shall meet all of the following requirements:

a. Because buildings larger than 10,000 square feet are required to have demand responsive controls, to qualify for the PAF, the building shall be 10,000 square feet or smaller.

b. The controlled lighting shall be capable of being automatically reduced in response to a demand response signal.

c. Lighting shall be reduced in a manner consistent with uniform level of illumination requirements in Table 140.6-A.

d. Spaces that are non-habitable shall not be used to comply with this requirement, and spaces with a lighting power of less than 0.5 watts per square foot shall not be counted toward the building's total lighting power.

5.6.6 Lighting Wattage Not Counted Toward Building Load

The Energy Standards do not require lighting power of certain types of luminaires in specific function areas, or for specific purposes, to be counted toward a building's installed lighting power.

Any nonresidential indoor lighting function not specifically listed below shall comply with all applicable nonresidential indoor lighting requirements. For example, lighting in guestrooms of hotels is not required to be counted for compliance with §140.6, however, lighting in all other function areas within a motel are required to comply with all applicable requirements in §140.6. Also, lighting in within the guestrooms is regulated by the low-rise residential lighting Standards.

The watts of the following indoor lighting applications are not required to be counted toward the actual installed indoor Lighting Power:

- In theme parks: Lighting for themes and special effects.
- Studio lighting for film or photography provided that these lighting systems are in addition to and separately switched from a general lighting system.
- Lighting for dance floors, lighting for theatrical and other live performances, and theatrical lighting used for religious worship, provided that these lighting systems are additions to a general lighting system and are separately controlled by a multiscene or theatrical cross-fade control station accessible only to authorized operators.

  Lighting intended for makeup, hair, and costume preparation in performance arts facility dressing rooms, provided that the lighting is separately switched from the general lighting system, switched independently at each dressing station, and is controlled with a Vacancy Sensor.
- In civic facilities, transportation facilities, convention centers, and hotel function areas: Lighting for temporary exhibits, if the lighting is an addition to a general lighting system and is separately controlled from a panel accessible only to authorized operators.
- Lighting installed by the manufacturer in walk-in freezers, vending machines, food preparation equipment, and scientific and industrial equipment.
- In medical and clinical buildings: Examination and surgical lights, low-ambient night-lights, and lighting integral to medical equipment, provided that these lighting systems are additions to and separately switched from a general lighting system.
- Lighting for plant growth or maintenance, if it is controlled by a multi-level astronomical time-switch control that complies with the applicable provisions of §110.9.
- Lighting equipment that is for sale.
- Lighting demonstration equipment in lighting education facilities.

- Lighting that is required for exit signs subject to the CBC. Exit signs shall meet the requirements of the Appliance Efficiency Regulations.
- Exitway or egress illumination that is normally off and that is subject to the CBC.
- In hotel/motel buildings: Lighting in guestrooms (lighting in hotel/motel guestrooms shall comply with §130.0(b). (Indoor lighting not in guestrooms shall comply with all applicable nonresidential lighting requirements in Part 6.)
- In high-rise residential buildings: Lighting in dwelling units (Lighting in high-rise residential dwelling units shall comply with §130.0(b).) (Indoor lighting not in dwelling units shall comply with all applicable nonresidential lighting requirements in Part 6.)
- Temporary lighting systems. *Temporary Lighting is defined in §100.1 as a lighting installation with plug-in connections, which does not persist beyond 60 consecutive days or more than 120 days per year.*
- Lighting in occupancy group U buildings less than 1,000 square feet.
- Lighting in unconditioned agricultural buildings less than 2,500 square feet.
- Lighting systems in qualified historic buildings, as defined in the State Historic Building Code (Title 24, Part 8), are exempt from the Lighting Power allowances, if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems in qualified buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other lighting systems in qualified historic buildings shall comply with the Lighting Power allowances.
- Lighting in nonresidential parking garages for seven or less vehicles: Lighting in nonresidential parking garages for seven or less vehicles shall comply with the applicable residential parking garage provisions of §150.0(k).
- Lighting for signs: Lighting for signs shall comply with §140.8.
- Lighting in refrigerated cases less than 3,000 square feet. (Lighting in refrigerated cases less than 3,000 square feet shall comply with the Title 20 Appliance Efficiency Regulations).
- Lighting in elevators where the lighting meets the requirements in §120.6(f).

5.7 Prescriptive Methods for Determining Lighting Power Allowances

This section contains information on the three prescriptive approaches available for complying with the Lighting Standards:

1. Complete Building Method
2. Area Category Method
3. Tailored Method

5.7.1 Complete Building Method

§140.6(c)1

The Complete Building Method shall only be applied when lighting will be installed throughout the entire building under the permit is prepared. The building must consist of one type of use for a minimum of 90 percent of the floor area of the entire building.

The Allowed Indoor Lighting Power allotment for general lighting for the entire building shall be calculated as follows:

1. For a conditioned building that qualifies to use the Complete Building Method of compliance, multiply the square feet of conditioned space of the building times the applicable allotment of watts per square foot described in Table 140.6-B.
2. For an unconditioned building that qualifies to use the Complete Building Method of compliance, multiply the square feet of unconditioned space of the building times the applicable allotment of watts per square feet described in Table 140.6-B.

5.7.1.1 **Requirements for Using the Complete Building Method**

The Complete Building Method shall be used only for building types, as defined in §100.1, that are specifically listed in Table 140.6-B. (For example, retail and wholesale stores, hotel/motel, and high-rise residential buildings shall not use this method.)

The Complete Building Method shall be used only on projects involving:

A. Entire buildings with one type of use occupancy.

   EXCEPTION to §140.6(c)1Bi: If a parking garage plus another type of use listed in Table 140.6-B are part of a single building, the parking garage portion of the building and other type of use portion of the building shall each separately use the Complete Building Method.

B. Mixed occupancy buildings where one type of use makes up at least 90 percent of the entire building (in which case, when applying the Complete Building Method, it shall be assumed that the primary use is 100 percent of the building).

C. A tenant space where one type of use makes up at least 90 percent of the entire tenant space (in which case, when applying the Complete Building Method, it shall be assumed that the primary use is 100 percent of the tenant space).

The Complete Building Method shall be used only when the applicant is applying for a lighting permit and submits plans and specifications for the entire building or the entire tenant space.

Only the lighting power allotment in Table 140.6-B is available for the entire building when using the Complete Building Method. There are no additional lighting power allowances available when using Complete Building Method. Also, there are no mounting height multipliers available when using the Complete Building Method.

5.7.1.2 **Definitions of Complete Building Types**

When using the Complete Building Method, qualifying building types shall be only those in which a minimum of 90 percent of the building floor area functions as one of the building types listed in Table 140.6-B, as defined below, which do not qualify as any other Building Occupancy Types more specifically defined in §100.1, and which do not have a combined total of more than 10 percent of the area functioning as any Nonresidential Function Areas specifically defined in §100.1:

- **Auditorium Building** is a public building in which a minimum of 90 percent of the building floor area are rooms with fixed seating that are primarily used for public meetings or gatherings
- **Classroom Building** is a building for an educational institution in which a minimum of 90 percent of the building floor area are classrooms or educational laboratories

- **Commercial and Industrial Storage Building** is a building for which a minimum or 90 percent of the building floor area is used for storing items
- **Convention Center Building** is a building in which a minimum of 90 percent of the building floor area are rooms for meetings and conventions, which have neither fixed seating nor fixed staging.
- **Financial Institution Building** is a building in which a minimum of 90 percent of the building floor area are rooms used for an institution which collects funds from the public and places them in financial assets, such as deposits, loans, and bonds.
- **General Commercial and Industrial Work Building** is a building in which a minimum of 90 percent of the building floor area are rooms for performing a craft, assembly or manufacturing operation.
- **Grocery Store Building** is a building in which a minimum of 90 percent of the building floor area is sales floor for the sale of foodstuffs.
- **Library Building** is a building which is in which a minimum of 90 percent of the building floor area are rooms use as a repository of literary materials, such as books, periodicals, newspapers, pamphlets and prints, are kept for reading or reference.
- **Medical Buildings and Clinic Buildings** are non “I” occupancy buildings in which a minimum of 90 percent of the building floor area are rooms where medical or clinical care is provided, does not provide overnight patient care, and is used to provide physical and mental care through medical, dental, or psychological examination and treatment.
- **Office Building** is a building of CBC Group B Occupancy in which a minimum of 90 percent of the building floor area are rooms in which business, clerical or professional activities are conducted.
- **Parking Garage Building** is a building in which a minimum of 90 percent of the building floor area is for the purpose of parking vehicles, which consists of at least a roof over the parking area enclosed with walls on all sides. The building includes areas for vehicle maneuvering to reach designated parking spaces. If the roof of a parking structure is also used for parking, the portion without an overhead roof is considered an outdoor parking lot instead of a parking garage.
- **Religious Facility Building** is a building in which a minimum of 90 percent of the floor area in the building floor area are rooms for assembly of people to worship.
- **Restaurant Building** is a building in which a minimum of 90 percent of the building floor area are rooms in which food and drink are prepared and served to customers in return for money.
- **School Building** is a building in which a minimum of 90 percent of the building floor area is used for an educational institution, but in which less than 90 percent of the building floor area is classrooms or educational laboratories, and may include an auditorium, gymnasium, kitchen, library, multi-purpose room, cafeteria, student union, or workroom. A maintenance or storage building is not a school building.
- **Theater Building** is a building in which a minimum of 90 percent of the building floor area are rooms having tiers of rising seats or steps for the viewing of motion pictures, or dramatic performances, lectures, musical events and similar live performances.

Example 5-10 Finding Lighting Power Density Allotments

Question

A 10,000-ft² medical clinic building is to be built. What is its Lighting Power Density Allotment under the complete building approach?

Answer

From Table 140.6-B, medical buildings and clinics are allowed 1.0 W/ft². The Lighting Power Density Allotment is 10,000 x 1.0 = 10,000 W.

5.7.2 Area Category Method

§140.6(c)2

5.7.2.1 Area Category Method General Lighting Power Allotment

The Area Category Method is more flexible than the Complete Building Method because it can be used for multiple tenants or partially completed buildings. For purposes of the Area Category Method, an "area" is defined as all contiguous spaces that accommodate or are associated with a single primary function as listed in Table 140.6-C. Areas not covered by the current permit are ignored. When the lighting in these areas is completed later under a new permit, the applicant may show compliance with any of the lighting options except the Complete Building Method.

The Area Category Method divides a building into primary function areas. Each function area is defined under occupancy type in §100.1. The Lighting Power Allotment is determined by multiplying the area of each function times the lighting power density for that function. Where areas are bounded or separated by interior partitions, the floor space occupied by those interior partitions shall be included in any area. The total allowed watts is the summation of the Lighting Power Allotment for each area covered by the permit application.

When using this method, each function area in the building must be included as a separate area. Boundaries between primary function areas may or may not consist of walls or partitions. For example, kitchen and dining areas within a fast food restaurant may or may not be separated by walls. For purposes of compliance they must still be separated into two different function areas. However, it is not necessary to separate aisles or entries within primary function areas. When the Area Category Method is used to calculate the allowed total lighting power for an entire building however, the main entry lobbies, corridors, restrooms, and support functions shall each be treated as separate function areas.

A. Requirements for using the Area Category Method include all of the following:

1. The Area Category Method shall be used only for primary function areas, as defined in §100.1, that are listed in Table 140.6-C.
2. Primary Function Areas in Table 140.6-C shall not apply to a complete building. Each primary function area shall be determined as a separate area.
3. For purposes of compliance with §140.6(c)2, an "area" shall be defined as all contiguous areas which accommodate or are associated with a single primary function area listed in Table 146.0-C.
4. Where areas are bounded or separated by interior partitions, the floor area occupied by those interior partitions may be included in a Primary Function Area.
5. If at the time of permitting for a newly constructed building, a tenant is not identified for a multi-tenant area, a maximum of 0.6 watts per square foot shall be allowed for

the lighting in each area in which a tenant has not been identified. The area shall be classified as Unleased Tenant Area.

6. Under the Area Category Method, the allowed indoor Lighting Power Density for each primary area is the Lighting Power Density value in Table 140.6-C times the square feet of the primary function. The total allowed indoor Lighting Power Density for the building is the sum of all allowed indoor Lighting Power Densities for all areas in the building.

5.7.2.2 **Additional Lighting Power - Area Category Method**

In addition to the allowed indoor Lighting Power calculated according to §140.6(c)2, additional lighting power allowances for specialized task work, ornamental, precision, accent, display, decorative, and white boards and chalk boards, may be added in accordance with the footnotes in Table 140.6-C under the following conditions:

1. Only primary function areas having a footnote next to the allowed Lighting Power Density allotments in Table 140.6-C shall qualify for the added lighting power allowances in accordance with the correlated footnote listed at the bottom of the table.
2. The additional lighting power allowances shall be used only if the plans clearly identify all applicable task areas and the lighting equipment designed to illuminate these tasks.
3. Tasks that are performed less than two hours per day or poor quality tasks that can be improved are not eligible for the additional lighting power allowances.
4. The additional lighting power allowances shall not utilize any type of luminaires that are used for general lighting in the building.
5. The additional lighting power allowances shall not be used when using the Complete Building Method, or when the Tailored Method is used for any area in the building.
6. The additional lighting power allowed is the smaller of lighting power listed in the applicable footnote in Table 140.6-C, or the actual design wattage.
7. In addition to the lighting power allowed under §140.6(c)2G(i through vi), up to 1.5 watts per square foot of additional lighting power shall be allowed in a videoconferencing studio, as defined in §100.1, provided the following conditions are met:
   a. Before the Additional Videoconference Studio Lighting power allotment will be allowed for compliance with §140.6 of the Energy Standards, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation.

      If any of the requirements in this Certificate of Installation fail the Additional Videoconference Studio Lighting installation tests, the installation shall not be eligible for the additional lighting power allotment.

   b. The Videoconferencing Studio is a room with permanently installed videoconferencing cameras, audio equipment, and playback equipment for both audio-based and video-based two-way communication between local and remote sites.
   c. General lighting is controlled in accordance with Table 130.1-A.
   d. Wall wash lighting is separately switched from the general lighting system.

e. All of the lighting in the studio, including general lighting and additional lighting power allowed by §140.6(c)2Gvii is controlled by a multiscene programmable control system (also known as a scene preset control system).

Example 5-11 Calculating allowed lighting power

Question

A small bank building has the following area distribution:

Corridors	800 ft²
Main Entry Lobby	200 ft²
Financial Transactions	1,200 ft²
Manager's Office	200 ft²

What is the allowed lighting power for this building under the Area Category Method?

Answer

The following Lighting Power Densities apply (from Table 140.6-C):

Space	LPD	Area	Allowed Watts
Corridors	0.6 W	800 ft²	480
Main Entry	0.95 W	200 ft²	190
Financial Transactions	1.0 W	1,200 ft²	1,200
Manager's Office	1.0 W	200 ft²	200
Total			2,070 W

Financial Transactions in this example are assumed to include all the spaces in which financial transactions for the public are taking place. The allowed lighting power for this building is 2,070 W

Example 5-12 Allowed lighting power including decorative lighting

Question:

What is the allowed maximum lighting power if the small bank in example 5-11 above incorporates decorative chandeliers and wall sconces as part of their lighting design?

Answer:

Provided the decorative lighting occurs in either the Financial Transaction area or Main Lobby and is, in addition to the general lighting, up to 0.5W/ft² added power is allowed for these areas. Therefore the added maximum power is as follows:

Main Entry 0.5 W X 200 ft² = 100 W

Financial Transactions 0.5 W X 1,200 ft² = 600 W

The maximum total of added watts allowed for the ornamental lighting (Chandeliers and sconces) is 100 + 600 = 700 W.

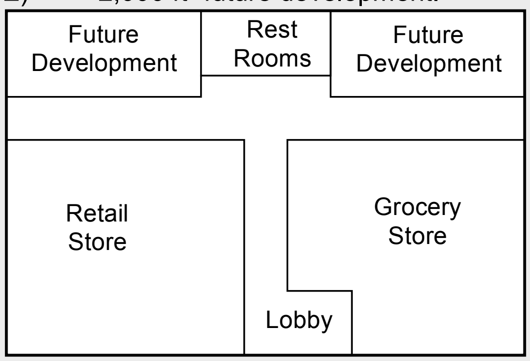
With the addition of these 700 W is revised allowed maximum watts for the small bank is 2,770 W (2,070 + 700 = 2,770).

Note that ornament lighting is "use-it–loose" therefore actual allowed maximum watts for the small bank is the base 2,070 W + the smaller of the actual power of the ornamental lighting or 700W. Therefore if the ornamental lighting uses 300 W the total allowed maximum is 2,370 W for the bank not 2,770 W. (2,070 + 300 = 2,370)

Example 5-13 Allowed lighting power for multi-use spaces

Question

A 10,000-ft² multi-use building is to be built consisting of:
A) 500 ft² main entry lobby,
B) 2,000 ft² corridors and restroom,
C) 3,000 ft² grocery store,
D) 2,500 ft² retail, and
E) 2,000 ft² future development.



What is the allowed lighting power under the area category method?

Answer

Space		LPD	Area	Allowed Watts
A)	Main Entry	0.95 W/ft²	500 ft²	475
B)	Corridors and Restrooms	0.6 W/ft²	2,000 ft²	1,200
C)	Grocery Sales	1.2 W/ft²	3,000 ft²	3,600
D)	Retail Store	1.2 W/ft²	2,500 ft²	3,000
	TOTAL		8,000 ft²	8,275

With 2,000 ft² for future development

Example 5-14 Maximum allowed wattage for spaces within a multiuse building

Question

What if in the multi-use building (example 5-13), the retail store is planning floor displays and wall displays, as well as decorative chandeliers. How do you determine the allowed maximum watts for this store?

Answer

A) As in the above example, determine the total square feet of the retails store (2,500 feet)

B) As in the above example multiply the allowed LPD (1.2 W/ft²) X 2,500 = 3,000 W (base allowance)

C) Determine the maximum allowed display and accent allowance by multiplying the retail stores 2,500 feet by 0.3 W/ft² (Footnote 6 from Table 140.6-C) = 750 W

D) Determine the maximum allowed ornamental lighting allowance (for chandeliers) by multiplying the retail stores 2,500 feet by 0.2 W/ft² (Footnote 7 from Table 140.6-C) = 500 W

E) Add the 3,000 W base plus 750 W for display and 500 W for ornamental = 4,250 W

The maximum allowed watts for this retail store, under the area method, is therefore 4,250W or 1.7 W/ft²

Note: The allowed maximum is usually somewhat less than the theoretical maximum of 1.7 W/ft² as the display/accent lighting and ornamental lighting components are “use-it-lose it” with the lower luminaire lighting power becoming the allowed power. Also for the added power to be allowed, it must be in addition to general lighting and must use the appropriate luminaires for the task as defined the luminaires

Example 5-15 Decorative lighting

Question

What is the wattage allowance for a 10 ft^3 chandelier with five 50 W lamps in a 300 ft² bank entry lobby?

Answer

The wattage based on the task space is 0.5 W/ft² x 300 ft² = 150 W (0.5 W/ft² is based on Footnote 3 of Table 140.6-C.)

The wattage based on actual design watts is 250 W.

The wattage allowance for the chandelier is the smaller of the two values, or 150 W

Example 5-16 Decorative LED lighting

Question

What is the wattage allowance for a LED chandelier with five 10 W LED lamps in a 300 ft² bank entry lobby?

Answer

The wattage based on the task space is 0.5 W/ft² x 300 ft² = 150 W

The wattage based on actual design watts is 50 W.

The wattage allowance for the chandelier is the smaller of the two values, or 50 W

5.7.3 Tailored Method

§140.6(c)3

5.7.3.1 Tailored Method Application

The Tailored Method is a lighting compliance approach which establishes an allowed lighting power budget on a room-by-room or area-by-area basis. In addition to providing a lighting power budget for general illumination, this compliance approach provides additional lighting power budgets for illuminating wall displays, floor displays, task lighting, and ornamental/special effects lighting.

These additional layers of lighting power have been informally referred to as “use-it or lose-it” lighting power allowances because these additional allowances cannot be traded-off to other areas or applications. If a lighting design does not include these additional layers of lighting power, the total lighting power budget using the Tailored Method may be less than if the Area Category Method or Whole Building Method of compliance is used.

Use of Tailored Method may also be helpful when a function area has a high room cavity ratio (RCR).

The Energy Standards allow the Tailored Method to be used for only a limited number of primary function areas. The primary function area shall only be one of the following:

1. As specifically listed in Table 140.6-D (Table 140.6-D).
2. As specifically listed in §140.6(c)3H.

5.7.3.2 Tailored Method General Rules

1. There shall be no lighting power allotment trade-offs between the separate conditioned and unconditioned indoor function areas. Indoor conditioned and indoor unconditioned lighting power allotments must each be separately determined on compliance documentation
2. There shall be no lighting power allotment trade-offs between the separate indoor and outdoor function areas. Indoor and outdoor lighting power allotments must each be separately determined on compliance documentation.
3. Some areas of a building may use the Tailored Method, while other areas of the same building may use the Area Category Method. However, no single area in a building shall be allowed to use both the Tailored Method and the Area Category Method.
4. The Tailored Method shall not be used in any building using the Complete Building method for compliance.

5.7.3.3 Room Cavity Ratio (RCR)

1. The room cavity ratio must be determined for any primary function area using the Tailored Lighting Method.
2. The lighting level in a room is affected in part by the configuration of the room, expressed as the room cavity ratio (RCR). Rooms with relatively high ceilings typically are more difficult to light and have a high RCR. Because luminaires are not as effective in a room with a high RCR, §140.6 allows a greater LPD to compensate for this effect.
3. The RCR is based on the entire space bounded by floor-to-ceiling partitions. If a task area within a larger space is not bounded by floor to ceiling partitions, the RCR of the entire space must be used for the task area. The exception to this rule allows for imaginary or virtual walls when the boundaries are established by “high stack” elements (close to the ceiling structure and high storage shelves) or high partial walls defined as “permanent full height partitions” described in §140.6(c)3Iiv wall display. These permanent full height partitions are only applicable when claiming additional lighting power for wall display lighting.

   Note: For use in calculating the RCR of the space, the walls are not required to be display walls as is required under §140.6(c)3Iiv.

   The RCR is calculated from one of the following formulas:

Equation 5-3 (Table 140.6-F) Rectangular Shaped Rooms

$$RCR = \frac{5 \times H \times (L + W)}{A}$$

Where:

RCR = The room cavity ratio
H = The room cavity height, vertical distance measured from the work plane to the center line of the luminaire
L = The room length using interior dimensions
W = The room width using interior dimensions
A = The room area

Equation 5-4 (Table 140.6-F) Non-Rectangular Shaped Rooms

$$RCR = \frac{[2.5 \times H \times P]}{A}$$

Where:
RCR = The room cavity ratio
H = The room cavity height (see equation above)
A = The room area
P = The room perimeter

4. For rectangular rooms, these two methods yield the same result and the second more general form of calculating RCR may be used in all instances, if desirable.
5. It is not necessary to document RCR values for rooms with an RCR less than 2.0. Rooms with a RCR higher than 2.0 are allowed higher LPDs under the Tailored Method. The figure below gives example RCR values calculated for rooms with the task surface at desk height (2.5 ft above the floor). This is useful in assessing whether or not a room is likely to have an RCR greater than 2.0.
6. A special situation occurs when illuminating stacks of shelves in libraries, warehouses, and similar spaces. In this situation, the lighting requirements are to illuminate the vertical stack rather than the horizontal floor area. In stack areas the RCR is assumed to be greater than seven. The non-stack areas are treated normally.

Table 5-3: Typical RCRs based on Equation 5-1

Room Length (ft)	Room Height (ft)															
	8	**12**	**16**	**20**	**24**	**30**	**36**	**40**	**8**	**12**	**16**	**20**	**24**	**30**	**36**	**40**
	8 feet from floor to ceiling and task is 2.5 ft above floor, so **H=5.5** (8 – 2.5)								10 feet from floor to ceiling and task is 2.5 ft above floor, so **H=7.5** (10 – 2.5)							
5	8.9	7.8	7.2	6.9	6.6	6.4	6.3	6.2	12.2	10.6	9.8	9.4	9.1	8.8	8.5	8.4
8	6.9	5.7	5.2	4.8	4.6	4.4	4.2	4.1	9.4	7.8	7.0	6.6	6.3	5.9	5.7	5.6
12	5.7	4.6	4.0	3.7	3.4	3.2	3.1	3.0	7.8	6.3	5.5	5.0	4.7	4.4	4.2	4.1
16	5.2	4.0	3.4	3.1	2.9	2.6	2.5	2.4	7.0	5.5	4.7	4.2	3.9	3.6	3.4	3.3
20	4.8	3.7	3.1	2.8	2.5	2.3	2.1	2.1	6.6	5.0	4.2	3.8	3.4	3.1	2.9	2.8
24	4.6	3.4	2.9	2.5	2.3	2.1	**1.9**	**1.8**	6.3	4.7	3.9	3.4	3.1	2.8	2.6	2.5
30	4.4	3.2	2.6	2.3	2.1	**1.8**	**1.7**	**1.6**	5.9	4.4	3.6	3.1	2.8	2.5	2.3	2.2
36	4.2	3.1	2.5	2.1	**1.9**	**1.7**	**1.5**	**1.5**	5.7	4.2	3.4	2.9	2.6	2.3	2.1	2.0
40	4.1	3.0	2.4	2.1	**1.8**	**1.6**	**1.5**	**1.4**	5.6	4.1	3.3	2.8	2.5	2.2	2.0	**1.9**

5.7.3.4 Determining Allowed General Lighting Power for Tailored Method

§140.6(c)3G; §140.6(c)3H

A. Tailored Method Trade-Off Allowances

Compliance forms shall be used to document trading-off Tailored Method Lighting Power allotments. Trade-offs are available only for general lighting, and only under the following circumstances:

1. From one conditioned primary function area using the Tailored Method, to another conditioned primary function area using the Tailored Method.
2. From one conditioned primary function area using the Tailored Method, to another conditioned primary function area using the Area Category Method.

3. From one unconditioned primary function area using the Tailored Method, to another unconditioned primary function area using the Tailored Method.
4. From one unconditioned primary function area using the Tailored Method, to another unconditioned primary function area using the Area Category Method.

B. Determine Lighting Power Allotments for Conditioned and Unconditioned Primary Function Areas

The allowed Tailored Method Indoor Lighting Power allotment for general lighting shall be separately calculated for conditioned and unconditioned primary functions are as follows:

1. For a conditioned primary function area, multiply the conditioned square feet of that area times the applicable allotment of watts per square feet for the area shown in Table 140.6-D.
2. For an unconditioned primary function area, multiply the unconditioned square feet of that area times the applicable allotment of watts per square feet for the area shown in Table 140.6-D.

An "area" is defined as all contiguous areas which accommodate or are associated with a single primary function area. Where areas are bounded or separated by interior partitions, the floor area occupied by those interior partitions may be included in a primary function area.

C. Calculating Tailored Method General Lighting Power Allotments

The Energy Standards define general lighting as installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting. To qualify as general lighting for the Tailored Method, the lighting system shall NOT use narrow beam direction lamps, wall-washers, valance, direct cove or perimeter linear slot types of lighting systems.

Table 140.6-D or §140.6(c)3H shall be used to determine the general lighting power density allotments as follows:

1. Using Table 140.6-D to Determine General Lighting Power Allotments:

a. Find the appropriate Primary Function Area in column 1 that fits one of the Nonresidential Function Area definitions in §100.1.

b. Find the corresponding General Illumination Level (Lux) in column 2.

c. Determine the room cavity ratio (RCR) for that primary function area, according to the applicable equation in Table 140.6-F. Use the RCR compliance form to document the RCR calculation.

d. Refer to Table 140.6-G, using the General Illumination Level (Lux, determined according to item ii),and the RCR (determined according to item iii),to determine the allowed Power Density Value.

e. Multiply the allowed Lighting Power Density Value times the square feet of the primary function areas. The product is the Allowed Indoor Lighting Power allotment for general lighting for that primary function area.

2. Using §140.6(c)3H to Determine General Lighting Power Allotments:

a. This section shall be used to determine general lighting power allotments ONLY for the following primary function areas, as defined in §100.1:

1. Exercise Center, Gymnasium
2. Medical and Clinical Care
3. Police Stations and Fire Stations
4. Public rest areas along state and federal roadways
5. Other primary function areas that are listed in neither Table140.6-C nor Table 140.6-D

b. Determine the illuminance values (Lux) for one of the primary function areas listed above as found in the Tenth Edition IES Lighting Handbook (IES HB), using the IES Recommended Horizontal Maintained Illuminance Targets for Observers 25-65 years old for illuminance.

c. Determine the room cavity ratio (RCR) for that primary function area, according to the applicable equation in Table 140.6-F. Use the RCR compliance form to document the RCR calculation.

d. Refer to Table 140.6-G, using the General Illumination Level (Lux, determined according to item b), and the RCR (determined according to item c), to determine the allowed Power Density Value.

e. Multiply the allowed Lighting Power Density Value times the square feet of the primary function areas. The product is the Allowed Indoor Lighting Power Density allotment for general lighting for that primary function area.

5.7.3.5 **Determine Additional Allowed Power for Tailored Method**

§140.6(c)3I thru §140.6(c)3L; Table 140.6-D

When using the Tailored Method for lighting compliance, in addition to the general lighting power allowance determined in accordance with Table 140.6-D, F, and G, additional allowed lighting power is available for wall display, floor display, task, ornamental/special effects, and very valuable display case lighting.

These additional layers of lighting power are not available when using §140.6(c)3H to determine the general Lighting Power allotment, and are not available for any primary function areas using the Complete Building or Area Category methods of compliance.

All of the additional lighting power allowances are "use it or lose it" allowances that cannot be traded-off. That is, if the installed watts are less than the allowed watts, the difference in watts is not available to trade-off anywhere else in the building.

A. Additional Wall Display Lighting Power:

Wall display lighting is defined by §100.1 as supplementary lighting required to highlight features such as merchandise on a shelf, which is displayed on perimeter walls; and that provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance.

Additional allowed power for wall display lighting is available only for lighting that illuminates walls having wall displays, only when there is a watt per linear foot allowance in column 3 of Table 140.6-D for the primary function area.

1. The wall display lighting power is NOT available for the following:

   a. When using §140.6(c)3H for determining the Allowed Indoor Lighting Power Density allotment for general lighting for the area.

   b. For any function areas using the Complete Building or Area Category methods of compliance.

   c. Floor displays shall not qualify for wall display lighting power allowances.

2. To qualify for the additional wall display lighting power, the lighting system shall be a type that is appropriate for creating a higher level of illuminance on the wall display.

   a. Lighting systems appropriate for wall lighting are lighting track adjacent to the wall, wall-washer luminaires, luminaires behind a wall valance or wall cove, or accent light. (Accent luminaires are adjustable or fixed luminaires with PAR, R, MR, AR, or other directional lamp types.)

   b. General lighting systems shall not qualify for this allowance.

3. Qualifying wall display lighting shall be mounted within 10 feet of the wall having the wall display.

   a. When track lighting is used for wall display, and where portions of that lighting track are more than 10 feet from the wall and other portions are within 10 feet of the wall, only those portions of track within 10 feet from the wall shall qualify for the wall display allowance.

4. The length of display walls shall include the length of the perimeter walls, including but not limited to closable openings, and permanent full height interior partitions.

   a. Permanent full height interior partitions are those that meet the following conditions:

      i. Extend from the floor to no more than two feet below the ceiling or are taller than ten feet.

      ii. Are permanently anchored to the floor, provided that neither commercial industrial stacks nor industrial storage stacks are permanent full height interior partitions.

5. Column 3 of Table 140.6-D shall be used to determine the additional allowed power for wall display lighting as follows:

   a. Use the same Primary Function Area Category row in column 1 that was used to determine the general lighting power density allotments for the area.

   b. Find the corresponding Wall Display Power (W/linear ft) in column 3.

   c. Determine the length of qualifying display walls in a single room or area.

   d. Multiply the Wall Display Power times the length of qualifying display walls, to calculate Wall Display lighting power allowance.

6. A mounting height multiplier is available in Table 140.6-E for wall display luminaires mounted 12 feet or higher, where mounting height is the distance from the finished floor to the bottom of the luminaire.

   a. The mounting height multiplier is NOT available for the general lighting power density allotment.

   b. The mounting height multiplier in Table 140.6-E shall be used to reduce the input wattage of luminaires (adjusted input wattage).

   c. Wall display lighting with varying mounting heights shall be separately determined.

In a single room, or single area having wall display lighting, using § 130.0(c) to determine luminaire classification and input wattage, do the following:

1. Separately add together the input wattage of all wall display luminaires mounted lower than 12 feet. These luminaires do not qualify for a height multiplier.
2. Separately add together the input wattage of all wall display luminaires mounted between 12 feet to 16 feet. Multiply the total input wattage of these luminaires times 0.87. This will be your adjusted input wattage for these luminaires.
3. Separately add together the input wattage of all wall display luminaires mounted higher than 16 feet. Multiply the total input wattage of these luminaires times 0.77. This will be your adjusted input wattage for these luminaires.

7. The additional allowed power for wall display lighting shall be the smaller of the calculated Wall Display Power allowance, or the sum total of the adjusted input wattage of all luminaires used for the wall display lighting systems in that room or area. Use the smaller of the two calculated allowances as follows:
   a. The additional allowed power for wall display lighting determined in accordance with Column 3 of Table 140.6-D, or
   b. The sum total of:
      i. Sum total input wattage of all wall display luminaires mounted lower than 12 feet, plus
      ii. Sum total adjusted input wattage of all wall display luminaires mounted 12 feet to 16 feet, plus
      iii. Sum total adjusted input wattage of all wall display luminaires mounted higher than 16 feet.
8. Use the appropriate compliance form, NRCC-LTI-04-E, to document the additional allowed power for wall display lighting.

B. Additional Floor Display and Task Lighting Power:

1. Floor display lighting is defined by §100.1 as supplementary lighting required to highlight features, such as merchandise on a clothing rack, which is not displayed against a wall; and provides a higher level of illuminance to this specific area than the level of surrounding ambient illuminance.
2. Task Lighting is defined by §100.1 as lighting that is not general lighting and that specifically illuminates a location where a task is performed.
3. Additional allowed power for floor display lighting and additional allowed power for task lighting may be used only for qualifying floor display lighting systems, qualifying task lighting systems, or a combination of both, only when there is a watt per square foot allowance in column 4 of Table 140.6-D for the primary function area.
4. For floor areas qualifying for both floor display and task lighting power allowances, the additional allowed power shall be used only once for the same floor area, so that the allowance shall not be additive.
5. Additional allowed power for a combination of floor display lighting and task lighting shall be available only for:

   a. Floors having floor displays; or
   b. Floors not having floor displays but having tasks having illuminance recommendations that appear in the Tenth Edition of the IES Lighting Handbook and that are higher than the general lighting level in column 2 of Table 140.6-D.

6. Floor display and task lighting shall be separately switched from the general lighting system.
7. The additional power for floor display and task lighting are NOT available for the following:
   a. When using §140.6(c)3H for determining the Allowed Indoor Lighting Power Density allotment for general lighting for the area.
   b. For any function areas using the Complete Building or Area Category methods of compliance.
   c. Displays that are installed against a wall shall not qualify for the floor display lighting power allowances.
   d. Any floor area designed to not have floor displays or tasks, such as floor areas designated as a path of egress, shall not be included for the floor display allowance.
8. Lighting internal to display cases shall be counted either as floor display lighting in accordance with §140.6(c)3J; or as very valuable display case lighting in accordance with §140.6(c)3Liii and iv.
9. To qualify for the additional power for floor display and task lighting, the lighting system shall be a type that is appropriate for creating a higher level of illuminance on the floor display or task. Floor display and task lighting shall be of a type different from the general lighting system.
   a. Lighting systems appropriate for floor display and task lighting consist of only directional lighting types, such as PAR, R, MR, AR; or of lighting employing optics providing directional display light from non-directional lamps.
   b. If track lighting is used, only track heads that are classified as directional lighting types qualify.
10. Qualifying floor display lighting shall be mounted no closer than 2 feet to a wall, and shall be located immediately adjacent to and capable of illuminating the task for which it is installed.
    a. When track lighting is used for floor or task lighting, and where portions of that lighting track are more than 2 feet from the wall and other portions are within 2 feet of the wall, only those portions of track more than 2 feet from the wall shall qualify for the floor display and task lighting power allowance.
11. Column 4 of Table 140.6-D shall be used to determine the additional allowed power for floor display and task lighting as follows:
    a. Use the same Primary Function Area Category row in column 1 that was used to determine the general lighting power density allotments for the area.
    b. Find the corresponding Allowed Combined Floor Display Power and Task Lighting Power (W/ft2) in column 4.
    c. Determine the square feet of the qualifying area.

d. Multiply the Allowed Combined Floor Display Power and Task Lighting Power Floor Display/Task Lighting Power allowance.

12. A mounting height multiplier is available in Table 140.6-E for floor display and task luminaires mounted 12 feet or higher, where mounting height is the distance from the finished floor to the bottom of the luminaire.
    a. The mounting height multiplier is NOT available for the general lighting power density allotment.
    b. The mounting height multiplier in Table 140.6-E shall be used to reduce the input wattage of luminaires (adjusted input wattage),
    c. Floor display lighting and task lighting luminaires with varying mounting heights shall be separately determined.

In a single room having floor display lighting and/or task lighting luminaires, using § 130.0(c) to determine luminaire classification and input wattage, do the following:

- Separately add together the input wattage of all floor display lighting and task lighting luminaires mounted lower than 12 feet. These luminaires do not qualify for a height multiplier.
- Separately add together the input wattage of all floor display lighting and task lighting luminaires mounted between 12 feet to 16 feet. Multiply the total input wattage of these luminaires times 0.87. This will be your adjusted input wattage for these luminaires.
- Separately add together the input wattage of all floor display lighting and task lighting luminaires mounted higher than 16 feet. Multiply the total input wattage of these luminaires times 0.77. This will be your adjusted input wattage for these luminaires.

13. The additional allowed power for all floor display lighting and task lighting luminaires lighting shall be the smaller of the calculated Floor Display/Task Lighting Power allowance, or the sum total of the adjusted input wattage of all luminaires used for floor display and task lighting systems in that room or area. Use the smaller of the two calculated allowances:
    a. The additional allowed power for wall display lighting determined in accordance with Column 4 of Table 140.6-D, or
    b. The sum total of:
        i. Sum total input wattage of all floor display luminaires and task lighting luminaires mounted lower than 12 feet, plus
        ii. Sum total of adjusted input wattage of all floor display luminaires and task lighting luminaires mounted from 12 feet to 16 feet, plus
        iii. Sum total adjusted input wattage of all floor display luminaires and task lighting luminaires mounted higher than 16 feet.
14. Use the appropriate compliance form, NRCC-LTI-04-E, to document the additional allowed power for Floor Display/Task Lighting Power lighting.

C. Additional Ornamental/Special Effects Lighting Power:

1. §140.6(c)3K(ii) defines qualifying ornamental lighting to include luminaires such as chandeliers, sconces, lanterns, neon and cold cathode, light emitting diodes,

theatrical projectors, moving lights, and light color panels when any of those lights are used in a decorative manner that does not serve as display lighting or general lighting.

2. Special effects lighting is defined as lighting installed to give off luminance instead of providing illuminance.
3. Additional allowed power for ornamental/special effects lighting may be used only for qualifying ornamental lighting systems, qualifying special effects lighting systems, or a combination of both, only when there is a watts per square foot allowance in column 5 of Table 140.6-D for the primary function area.
4. Additional ornamental and special effects lighting power is NOT available for the following:
    a. When using §140.6(c)3H for determining the Allowed Indoor Lighting Power Density allotment for general lighting for the area.
    b. For any function area using the Complete Building or Area Category methods of compliance.
5. For floor areas qualifying for both ornamental and special effects lighting power allowances, the additional allowed power shall be used only once for the same floor area, so that the allowance shall not be additive.
6. Any floor area not designed to have ornamental or special effects lighting shall not be included for the ornamental/special effects lighting allowance.
7. Column 5 of Table 140.6-D shall be used to determine the additional allowed power for ornamental/special effects lighting as follows:
    a. Use the same Primary Function Area Category row in column 1 that was used to determine the general lighting power density allotments for the area.
    b. Find the corresponding Allowed Ornamental/Special Effects Lighting Power (W/ft2) in column 5.
    c. Determine the square feet of the qualifying area.
    d. Multiply the Allowed Ornamental/Special Effects Lighting Power, times the square feet of the qualifying area, to determine calculated Allowed Ornamental/Special Effects Lighting Power allowance.
8. A mounting height multiplier is NOT available for ornamental/special effects lighting.
9. The additional allowed power for Ornamental/Special Effects Lighting shall be the smaller of the calculated Allowed Ornamental/Special Effects Lighting Power allowance, or the actual power used for the Allowed Ornamental/Special Effects Lighting systems;
10. Use the appropriate compliance form, NRCC-LTI-04-E, to document the additional allowed power for Ornamental/Special Effects Lighting.

D. Additional Very Valuable Display Case Lighting Power:

1. Case lighting is defined by §100.1 as lighting of small art objects, artifacts, or valuable collections which involves customer inspection of very fine detail from outside of a glass enclosed display case.
2. To qualify for additional allowed power for very valuable display case lighting, a case shall contain jewelry, coins, fine china, fine crystal, precious stones, silver, small art

objects and artifacts, and/or valuable collections the display of which involves customer inspection of very fine detail from outside of a locked case.

3. Additional allowed power for very valuable display case lighting shall be available only for display cases in retail merchandise sales, museum, and religious worship areas.
4. Qualifying lighting includes internal display case lighting or external lighting employing highly directional luminaires specifically designed to illuminate the case or inspection area without spill light, and shall not be fluorescent lighting unless installed inside of a display case.
5. Any floor area designed to not have very valuable display case lighting shall not be included for the very valuable display case lighting allowance.
6. The valuable display case lighting power is NOT available for the following:
   a. When using §140.6(c)3H for determining the Allowed Indoor Lighting Power Density allotment for general lighting for the area.
   b. For any function areas using the Complete Building or Area Category methods of compliance.
7. A mounting height multiplier is NOT available for very valuable display case lighting.
8. The very valuable display case lighting allowance shall be the smallest of the following:
   a. The product of the area of the primary function and 0.8 watt per square foot.
   b. The product of the area of the display case and 12 watts per square foot.
   c. The actual power of lighting for very valuable displays.
9. Use the appropriate compliance form, Form NRCC-LTI-04-E, to document the additional allowed power for valuable display case lighting.

Example 5-17 Room Cavity Ratio

Question

A small retail shop "Personal Shopper" room is 14 ft wide by 20 ft long by 8 ft high. The lighting system uses recessed ceiling fixtures. The task surface is at desk height (2.5 ft above the floor). What is the room cavity ratio?

Answer

The room cavity height is the distance from the ceiling (center line of luminaires) to the task surface (desk height). This is 8 ft -2.5 ft = 5.5 ft

RCR = 5 x H x (L + W) / Area

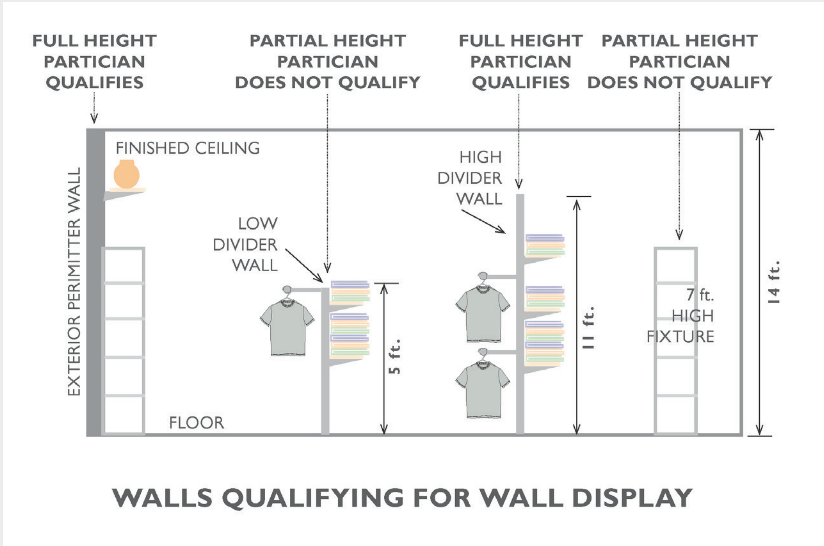
RCR = 5 x 5.5 (14+20) / (14 x 20) = 3.34

Example 5-18 Retail space lighting allocation

Question

A large retail store with a sales area that has a 14 ft high ceiling and full height perimeter wall also has several other walls and a high fixture element in the space. Based on the definition of "full-height" partitions (per §140.6(c)3Iiv), which components qualify for the wall display allocation?

Answer

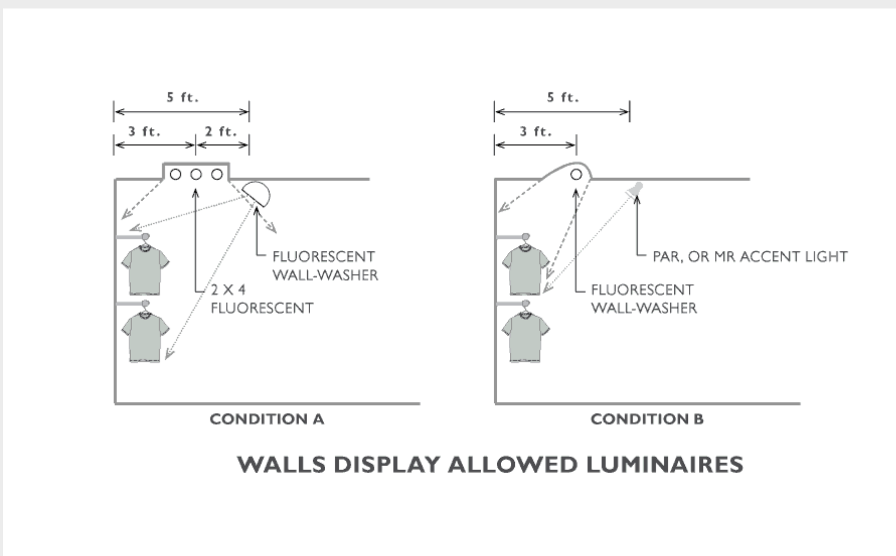


Example 5-19 Wall display lighting – Tailored Method

Question

In this question, condition A has 2X4 troffers placed 3 ft from a perimeter sales wall as well as fluorescent wall-washers 5 ft from the sales wall. Condition B has fluorescent wall-washers 3 ft from the wall and PAR adjustable accent lights 5 ft from the wall. Which luminaires qualify for the wall display lighting allocation?

Answers



Per §140.6(c)3Iiia, qualifying lighting must be mounted within 10 ft of the wall and appropriate wall lighting luminaires. (Luminaires with asymmetric distribution toward the wall or adjustable –directed toward the wall)

CONDITION A

While both luminaires are within ten feet of the wall only the wall-washer qualifies for the wall display allocation. The 2X4 is a general lighting luminaire with symmetric versus asymmetric distribution and does not qualify for the allocation.

CONDITION B

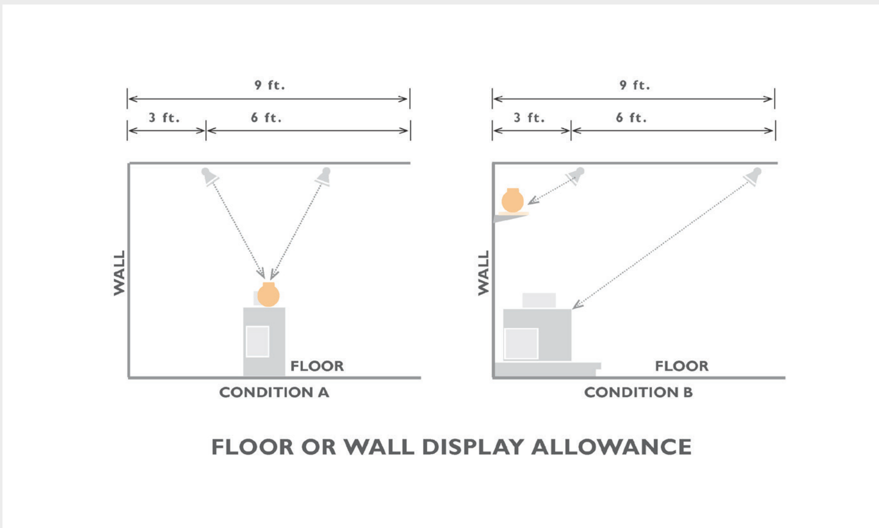
Both luminaires are within ten feet of the wall and both qualify for the wall display allocation. The fluorescent wall-washer has an asymmetric distribution and the PAR accent light at 5 ft from the wall is directional and is lamped with a projetor lamp.

Example 5-20 Museum lighting – Tailored Method

Question

A museum space has directional accent lighting luminaires on a track mounted to the ceiling. The first track is three feet from the perimeter wall of the exhibit space and the second track is nine feet from the wall. There is a third track (not shown) that is fifteen feet into the space. To what display category should these luminaires be assigned under §140.6(c) 3I and 3J

Answers



Per §140.6(c)3Iiv& 3Jv wall display luminaires must be within 10 ft of the wall and directional and floor displays must be at least two feet away from the wall and also directional. Using these criteria, the allocations for the two conditions shown are as follows:

CONDITION A

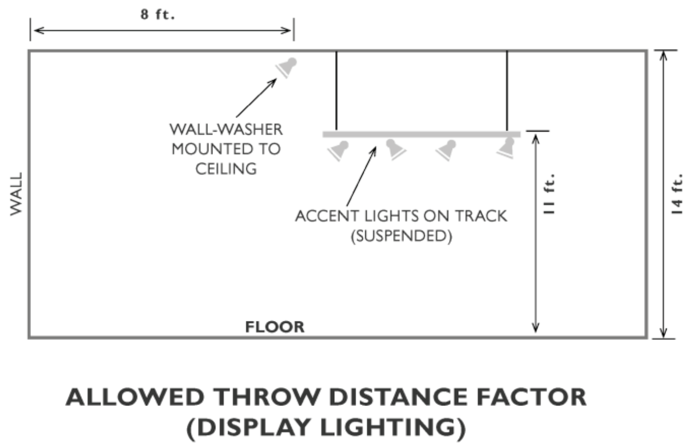
Both sets of luminaires shown are at least 2 ft away from the wall and are directed onto a floor exhibit (display) therefore they both qualify for the floor display allocation. The third track with directional luminaires also qualifies as floor display.

CONDITION B

Both sets of luminaires shown are also closer than 10 ft to the wall and are directed onto a wall exhibit (display) therefore they both, when directed toward the wall qualify for the wall display allocation. The third track with directional luminaire (15 ft from the wall) does not qualify for wall display, only floor display.

Note: Luminaires within a 2 ft to 10 ft zone may be assigned to either wall or floor display depending on the focus direction of the luminaires. However only one classification, either wall or floor can be used for luminaire compliance, not both.

Example 5-21 Adjustments for luminaire mounting height – Tailored Method



Question

A high ceiling space with allowed display lighting has wall-washers mounted on the ceiling near the wall and accent lights mounted on suspended track in the center of the space. Because of the 18 ft high ceiling, does the display lighting qualify for a mounting height factor adjustment?

Answer

Per §140.6(c) 3Iv and 3Jix, some but not all of the display lighting qualifies for the mounting height adjustment. The wall directional lighting that mounted at the ceiling is above 12 ft which then qualifies it for an adjustment factor of 0.87 in accordance with Table 140.6-E. However the track that is suspended at 11 ft is excluded from an adjustment factor. It must use the default factor of 1 with the allowed LPD as shown in column 4 in Table 140.6-E.

Example 5-22 Tailored Method lighting power allowance

Question

The customer area of a bank building includes financial transaction counters, wall displays and seating. The size of the space is 20 ft wide by 50 ft long and 11 ft high. Transaction counters are 3-feet off the floor and there is 75 ft of wall display. Proposed luminaires used for general illumination are recessed down lights and for wall display lighting are wall-washer luminaires. Under the Tailored Method, what is the maximum allowed Lighting Power Density (LPD) (excluding any control credits)?

Answer

From Table 140.6-D in the EnergyStandards, target general illumination of 300 lux is recommended for financial transaction area. Using the dimensions given (20 ft x 50 ft x 11 ft and a task height of 3-feet), the room cavity ratio (RCR) is calculated to be 2.8. Using Table 140.6-G, 0.82 W/ft^2 of LPD is allowed for the 300 lux target and RCR of 2.8 . Therefore, the general lighting allowance is 820 W (= 20 ft x 50 ft x 0.82 W/ft^2).

For the wall display lighting, 3.15 W/ft of LPD is allowed (per Table 140.6-D Column 3) . The wall display lighting power allowance is 236 W (=75 ft X 3.15 W/ft).

For floor display and task lighting, 0.2 W/ft^2 of LPD is allowed (per Table 140.6-D Column 4). The combined floor display and task lighting power allowance is 200 W (= 20 ft x 50 ft x 0.2 W/ft^2).

Total allowed lighting power for this financial transaction area is 1,256 W (= 820 W + 236 W + 200W).

Example 5-23 Tailored Method lighting power allowance

Question

If, in the previous question, the design used only down lights or 2X2 fluorescent troffers, what is the maximum allowed power *(excluding any control credits)?*

Answer

Since the proposed downlights or 2X2 fluorescent troffers provide general illumination only and there are no luminaires providing wall display lighting, the wall display lighting power allowance cannot be applied here as there are no qualifying luminaires in the design. Display lighting is a use-it-loose-it component and the lighting equipment used must meet the optical characteristics of display and focal lighting.

The maximum allowed power 1,020 W (= 820W + 200W).

The 1,020 W comprises 820W for the allowed general lighting and 200 watts for the task lighting.

Example 5-24 Decorative lighting - Tailored Method

Question

The bank from the previous question wants to add chandeliers in addition to down lights and wall-washers. What is the maximum allowed power under Tailored Method *(excluding any control credits)?*

Answer

1,756W (=1256W + 500W) is the maximum allowed lighting power. See below for details.

In addition to the 1,256 W allowed for the combination of general lighting display lighting and task lighting, a maximum of 500 W (per Table 140.6-D column 5) of Ornamental/Special effects lighting is allowed. Note: for this wattage to be allowed the decorative lighting must be in addition to general lighting and the luminaire must meet the ornamental lighting criteria. The actual allowed Ornamental lighting power will be the lower of the maximum allowed or total ornamental lighting power.

Example 5-25 Ornamental lighting and very valuable display lighting - Tailored Method

Question

A 5,500-ft² retail store has:

- 5,000 ft² of gross sales floor area with a RCR of 2.5
- 200 ft² of restrooms (with a RCR of 6.0)
- 300 ft² of corridors (with a RCR of 6.5)
- 100 ft² of very valuable merchandise case top with 1,200 W of actual lighting

There are 300 linear ft of perimeter wall including closeable openings and Ornamental/special effects lighting is being used as part of the retail scheme.

What are the allowed lighting power for general lighting, wall display, floor display, ornamental/special effect, and very valuable display lighting in this store using the Tailored Method?

Answer

The general illumination for retail is 400 Lux per Standards Table 140.6-D. The Lighting Power Density (LPD) is 0.98 W/ft² for a 400 Lux space with an RCR of 2.5 per Table 140.6-G. Therefore, the allowed general lighting power for the retail store is 0.98 W/ft² X 5,000 ft² = **4,900 W**.

Corridors and restrooms are not included in the Tailored Method tables and therefore must comply under the area category method. Look up Table 140.6-C for the allowed LPD for these spaces. Table 140.6-C contains LPD values for primary functional areas and it allows 0.6 W/ft^2 of LPD for corridors and restrooms. *(RCR is not relevant in looking up LPD values in Table 140.6-C. This is different from how to look up values from Table 140.6-G)*

The allowed power for the restrooms is 200 ft² x 0.6 W/ft² = **120 W**. The allowed power for the corridors is 300 ft² x 0.6 W/ft² = **180 W**.

The wall display lighting is computed from the entire wall perimeter, including all closeable openings, times the wall display power allowance. Therefore, the allowed wattage is 300 ft x 14 W/ft = **4,200 W**. The allowance is taken from column three of Standards Table 140.6-D.

The floor display allowance is computed from the area of the entire space with floor displays times the floor display lighting power density. Therefore, the allowed wattage is 5,000 ft² x 1.0 W/ft² = **5,000 W**. The allowance is taken from column four of Table 140.6-D.

The ornamental/special effect allowance is computed from the area of the entire space with floor displays times the ornamental/special effect lighting power density. Therefore, the allowed wattage is 5,000 ft² x 0.5 W/ft² = **2,500 W**. The allowance is taken from column five of Table 140.6-D.

The allowed wattage for very valuable display case top is smaller of the product of 0.8 W/ft² and the gross sales area (5,000 ft²) or the product of 14 W/ft² and the actual area of the case tops (100 ft²). The maximum allowed power is the smaller of 0.8 W/ft² X 5,000 ft² = 4,000 watts, or 14 W/ft² X 100 ft² = 1,200 watts. 0.8 W/ft² for very valuable display case lighting, is allowed per §140.6(c)3Lv. Therefore, the maximum allowed power is **1,200 W**.

Therefore, the total allowed lighting power is 4,900 + 120 + 180 + 4,200 + 5,000 + 2,500 + 1,200 = **18,100 W**. Note that in the Tailored Method, the allowed wattage for each lighting task other than general lighting is of the use-it-or-lose-it variety, which prohibits trade-offs among these wattages and different tasks or areas. Only the General Lighting component of the Tailored Method is tradable between areas using tailored compliance or areas using Area compliance.

Example 5-26 Very valuable display lighting – Tailored method

Question

If in the question above, the actual design wattages for floor display and very valuable display are 4,500 W and 1,000 W respectively, what are the maximum allowed floor display and very valuable display power allowances?

Answer

Because the floor display and very valuable display allowances are use-it-or-lose-it allowances, the maximum power allowed is the smaller of allowed watts for floor display (5,000 W) and very valuable display (1,200 W) or the actual design watts for floor display (4,500 W) and very valuable display (1,000 W). Therefore, the maximum allowed watts for floor display and very valuable display lighting are 4,500 W and 1,000 W actual design watts, not 5,000 W and 1,400 W maximum allowed watts.

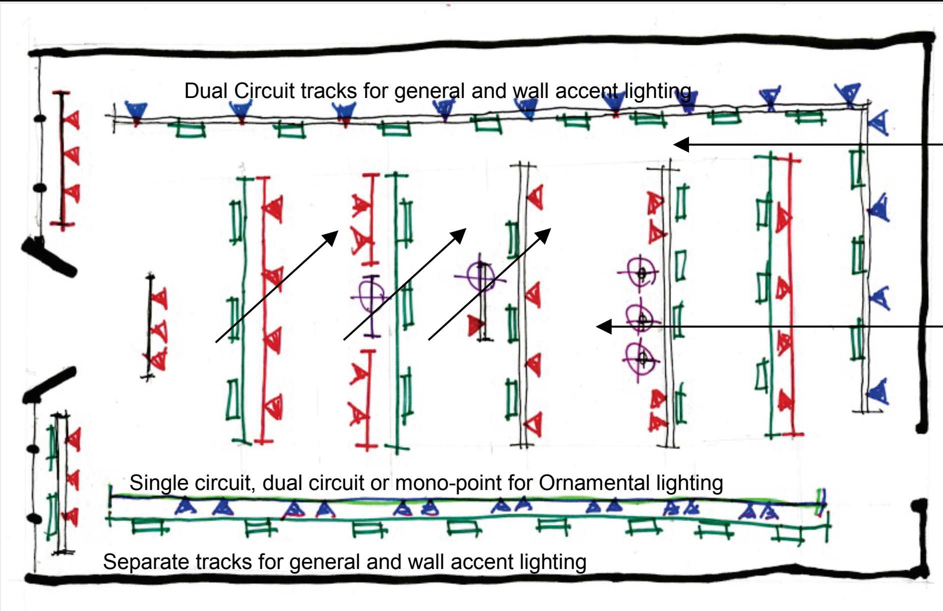
Example 5-27 Retail store lighting - Tailored Method

Question (Two Parts – Part 1 and 2)

Owners of a retail store want to use track lights for all the sales floor lighting. The sales floor is 50 ft x 100 ft with 10 ft high ceilings. There are 125 ft of sales wall and decorative pendants for ornamental effect lighting also mounted on track. All the merchandise is on open sell racks, tables or on wall shelves and hangers. There will be no casework or high-end valuable merchandise lighting required in the design.

<u>Part 1</u>: using tailored compliance, what is the maximum allowed lighting power?

<u>Part 2:</u> based on the design description, what other compliance requirements are unique to this approach?



Answer – Part 1

The allowed maximum wattage is **13,150 W** which is determined as follows:

From Standards Table140.6-D, Column 2, the general illumination for retail is 400 lux. From Standards Table 141.0-G, the LPD for 400 lux in a space with the RCR determined as <2.0 is 0.78W/ft². Therefore, the allowed general lighting power is 0.78 W/ft² X 5,000 ft² = 3,900 W along with the allowed floor display lighting from Table 140.6-D column 4 which is 1.0W/ft² X 5,000 ft² = 5,000 W and the allowed wall display lighting from the same table column 3 which is 14 W/ft X 125 ft = 1,750 W. Plus an ornamental lighting adder from column 5 of 0.5 W/ft² X 5,000 ft² = 2,500 W. [3900 + 5000 +1750 + 2500 =13,150]

Answer – Part 2

Dual circuit track, multiple independently circuited tracks or combination of both will be required for an all track design to conform to Title 24-2016 Tailored Method lighting compliance.

Retail stores or other spaces using the Tailored Method that use track lighting exclusively for the layered lighting approach as defined in the Tailored Method must provide a system for separately switching and controlling the layered lighting components (general, floor display, wall display and ornamental lighting). One solution is the use of dual circuit track with one circuit dedicated to general lighting and the other to wall display or floor display, based on where the track is located and on its assigned function. If/when ornamental lighting is also powered by track; it must also be separately circuited using dual circuit track or a separate dedicated track.

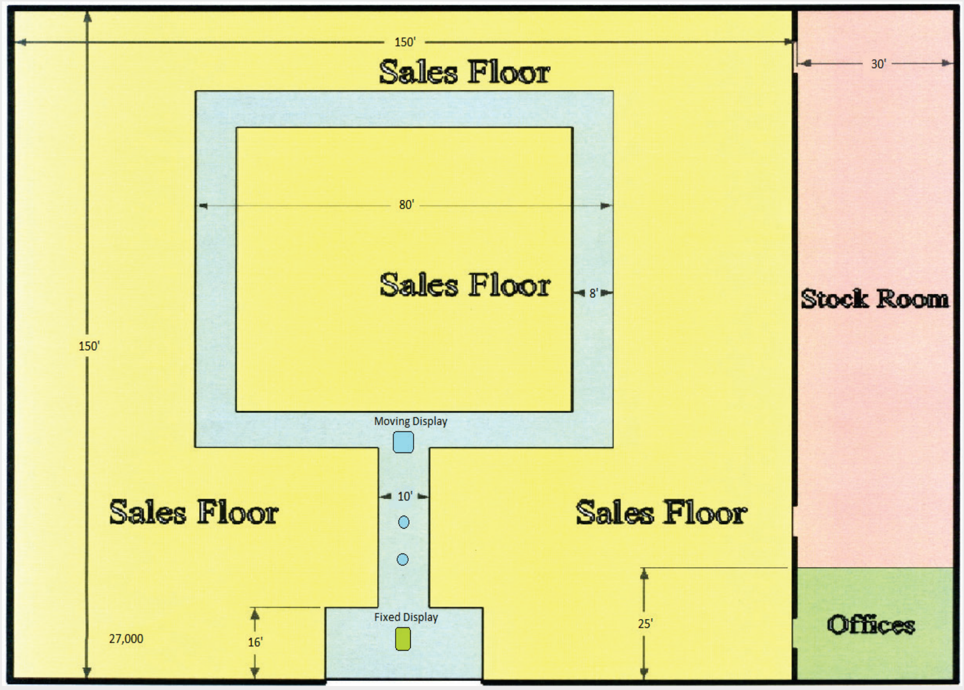
Another solution is to use multiple, single circuit tracks, as needed, with each track circuited for its specific task (general, display or ornamental lighting).

Note: each lighting task; general, display and/or ornamental lighting must be separately circuited and controlled. Therefore, in an application that has an area with general lighting, wall and floor display and ornamental lighting all occurring multiple adjacent dual circuit tracks or a combination of tracks and other power connections (such as mono-points) may be needed.

Example 5-28 Retail store lighting - Tailored Method

Question

How are the task spaces and allowed LPD's determined for a 27,000 square foot retail store with sales areas, stockrooms and offices using Tailored Method?



Answer

Determine square footage allowances by space type, as well as allowed maximum watts, for each area as follows:

1) First, identify spaces allowed to use the Tailored Method and those requiring the Area Category Method. Only the sales area can use the Tailored Method (per Table 140.6-D of the standards). Stock rooms and offices are not in the Tailored table and therefore must comply under the Area Category Method (Table 140.6-C).

2). The area of offices and stockrooms are determined by multiplying the length and width of each space (25 X 30 = **750 ft²** for offices) (30 X 125 = **3,750 ft²** for stockrooms). The allowed maximum watts for offices and stockrooms are then determined by multiplying the allowed LPD of the space (Table 140.6-C) by the area of the space.

3) The area of the sales floor is also determined by multiplying the length and width of the space. However the gross sales area also includes major circulation paths that are required by code (evacuation egress). Therefore these egress areas must be deducted from the total sales floor footprint to determine allowed sales area when using the Tailored Method. Note: the same is also true for a sales area complying under the Area Category Method. The allowed sales floor square footage is therefore **19,980 ft²** (150 X 150 = 22,500 minus 2,520 total egress area shown in pale blue on the plan).

To determine maximum allowed lighting power for the sales floor it is also necessary to identify the lineal foot of qualifying walls eligible for wall display. Total maximum watts for the sales floor is then determined by using the allowed LPD (from Table 140.6-G) for general lighting based on the RCR of the space and the LPD for allowed floor display, wall display and ornamental effect lighting (columns 2, 3, 4 from Table 140.6-D).

4) LPD for the 2,520 ft² of egress space is determined by using the Area Category Method, as egress space is not in the Tailored table (Table 140.6-D). Table 140.6-C of the Area Category Method will determine the allowed LPD as egress space falls under the category of corridor. Multiply the LPD for corridor by the egress area for the allowed maximum watts.

Example 5-29 Exercise center lighting – Tailored method

Question

Using provisions as defined under §140.6(c)3H Tailored Compliance, what is the Allowed Lighting Power for an exercise center with two separate rooms? One room is 40 ft wide X 60 ft long with a 16 ft ceiling. The other room is 16 ft wide X 30 ft long with a 12 ft ceiling. The luminaires are mounted at the ceiling for both rooms.

Answer

2,995 W total for the two room Exercise Center. This allowed wattage is determined by:

1) Illuminance values (Lux) for an Exercise Center according to the IESNA Lighting Handbook Tenth Edition using the horizontal illuminance targets for observers in the 25-65 age bracket. From the handbook, the horizontal illumination target is determined to be a maximum of **400 lux** measured at 4 to 5 ft above the floor.

2) The RCR in accordance with Table 140.6-F. Because there are two different rooms, each will need to have its RCR determined.

a) The RCR for the 40' X 60' with 16' ceiling has an RCR of **2.4** (5 X 12 X 100 ÷ 2400 =2.4)

b) The RCR for the 16' X 30' with 12' ceiling has an RCR of **3.83** (5 X 8 X 46 ÷ 480 = 3.83)

3) The allowed lighting power density (LPD) in Table 140.6-G.

a) The first room with an RCR of 2.4 and a lux target of 400 is allowed 0.98 W/ft²

b) The second room with an RCR of 3.83 and a lux target of 400 is allowed 1.34 W/ft²

4) The square feet of the areas; One room is 40 ft wide X 60 ft long = 2,400 feet and the other 16 ft wide X 30 ft long = 480 feet. Therefore the allowed watts are as follows:

a) 2,400 X 0.98 = 2,352 W

b) 480 X 1.34 = 643 W

5) The total allowed lighting power in watts is 2352 W + 643 W or a total of **2,995 W** for the two room exercise center.

Example 5-30 Decorative lighting in exercise center - Tailored Method

Question

Using provisions as defined under §140.6(c)3H, what is the Allowed Lighting Power for the exercise center if a portion of the lighting will use decorative chandeliers?

Answer

2,995 W total for the two room exercise center using the same procedure as outlined in Example 5-29 above.

Although some of the lighting is being created with use of decorative chandeliers, Table 140.6-D column 5 doesn't apply when using §140.6(c)3H.

A provision of §140.6(c)3Hii requires that when calculating allowed indoor Lighting Power Density allotments for general lighting using §140.6(c)3H, the building shall not add additional lighting power allowances for any other use, including but not limited to wall display, floor display and task, ornamental/special effects, and very valuable display case lighting.

5.8 Performance Approach

The performance approach provides an alternative method to the prescriptive approach for establishing the allowed lighting power for the building.

Under the performance approach, the energy use of the building is modeled using a compliance software program approved by the Energy Commission. In this energy analysis, the standard lighting power density for the building is determined by the compliance software program based on occupancy type, in accordance with either the complete building, area category, or tailored method described above. This standard lighting power density is used to determine the energy budget for the building.

When a lighting permit is sought under the performance approach, the applicant uses a proposed lighting power density to determine whether or not the building meets the energy budget. If it does, this proposed lighting power density is automatically translated into the allowed lighting power for the building (by multiplying by the area of the building).

If the building envelope or mechanical systems are included in the performance analysis (because they are part of the current permit application), then the performance approach allows energy trade-offs between systems that can let the allowed lighting power go higher than any other method. Alternatively, it allows lighting power to be traded away to other systems, which would result in a lower allowed lighting power. This flexibility in establishing allowed lighting power is one of the more attractive benefits of the performance approach.

General lighting power is the power used by installed electric lighting that provides a uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect, exclusive of daylighting, and also known as ambient lighting.

Trade-offs in general lighting power are allowed between all spaces using the Area Category Method, between all spaces using the Tailored Method, and between all spaces using the Area Category and Tailored Methods.

Also, with the Area Category Method and the Tailored Method, the Energy Standards provide an additional lighting power allowance for special cases. Each of these lighting system cases are treated separately as “use-it-or-lose-it” lighting: the user receives no credit (standard design matches proposed), but there is a maximum power allowance for each item).

See the 2016 Nonresidential ACM Reference Manual for additional information.

5.9 Additions and Alterations

5.9.1 Overview

New additions, similar to newly constructed buildings, must meet all mandatory measures for both the prescriptive and performance method of compliance. Prescriptive requirements, including the lighting power densities, must be met if the prescriptive method of compliance is used. If the performance approach is used and the new addition includes envelope or mechanical systems in the performance analysis, the lighting power densities may be traded-off against other system energy budgets.

Any space with a lighting system installed for the first time must meet the same lighting requirements as a newly constructed building.

Entire Luminaire alterations include removing and reinstalling more than 10 percent of the existing luminaires, replacing or removing and adding luminaires, and redesign of the lighting system that includes adding, removing, or replacing walls or ceilings.

Luminaire Component Modifications include replacing the ballasts or drivers and the associated lamps, permanently changing the light source, and changing the optical system such as reflectors.

Lighting Wiring alterations include wiring alterations that add a circuit feeding luminaires; that relocate, modify, or replace wiring between a switch or panelboard and luminaires; or that replace lighting control panels, panelboards or branch circuit wiring.

5.9.2 Additions

§141.0(a)

The nonresidential indoor lighting of the addition shall meet either the prescriptive approach or the performance approach.

When using the prescriptive approach, the indoor lighting in the addition must meet the lighting requirements of §110.9, §130.0 through §130.5, §140.3(c), and §140.6.

When using the performance approach, the indoor lighting in the addition must meet the lighting requirements of §110.0 through §130.5; and one of the following two options of the performance requirements of §140.1:

1. The addition alone; or
2. The existing building, plus the addition, plus the alteration.

5.9.3 Alterations – General Information

§141.0(b)

5.9.3.1 Scope

Alterations to existing nonresidential, high-rise residential, hotel/motel, or re-locatable public school buildings; or alterations in conjunction with a change in building occupancy to a nonresidential, high-rise residential, or hotel/motel occupancy; shall meet the following requirements:

1. Comply with the requirements for Additions, or
2. Comply with the Prescriptive lighting requirements, or
3. Comply with the Performance approach.

An Alteration is defined by the Energy Standards as follows:

1. Any change to a building's water-heating system, space-conditioning system, lighting system, electrical power distribution system, or envelope that is not an addition; and
2. Any regulated change to an outdoor lighting system that is not an addition; and
3. Any regulated change to signs located either indoors or outdoors; and
4. Any regulated change to a covered process that is not an addition.

An Altered Component is defined by the Energy Standards as a component that has undergone an alteration and is subject to all applicable requirements.

5.9.3.2 Indoor Lighting Exceptions

The following indoor lighting alterations are not required to comply with the lighting requirements in the Energy Standards:

1. Entire luminaire alterations or component modification of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.
2. In an enclosed space where only two luminaires are affected by entire luminaire alterations, luminaire component modifications, or lighting wiring alterations.
3. Disturbance of asbestos directly caused by entire luminaire alterations, luminaire component modifications, or lighting wiring alterations, unless the modifications are made in conjunction with asbestos abatement.
4. Lighting wiring alterations strictly limited to addition of lighting controls.

   EXCEPTION: Lighting alterations made in conjunction with asbestos abatement shall comply with the applicable requirements in §141.0(b)2I

5.9.3.3 Skylight Exception

When the daylighting control requirements of §130.1(d) are triggered by the addition of skylights to an existing building and the lighting system is not re-circuited, the daylighting control need not meet the multi-level requirements in § 130.1(d). Daylit areas must be controlled separately from non-daylit areas. An automatic control must be able to reduce lighting power by at least 65 percent when the daylit area is fully illuminated by daylight.

5.9.3.4 Alterations – Performance Approach

When using the Performance Approach (using a software program certified to the Energy Commission) the altered envelope, space–conditioning system, lighting and water heating components, and any newly installed equipment serving the alteration, shall meet the applicable requirements of §110.0 through §110.9, §120.0 through §120.6, and §120.9 through §130.5.

5.9.3.5 Alterations – Prescriptive Approach

When using the Prescriptive Approach, the altered lighting shall meet the applicable requirements of §110.0, §110.9, and §130.0 through §130.4.

5.9.4 Lighting Alterations

§141.0(b)2I, §141.0(b)2J

Lighting alterations are either alterations to entire luminaires, called Entire Luminaire Alterations, or modifications of installed luminaires, called Luminaire Component Modifications.

Entire Luminaire Alterations are alterations that include or affect the entire luminaire, such as the complete replacement of old luminaires with new; completely disconnecting the luminaire from the circuit, modifying it, and reinstalling it; or moving or modifying the walls or ceilings of the space along with modifying the space's lighting system. Luminaire Component Modifications are modifications in place that include replacing the ballasts or drivers and the associated lamps in the luminaire, permanently changing the light source of the luminaire, or changing the optical system of the luminaire. The Energy Standards compliance goals for the lighting alterations are twofold: first, the installation must meet the lighting power level specified in the Energy Standards, and second, the installation must provide the lighting controls functionality specified in the Energy Standards.

The 2016 Energy Standards allow three options for meeting the installed power and associated control requirements:

1. Installed lighting power that is greater than 85 percent of Table 140.6-C
2. Installed lighting power that is equal or less than 85 percent of Table 140.6-C
3. Where total rated power of the replacement luminaires in the occupancy, compared to the total rated power of the existing luminaires in the occupancy, have 50 percent lower power in hotel, office, and retail occupancies, and 35 percent lower power in all other occupancies.

Option 3 is new for 2016 and allows the maximum installed lighting power to be determined by totaling and taking a percentage of the currently installed lighting power, rather than by measuring the square footage of the space and multiplying it by a lighting power allowance. As this is likely to result in a lower allowed lighting power than option 2, bi-level controls are not required for this option. The control requirements for each option are described in Table 5-4.

Table 5-4 (Modified Table 141.0-E): New Control Requirement for Lighting Alterations

Applicable §130.1 Control requirements:	Lighting power is reduced by 35/50% compared to existing	Resulting lighting power, compared to the lighting power allowance specified in §140.6(c)2, Area Category Method	
		Lighting power is ≤ 85% of allowance	Lighting power is > 85% to 100% of allowance
§130.1(a)1, 2, and 3 Area Controls	Yes	Yes	Yes
§130.1(b) Multi-Level Lighting Controls – only for alterations to general lighting of enclosed spaces 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per square foot	Not Required	Bi-level control for each enclosed space, minimum one step between 30-70 percent of lighting power regardless of luminaire type, or meet Section 130.1(b)	Yes
§130.1(c) Shut-Off Controls	Yes[1]	Yes	Yes
§130.1(d) Automatic Daylight Controls	Not Required	Not Required	Yes
§130.1(e) Demand Responsive Controls – only for alterations > 10,000 ft^2 in a single building, where the alteration also changes the area of the space, or changes the occupancy type of the space, or increases the lighting power	Not Required	Not Required	Yes

[1] As bi-level controls are not required for this option, partial-off controls are not required to be installed in place of “full off” automatic shutoff controls for library book stack aisles, corridors and stairwells (see Sections 141.0(b)2Iii and Jii).

The following lighting alterations are not required to comply with §141.0(b)2I, Entire Luminaire Alterations, or §141.0(b)2J, Luminaire Component Modifications:

1. Alterations in an enclosed space where only two luminaires are replaced or reinstalled.
2. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.
3. Alterations of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.

The acceptance testing requirement of §130.4 is not required for alterations where lighting controls are added to control 20 or fewer luminaires.

Example 5-31 Entire Luminaire Alteration OptionsQuestion

All light fixtures are being replaced in one enclosed room of a commercial tenant space. The entire tenant space has a total of 25 light fixtures. The altered room will receive a total of eight new light fixtures. Which Energy Standards requirements must we comply with?

Answer

Since all lighting fixtures within the enclosed area (room) are being replaced and there are no alterations to walls or ceilings, it can comply with the requirement of either subparagraph i or subgraph ii of §141.0(b)2I.

Example 5-32 Threshold for entire luminaire alterations requirements (changeout example)

Question

There are 100 lighting fixtures in an existing office space. Ceilings are being replaced with new, together with replacing all the existing light fixtures with new. There is no change in the fixture layout. Which Standards requirements must we comply with?

Answer

Since the scope of work includes replacing all existing light fixtures, the project must comply with §141.0(b)2I. However, since the scope also includes ceiling replacement, it must comply specifically with subsection “i” of this section: the luminaires must meet the lighting power allowance in §140.6 and the altered luminaires must meet the applicable requirements in Table 141.0-E.

Example 5-33 Threshold for entire luminaire alterations requirements (remodel example)

Question

There are 100 lighting fixtures in an existing office space. Walls are being altered, together with a replacement of the existing light fixtures with 80 new fixtures. Which Energy Standards requirements must we comply with?

Answer

Since the scope of work includes a redesign of the lighting system along with wall alterations, it must comply with §141.0(b)2Ii. It must meet requirements include the lighting power allowance in §140.6 and applicable control requirements in Table 141.0-E.

Example 5-34 Rewiring of replacement luminaires (example compliance with lighting wiring alterations)

Question

If the lighting system is being rewired as part of a lighting alteration project, which Energy Standards requirement must be complied with?

Answer

When the alteration involves a wiring alteration, it must comply with the control requirements as specified in §141.0(b)2K. This is in addition to any applicable lighting alteration requirements. Note: many of the requirements for wiring alterations and lighting alterations are the same. Acceptance test requirement is triggered if controls are added to control more than 20 luminaires.

Example 5-35 Multi-floor retail project (example compliance with lighting alterations)

Question

The lighting is being retrofitted in a retail building with two floors. The first floor has fixtures which are being replaced with new LED fixtures. Also on this floor are two offices with one fixture each and a conference room with two fixtures. The aggregate wattage of the new first floor fixtures is 55 percent less than the original fixture wattage. The second floor has linear fluorescent ceiling fixtures which are being retrofitted with LED conversion kits. How do the Energy Standards impact the overall project?

Answer

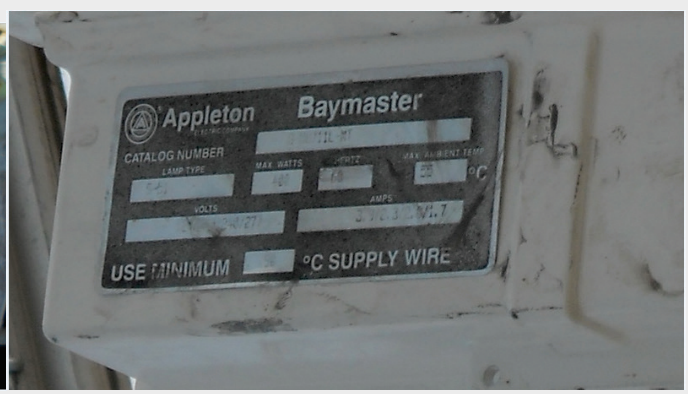
The retrofits on the first floor are entire luminaire alterations. The building occupancy is retail so the power reduction threshold is 50 percent; a lighting power allowance could be calculated based on square footage, but because the new fixtures use less than half the power of the original fixtures, it makes sense to use the percent reduction approach. The new fixtures must comply with the controls requirements in §141.0(b)2Iii. Those applicable provisions are §130.1(c)1A through C, §130.1(c)2, §130.1(c)3, §130.1(c)4, and §130.1(c)5. However, since there are offices and conference rooms with two or fewer fixtures, per Exception 2 to §141.0(b)2I those rooms are not required to comply with control requirements. The retrofits on the second floor are luminaire component modifications. Luminaire component modifications have the same option to either determine the lighting power allowance based on the area type and square footage, or based on a percent reduction in the lighting power. In short, even though the two floors are using different retrofit approaches, the same options and the same requirements ultimately apply.

Example 5-36 Example Warehouse Lighting Alteration (example compliance with the 50/35 percent lighting power reduction option)

Question

The existing metal halide luminaires in a warehouse facility are proposed to be replaced by LED luminaires (shown below). There are 100 existing metal halide luminares that use 250 watts each, all of which will be replaced. The replacement LED luminaires use 150 watts each; it seems easy to see that this is more than a 35 percent reduction. How is compliance determined under the new power reduction option, and what controls are required?

A lamp taken from an existing luminaire
Source: EcologyAction



Label of an existing luminaire
Source: EcologyAction

Picture of one of the new LED luminaire
Source: EcologyAction

Answer

As a warehouse is not an “office, hotel, or retail” space, the power reduction option requires a 35 percent reduction in installed lighting power. Thus, enter the number and wattage of the existing luminaires into NRCC-LTI-06, and use the form to calculate both the existing installed lighting power (100 x 250 = 25,000) and the maximum allowance based on a 35 percent reduction (25,000 x 0.65 = 16,250). Enter the number and wattage of the new luminaires into NRCC-LTI-01, just like any other project; if this is a one-for-one replacement, then the total lighting power of the new luminaires would be under the allowance (100 x 150 = 15,000).

As the lighting power reduction exceeds 35 percent, only area on/off controls and automatic shutoff controls are mandatory as specified in Section 141.0(b)2Iii and summarized in Table 5-4.

5.9.5 Alterations - Luminaire Component Modifications

§141.0(b)2J

The followings are defined as luminaire component modifications in the 2016 Energy Standards:

1. Replacing the ballasts or drivers and the associated lamps in the luminaire;
2. Permanently changing the light source of the luminaire; or
3. Permanently changing the optical system of a luminaire.

Lamp replacement alone and ballast replacement alone is not considered a modification of the luminaire as long as the replacement lamps or ballasts are installed and powered without modifying the luminaire. In addition, the following luminaire modifications are not required to comply with §141.0(b)2J, Luminaire Component Modifications:

1. Modifications that would cause the disturbance of asbestos, unless the modifications are made in conjunction with asbestos abatement; and
2. Modification of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.

Acceptance testing requirement of §130.4 is not required for modifications where lighting controls are added to control 20 or fewer luminaires.

Example 5-37 Threshold for luminaire component modifications

Question

There are 100 lighting fixtures in an existing office space. For 20 fixtures, the internal components are being replaced with new kits that only require disconnecting the existing luminaires, and reconnecting the new luminaires, which Energy Standards requirements apply?

Answer

Because this alteration is considered luminaire component modifications, and less than 70 fixtures are being modified, the space may maintain its existing installed lighting power and controls provisions.

Example 5-38 Standards for luminaire component modifications

Question

If in the example above, 70 fixtures are being replaced with fixture kits, which Energy Standards requirements must be complied with?

Answer

Because 70 or more fixtures are being modified, the lighting system in the space with the modifications can either comply with §140.6 or comply with the 35/50 percent lower rated power compared to the original luminaires approach. It must also comply with §130.1(a)1, 2 and 3, and §130.1(c)1A through 1C, §130.1(c)2, §130.1(c)3 through §130.1(c)6A, and for parking garages §130.1(c)7B.

Example 5-39 Luminaire Component Modification Counting

Question

If a project includes 70 or more luminaire component modifications on a floor, but a portion of those modifications are enclosed spaces containing two or fewer luminaires, do the luminaires in the enclosed spaces count toward the total 70 or more trigger under §141.0(b)2J?

Answer

Yes, the Exception 2 to §141.0(b)2J that exempts two or fewer luminaire component modifications in an enclosed space only exempts the luminaires in those spaces from the control requirements, but does not reduce the total luminaire count on a floor. Therefore the controls would not be required in the enclosed spaces with two or fewer luminaires, but controls would be required for the rest of the floor if the total count (including the luminaires in the enclosed spaces) were more than the 70 trigger.

Example 5-40 Lamp replacements as part of a project

Question

A single-story retail store has 60 T12 linear fluorescent strip fixtures and two sections of track lighting. One of the tracks has 10 screw-in incandescent flood lights and the other track has 10 pin-based halogen PAR lamps. The linear fixtures are being retrofitted with T8 lamps and premium ballasts and in the track fixtures the screw-in and pin-based incandescent lamps are being replaced with equivalent screw-in and pin-based LED lamps. What are the Energy Standards requirements for this job?

Answer

The Energy Standards are not triggered for this project because fewer than 70 fixtures are being modified. Even though a total of 80 fixtures are included in the project, the 20 incandescent fixtures do not count toward the 70 threshold because they are simple lamp replacements that do not count as modifications (per §141.0(b)2J).

Example 5-41 Compliance documentation

Question

A warehouse project has 100 existing HID high bay fixtures which are being converted to third generation T8 high bays. The building occupancy is warehouse so the savings threshold is 35 percent. The aggregate wattage of the new replacement fixtures is 45 percent below the original fixture wattage, so the controls requirements in 141.0(b)2Iii apply. How is the 45 percent wattage delta between the existing fixtures and the new fixtures documented for compliance purposes?

Answer

Documentation is the same as for an Entire Luminaire Alteration, as described in Example 5-36: you will complete the NRCC-LTI-06 form to record the number and wattage of the original fixtures, and calculate both the total existing wattage and the allowed lighting power based on a 35 percent reduction. The newly modified lighting will be documented on the NRCC-LTI-01, just like any other project. As the lighting power reduction exceeds 35 percent, only area on/off controls and automatic shutoff controls are mandatory as specified in Section 141.0(b)2Iii and summarized in Table 5-4.

5.9.6 Alterations - Lighting Wiring Alterations

§141.0(b)2K

Lighting Wiring Alterations are defined in the 2016 Energy Standards as one of the following:

1. Adding a circuit feeding luminaires;
2. Replacing, modifying, or relocating wiring between a switch or panelboard and luminaires;
3. Replacing lighting control panels, panelboards, or branch circuit wiring.

Changes to wiring not listed above are not considered to be “lighting wiring alterations” as the term is used in the Energy Standards, and it is not mandatory to comply with §141.0(b)2K requirement. *Note:* Alterations that include adding, removing, or replacing walls or ceilings resulting in redesign of the lighting system must meet the requirements of Table 141.0-E, as specified in §141.0(b)2I.

The following wiring alterations are not required to comply with §141.0(b)2K, Lighting Wiring Alterations:

1. Alterations strictly limited to addition of lighting controls.
2. In an enclosed space where wiring alterations involve only two of fewer luminaires.
3. Alterations that would cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.

Acceptance testing requirement of §130.4 is not required for wiring alterations where lighting controls are added to control 20 or fewer luminaires.

Example 5-42 Standards for Lighting Wiring Alterations

Question

If occupancy sensing controls are added to a suite of office spaces, does this addition trigger the requirements of §141.0(b)2K (Lighting Wiring Alterations)?

Answer

No, since the alterations are limited to the addition of occupancy sensing controls, it does not trigger any of the requirements of §141.0(b)2, including Lighting Wiring Alterations.

Example 5-43 Skylights

Question

A 30,000 ft² addition has a 16,000 ft² space with an 18 ft high ceiling and a separate 14,000 ft² space with a 13 ft high ceiling. The lighting power density in this building is 1 W/ft². Do skylights have to be installed in the portion of the building with 18 ft ceiling?

Answer

Yes. §140.3(c) requires skylights in enclosed spaces that are greater than 5,000 ft² directly under a roof with a ceiling height over 15 ft. In this example the area with a ceiling height greater than 15 ft is 16,000 ft²; therefore there are mandatory skylight requirements. (Note: skylight requirements do not apply in climate zones 1 and 16).

Example 5-44 Skylighting requirements for alterations

Question

A pre-existing air-conditioned 30,000 ft² warehouse with a 30 ft ceiling and no skylights will have its general lighting system replaced as part of a conversion to a big box retail store. Are skylights prescriptively required?

Answer

No. The general lighting system is being replaced and is not “installed for the first time.” Thus, §141.0(b)2F does not apply and therefore does not trigger the requirements in §140.3(c) for skylighting.

5.10 Indoor Lighting Compliance Documents

5.10.1 Overview

This subchapter describes the documentation (compliance forms) recommended for compliance with the nonresidential indoor lighting requirements of the 2016 Energy Standards.

5.10.2 Submitting Compliance Documentation

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the recommended compliance documentation (forms) for complying with the nonresidential indoor lighting Energy Standards. It does not describe the details of the requirements.

This section is addressed to the person preparing construction and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance.

5.10.3 Separately Documenting Conditioned and Unconditioned Spaces

The nonresidential indoor lighting requirements are the same for conditioned and unconditioned spaces. However, the Energy Standards do not allow lighting power trade-offs to occur between conditioned and unconditioned spaces. Therefore, most nonresidential indoor lighting compliance documents are required to be separately completed for conditioned and unconditioned spaces.

5.10.4 Varying Number of Rows per Document

The paper prescriptive compliance documents have a limited number of rows per section for entering data. Some designs may need fewer rows, and some designs may need additional rows. If additional rows are required for a particular design, then multiple copies of that page may be used.

5.10.5 Compliance Documentation Numbering

Following is an explanation of the 2016 nonresidential lighting compliance documentation numbering:

- NRCC Nonresidential Certificate of Compliance
- NRCA Nonresidential Certificate of Acceptance
- NRCI Nonresidential Certificate of Installation
- LTI Lighting, Indoor
- LTO Lighting, Outdoor
- LTS Lighting, Sign
- 01 The first set of compliance documents in this sequence
- E Primarily used by enforcement authority
- A Primarily used by acceptance tester

5.10.6 Certificate of Compliance Documents

Nonresidential indoor lighting Certificate of Compliance documents are listed below:

- NRCC-LTI-01-E; Certificate of Compliance; Indoor Lighting
- NRCC-LTI-02-E; Certificate of Compliance; Indoor Lighting Controls
- NRCC-LTI-03-E; Certificate of Compliance; Indoor Lighting Power Allowance
- NRCC-LTI-04-E; Certificate of Compliance; Tailored Method Worksheets
- NRCC-LTI-05-E; Certificate of Compliance; Line Voltage Track Lighting Worksheet

LTI-01-E through LTI-03-E are required for all projects; LTI-04-E is required when the tailored method is used for prescriptive compliance, and LTI-05-E is required when line voltage track lighting is installed.

5.10.7 Certificates of Installation Documents

There are six different Certificates of Installation listed as follows. See Section 5.4.7 of this chapter for additional information.

- NRCI-LTI-01-E, Certificate of Installation, Indoor Lighting
- NRCI-LTI-02-E, Certificate of Installation, EMCS Lighting Control System

- NRCI-LTI-03-E, Certificate of Installation, Line Voltage Track Lighting
- NRCI-LTI-04-E, Certificate of Installation, Two Interlocked Lighting Systems
- NRCI-LTI-05-E, Certificate of Installation, Power Adjustment Factors
- NRCI-LTI-06-E, Certificate of Installation, Additional Video Conference Studio Lighting

The Certificates of Installation are primarily used as declarations, signed by a person with an approved license, that what was claimed on the Certificates of Compliance is actually what was installed.

The required nonresidential indoor lighting Certificates of Installation include the following:

- NRCI-LTI-01-E - must be submitted for all buildings. This is the general Certificate of Installation used to declare that what was proposed in the Certificates of Compliance is actually what was installed.

  In addition to the NRCI-LTI-01-E, the following Certificates of Installation are also required if the job includes any of the measures covered by these Certificates of Installation. If any of the requirements in any of these Certificates of Installation fail the respective installation requirements, then that application shall not be recognized for compliance with the lighting Standards.

  These additional Certificates of Installation are different than Certificates of Acceptance, in that Certificates of Installation consist primarily of declarations that each of the minimum requirements has been met, while Certificates of Acceptance include tests which must be conducted.

- NRCI-LTI-02-E - Must be submitted whenever a lighting control system, and whenever an Energy Management Control System (EMCS), has been installed to comply with any of the lighting control requirements.

- NRCI-LTI-03-E - Must be submitted whenever a line-voltage track lighting integral current limiter, and whenever a supplementary overcurrent protection panel, has been installed and used to determine the installed wattage of any line-voltage track lighting system.

  Note that a supplementary overcurrent protection panel shall be recognized for use only with line-voltage track lighting,

  See Section 5.2.3 of this chapter for requirements of track lighting current limiters and track lighting protection panels.

  Note: In addition to submitting the NRCI-LTI-03-E after installation, the NRCC-LTI-05-E (Line-Voltage Track Lighting Worksheet) must be included with the Certificates of Compliance whenever any type of line-voltage track lighting is installed in a project.

- NRCI-LTI-04-E - Must be submitted for two interlocked systems serving an auditorium, a convention center, a conference room, a multipurpose room, or a theater to be recognized for compliance.

  See Section 5.6.4 of this chapter for two interlocked system requirements.

- NRCI-LTI-05-E - Must be submitted for a Power Adjustment Factor (PAF) to be recognized for compliance.

  See Section 5.6.5 of this chapter for requirements of PAFs.

- NRCI-LTI-06-E - Must be submitted for additional wattage installed in a video conferencing studio to be recognized for compliance

5.10.8 Certificate of Acceptance

Acceptance requirements ensure that equipment, controls, and systems operate as required and specified. There are three steps to acceptance testing:

- Visual inspection of the equipment and installation
- Review of the certification requirements
- Functional tests of the systems and controls

Third-party review of the information provided on the Certificate of Acceptance forms is not required for lighting.

Individual acceptance tests may be performed by one or more Field Technicians under the responsible charge of a licensed contractor or design professional, (Responsible Person) eligible under Division 3 of the Business and Professions Code, in the applicable classification, to accept responsibility for the scope of work specified by the Certificate of Acceptance document. The Responsible Person must review the information on the Certificate of Acceptance form and sign the form to certify compliance with the acceptance requirements. Typically, the individuals who participate in the acceptance testing/verification procedures are contractors, engineers, or commissioning agents. The individuals who perform the field testing/verification work and provide the information required for completion of the acceptance form (Field Technicians) are not required to be licensed contractors or licensed design professionals. Only the Responsible Person who signs the Certificate of Acceptance form to certify compliance must be licensed.

The acceptance tests required for nonresidential indoor lighting include the following:

- Lighting controls
- Automatic daylighting controls
- Demand responsive lighting controls
- Institutional Tuning for Power Adjustment Factor

Instructions for completing the Certificates of Acceptance are imbedded in the certificates.

See Chapter 13 of this manual for additional information about acceptance requirements.

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6. Outdoor Lighting

This chapter covers the Title 24 California Code of Regulations, Part 6 (the Energy Standards), requirements for nonresidential outdoor lighting design and installation, including controls. This chapter applies to all outdoor lighting, whether attached to buildings, poles, structures or self-supporting; including but not limited to hardscape areas including parking lots, lighting for building entrances, sales and non-sales canopies; lighting for all outdoor sales areas; and lighting for building facades. It is addressed primarily to lighting designers, electrical engineers, and enforcement agency personnel responsible for lighting.

Chapter 5 addresses nonresidential indoor lighting requirements.

Chapter 7 addresses sign lighting requirements.

6.1 Overview

6.1.1 Significant Changes in the 2016 Energy Standards

- The values in Tables 140.7-A and 140.7-B of the Energy Standards have been modified to reflect the industry shift to LED lighting as the basis of design.
- Table 140.7-A and 140.7-B of the Energy Standards have an added column for Lighting Zone 0, which is the Lighting Zone designated specifically for undeveloped areas in parks and preserves, where no continuous lighting is intended.
- Table 140.7-A has been modified to incorporate the new requirements of the recently revised Illuminating Energy Society of North America (IES) document RP-20-2014, Parking Lot Lighting Recommended Practice.
- ATM, tunnel, and bridge lighting are no longer listed as exemptions from the LPA calculations.
- The controls requirements have changed, expanding to include lighting in outdoor sales canopies and outdoor sales lots, which were previously exempted from occupancy-based dimming controls requirements.
- An increase of the maximum dimming permitted as part of an active motion-controlled lighting system from 80% to 90%.

6.1.2 Prescriptive Changes

The general hardscape power allowances have been updated for all Lighting Zones (LZ), including a new lighting zone (LZ0). The additional lighting power allowances for specific applications have been updated for building entrances and exits. ATM machine lighting and tunnels are newly added to Table 140.7-B in the 2016 Energy Standards update.

6.1.3 Additions and Alterations Changes

The requirements for lighting alterations have been clarified and streamlined, and a new compliance path has been added to allow compliance based on a reduction of existing lighting power rather than by using area category and square footage to calculate lighting power allowances. Other streamlining changes include an exception to acceptance testing for projects that add controls for 20 or fewer luminaires.

6.2 History and Scope

The outdoor lighting requirements within the Energy Standards conserve energy, reduce winter peak electric demand, and are both technically feasible and cost effective. They set minimum control requirements, maximum allowable power levels, minimum efficacy requirements, and cutoff (uplight and glare) zonal lumen limits for large luminaires.

The lighting power allowances are based on current Illuminating Engineering Society of North America (IES) recommendations for the quantity and design parameters of illumination, current industry practices, and efficient sources and equipment that are readily available. Data indicates that the IES recommendations provide more than adequate illumination, based on a 2002 baseline survey of outdoor lighting practice in California that showed that the majority of outdoor lighting illuminates at substantially lower levels than IES recommendations.[1]

The Energy Standards do not allow trade-offs between outdoor lighting power allowances and indoor lighting, sign lighting, HVAC, building envelope, or water heating (§140.1 and 140.7).

Lighting in unconditioned buildings (including parking garages) is addressed in Chapter 5.

6.2.1 History and Background

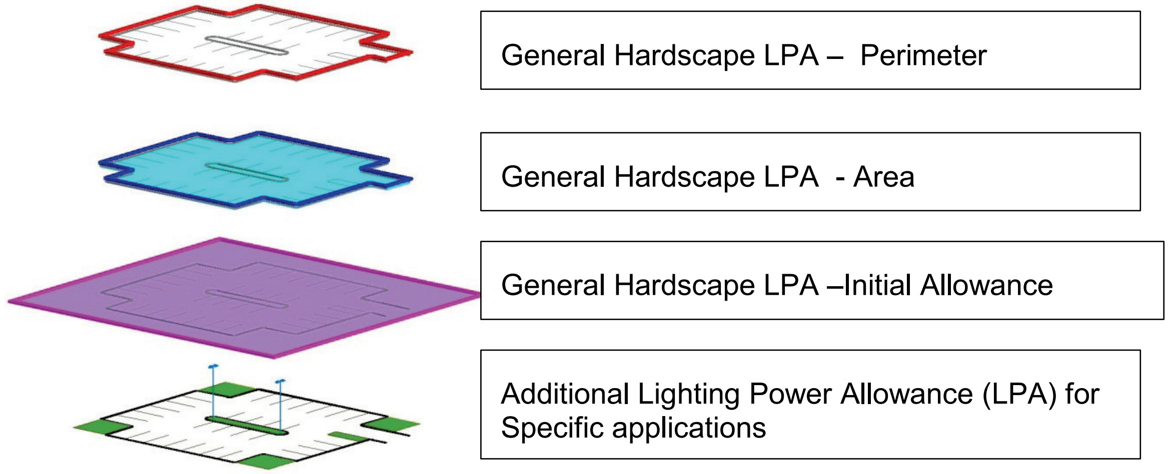
In response to the 2000 electricity crisis, the legislature charged the Energy Commission to develop outdoor lighting standards that are both technologically feasible and cost-effective. The intent of the legislature was that the Energy Standards would provide ongoing reliability to the electricity system and reduce energy consumption.

Regulations for lighting have been on the books in California since 1977, but have only addressed indoor lighting through control requirements and maximum allowable lighting power. In 2005 Standards the scope was expanded to include outdoor lighting applications as well as indoor applications in unconditioned buildings.

Outdoor lighting power densities are structured using a layered lighting approach. With the layered approach, the first layer of allowed lighting power is general hardscape for the entire site. After the allowed lighting power has been determined for this first layer, additional layers of lighting power are allowed for specific applications when they occur on the site. For example, the total allowed power for a sales lot with frontage is determined by layering the General Hardscape, Outdoor Sales Lot and Outdoor Sales Lot Frontage allowances, with specific restrictions associated with the location of the power used for frontage and sales lot lighting.

[1]Integrated Energy Systems Productivity and Building Science, Outdoor Lighting Baseline Assessment, New Buildings Institute, August 12, 2002

Figure 6-1: Concept of a layered lighting approach for outdoor lighting - Lighting Power Allowance (LPA)



6.2.2 Scope and Application

The outdoor lighting applications that are addressed by the Energy Standards are shown in the first two columns of Table 6-1. The first column is general site illumination applications, which allow trade-offs within the outdoor portion only. The second column is specific outdoor lighting applications, which do not allow trade-offs, and are considered “use it or lose it”. The lighting applications in the third column are not regulated. The Energy Standards include control requirements as well as limits on installed lighting power.

All Section (§) and Table references in this Chapter refer to sections and Tables contained in the Energy Standards or California Energy Code.

6.2.2.1 **Trade-offs**

The Energy Standards do not allow trade-offs between outdoor lighting power allowances and indoor lighting, sign lighting, HVAC, building envelope, or water heating [(§140.7(a)].

There is only one type of trade-off permitted for outdoor lighting power. Allowed lighting power determined according to §140.7(d)1 for general hardscape lighting may be traded to specific applications in §140.7(d)2, provided the luminaires used to determine the illuminated area are installed as designed. This means that if luminaires used to determine the total illuminated area are removed from the design, resulting in a smaller illuminated area, then the general hardscape lighting power allowance must also be reduced accordingly.

Allowed lighting power for specific applications shall not be traded between specific applications, or to hardscape lighting in §140.7(d)1. This means that for each and every specific application, the allowed lighting power is the smaller of the allowed power determined for that specific application according to §140.7(d)2, or the actual installed lighting power that is used in that specific application. These additional power allowances are “use it or lose it” allowances.

Table 6-1: Scope of the Outdoor Lighting Requirements

Lighting Applications Covered		Lighting Applications Not Regulated (only as detailed in §140.7)
General Hardscape (trade-offs permitted)	**Specific Applications (trade-offs not permitted)**	
The general hardscape area of a site shall include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s) and other improved area(s) that are illuminated.	Canopies: Sales and Non-sales Drive-Up Windows Emergency Vehicle Facilities Building Entrances or Exits Building Facades Guard Stations Hardscape Ornamental Lighting Outdoor Dining Primary Entrances for Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities Outdoor Sales Frontage and Lots Special Security Lighting for Retail Parking and Pedestrian Hardscape Student Pick-up/Drop-off zone Vehicle Service Station: Canopies, Hardscape, and Uncovered Fuel Dispenser ATM Machine Lighting	Temporary Required & regulated by FAA Required & regulated by the Coast Guard. For public streets, roadways, highways, and traffic signage lighting, and occurring in the public right-of-way For sports and athletic fields, and children's playground For industrial sites For public monuments Signs regulated by §130.3 and §140.8 For stairs, wheelchair elevator lifts For ramps that are other than parking garage ramps Landscape lighting For themes and special effects in theme parks For outdoor theatrical and other outdoor live performances For qualified historic buildings
Other outdoor lighting applications that are not included in Energy Standards Tables 140.7-A or 140.7-B are assumed to be not regulated by these Standards. This includes decorative gas lighting and emergency lighting powered by an emergency source as defined by the California Electrical Code. The text in the above list of lighting applications that are not regulated has been shortened for brevity. Please see Section 6.2.2.2 for details about lighting applications not regulated.		

6.2.2.2 Outdoor Lighting Applications Not Regulated by §140.7

When a luminaire is installed only to illuminate one or more of the following applications, the lighting power for that luminaire shall be exempt from §140.7(a). The Energy Standards clarify that at least 50 percent of the light from the luminaire must fall within an application to qualify as being installed for that application.

- Temporary outdoor lighting.

  Temporary Lighting is defined in §100.1 as a lighting installation with plug-in connections that does not persist beyond 60 consecutive days or more than 120 days per year.

- Lighting required and regulated by the Federal Aviation Administration and the Coast Guard.
- Lighting for public streets, roadways, highways, and traffic signage lighting, including lighting for driveway entrances occurring in the public right-of-way.
- Lighting for sports and athletic fields, and children's playground.
- Lighting for industrial sites, including but not limited to, rail yards, maritime shipyards and docks, piers and marinas, chemical and petroleum processing plants, and aviation facilities.

- Lighting of public monuments.
- Lighting of signs. Signs shall meet the requirements of §130.3 and 140.8.
- Lighting of stairs, wheelchair elevator lifts for American with Disabilities Act (ADA) compliance, and ramps that are other than parking garage ramps.
- Landscape lighting.

  Landscape lighting is defined in §100.1 as lighting that is recessed into or mounted on the ground, paving, or raised deck, which is mounted less than 42 inches above grade or mounted onto trees or trellises, and that is intended to be aimed only at landscape features. Lighting installed for a purpose other than landscape, such as walkway lighting, shall not be considered exempt landscape lighting if only incidental lighting from the walkway luminaires happens to spill onto the landscape.
- In theme parks: outdoor lighting only for themes and special effects. However, all non-theme lighting, such as area lighting for a parking lot, shall not be considered theme lighting, even if the area luminaires are mounted on the same poles as the theme lighting.
- Lighting for outdoor theatrical and other outdoor live performances, provided that these lighting systems are additions to area lighting systems and are controlled by a multi-scene or theatrical cross-fade control station accessible only to authorized operators.
- Outdoor lighting systems for qualified historic buildings, as defined in the California Historic Building Code (Title 24, Part 8), if they consist solely of historic lighting components or replicas of historic lighting components. If lighting systems for qualified historic buildings contain some historic lighting components or replicas of historic components, combined with other lighting components, only those historic or historic replica components are exempt. All other outdoor lighting systems for qualified historic buildings shall comply with §140.7.

6.3 Mandatory Measures

The mandatory features and devices must be included in all outdoor lighting projects when they are applicable. These features have been proven to be cost-effective over a wide range of outdoor lighting applications.

Mandatory measures for outdoor lighting and signs are specified in §110.9, §130.0, and §130.2. These are similar to the mandatory measures for indoor lighting. Even if the design has errors and has specified incorrect features and devices, the installer is responsible to meet all of the applicable requirements that he or she installs. The installer is also required to sign the appropriate Installation Certificate to verify correct installation.

6.3.1 Outdoor Incandescent Lighting

All outdoor incandescent luminaires rated over 100 W must be controlled by a motion sensor. The ability or intent to use a lower wattage is not relevant to the labelled wattage of the luminaire, which is the ultimate determining factor.

Example 6-1 Motion Sensors for Incandescent Lamps

Question

I am installing outdoor luminaires with screw-based sockets and I intend to use 60W incandescent lamps. The luminaire has a label on it that indicates that the maximum rated wattage is 75 watts. Am I required to put these luminaires on motion sensors?

Answer

It depends on the maximum relamping rated wattage of the luminaires, not on the wattage of the lamps that are used for incandescent luminaires with screw-based sockets. If the maximum relamping rated wattage of a screw-based luminaire as listed on a permanent factory-installed label is less than or equal to 100 W, then motion sensors are not required. However, if the maximum relamping rated wattage of the luminaire, as listed on permanent factory-installed labels is more than 100 W, or if the luminaire is not labeled, then motion sensors are required. This luminaire is rated below 100 watts, and therefore is not required to be connected to a motion sensor.

Example 6-2 Motion Sensors for Incandescent Lamps

Question

I am installing outdoor luminaires with screw-based sockets and I intend to use 60W incandescent lamps. There are three lamps per luminaire, and the rated lamp wattage per socket is 75 watts. Am I required to put these luminaires on motion sensors?

Answer

For incandescent luminaires with screw-based sockets it depends on the maximum relamping rated wattage of the luminaires, not on the wattage of the lamps that are used. If the maximum combined relamping rated wattage of a screw-based luminaire as listed on a permanent factory-installed label is less than or equal to 100 W, then motion sensors are not required. However, this luminaire has three lamps rated for a combined wattage of 225 watts, therefore motion sensors are required.

6.3.2 Luminaire Cutoff Requirements

§130.2(b)

All outdoor luminaires rated for use with lamps greater than 150 lamp watts must comply with Backlight, Uplight, and Glare (collectively referred to as "BUG") requirements as follows:

1. There are no Backlight requirements in the Energy Standards.
2. Maximum zonal lumens for Uplight shall be in accordance with Table 6.2-A.
3. Maximum zonal lumens for Glare shall be in accordance with Table 6.2-B.

Note: Title 24, Part 11, Section 5.106.8 includes additional restrictions on backlight, uplight and glare that may apply.

Table 6.2-A: Uplight Ratings (Maximum Zonal Lumens)

Secondary Solid Angle	Maximum Zonal Lumens per Outdoor Lighting Zone				
	LZ0	LZ 1	LZ 2	LZ 3	LZ 4
Uplight High (UH) 100 to 180 degrees	0	10	50	500	1,000
Uplight Low (UL) 90 to <100 degrees	0	10	50	500	1,000

Table 6.2-B: Glare Ratings (Maximum Zonal Lumens)

	Glare Rating for Asymmetrical Luminaire Types (Type 1, Type II, Type III, Type IV)				
Secondary Solid Angle		Maximum Zonal Lumens per Outdoor Lighting Zone			
	LZ 0	LZ 1	LZ 2	LZ 3	LZ 4
Forward Very High (FVH) 80 to 90 degrees	10	100	225	500	750
Backlight Very High (BVH) 80 to 90 degrees	10	100	225	500	750
Forward High (FH) 60 to <80 degrees	660	1,800	5,000	7,500	12,000
Backlight High (BH) 60 to <80 degrees	110	500	1,000	2,500	5,000
	Glare Rating for Quadrilateral Symmetrical Luminaire Types (Type V, Type V Square)				
Secondary Solid Angle		Maximum Zonal Lumens per Outdoor Lighting Zone			
	LZ 0	LZ 1	LZ 2	LZ 3	LZ 4
Forward Very High (FVH) 80 to 90 degrees	10	100	225	500	750
Backlight Very High (BVH) 80 to 90 degrees	10	100	225	500	750
Forward High (FH) 60 to <80 degrees	660	1,800	5,000	7,500	12,000
Backlight High (BH) 60 to <80 degrees	660	1,800	5,000	7,500	12,000

Outdoor luminaires that use lamps or light sources rated greater than 150 W in the following areas are required to comply with uplight and glare zonal lumen limits specified in Tables 6.2-A and B:

- Hardscape areas, including parking lots and service stations hardscape
- Building entrances
- All sales and non-sales canopies
- Outdoor dining
- All outdoor sales areas

Uplight and glare zonal lumen limits are not considered for outdoor luminaires when they are used to illuminate the following:

- Signs
- Lighting for building facades, public monuments, statues, and vertical surfaces of bridges
- Lighting required by a health or life safety statute, ordinance, or regulation that may fail to meet the uplight and glare limits due to application limitations
- Temporary outdoor lighting as defined by §100.1
- Replacement of existing pole mounted luminaires in hardscape areas meeting all of the following conditions:
  - Where the existing luminaire does not meet the luminaire uplight and glare zonal lumen limits.

- Spacing between existing poles is greater than 6 times the mounting height of the existing luminaires.
- Where no additional poles are being added to the site.
- Where new wiring to the luminaires is not being installed.
- Provided that the connected lighting power wattage is not increased.

IES published the technical memorandum *'Luminaire Classification for Outdoor Luminaires'* in 2011 (TM-15-11). This document defines three-dimensional regions of analysis for exterior luminaires and further establishes zonal lumen limits for these regions as part of a larger method of categorizing outdoor lighting equipment into Backlight, Uplight, and Glare components. Collectively, the three components are referred to as the BUG system.

The zonal lumen limits per secondary solid angles for uplight and glare are based upon the methodology found in TM-15. The Lighting Zone that the project is located in determines the maximum zonal lumens for both uplight and glare. There are no separate zonal lumen limits for the Backlight component in the Energy Standards, regardless of the lighting zone. This component is intended for property boundary conditions and is intended to help determine the suitability of specific products to mitigate light trespass, and is therefore outside the prevue of Title 24.

To comply with this mandatory measure, the luminaire must not exceed the maximum zonal lumen limits for each secondary solid angle region (within both the Uplight and Glare component) per lighting zone. The zonal lumen values in a photometric test report must include any tilt or other non-level mounting condition of the installed luminaire.

The BUG rating for luminaires may be determined with outdoor lighting software or by contacting the manufacturer. There is also software available to produce a BUG rating for a tilted luminaire condition (which is not a typical circumstance for most applications). Since the California BUG limits and calculation procedures match the IES, no deviation from the IES BUG rating is necessary.

Example 6-3 Backlight Zonal Lumen Limits

Question

I am installing four 200W luminaires. What are the maximum zonal lumen limits for Backlight that I have to meet?

Answer

You will need to comply with the zonal lumen limits for each solid angle zone found within the Uplight and Glare components only (the U and G portions of the BUG rating) and the Energy Standards does not have backlight requirements. Note that within the Glare component, there are two solid angle zones that include some backwards propagating light portions. This is built into the zonal lumen limits, and if the U and G ratings meet the Lighting Zone, then no further consideration is necessary.

Example 6-4 Obtaining Zonal Lumen Limits

Question

How are luminaire zonal lumen limits obtained?

Answer

The zonal lumen values for a particular luminaire, lamping and orientation are obtained from the manufacturer or may be calculated from photometric data. In the Code, Tables 130.2-A and 130.2-B list the maximum zonal lumens allowed in each solid angle zone within the Uplight and Glare categories. If the zonal lumens in any solid angle zone is exceeded in any category, the uplight or glare rating moves into a higher outdoor lighting zone.

For instance, an example photometric report indicates the following for a Type III luminaire:

Uplight Zonal Lumins
UH: 135.4 UL: 74.9

Glare Zonal Lumins
FVH: 104.3 BVH: 65.2 FH: 1935.7 BH: 440.8

Referring to Table 130.2-A, the luminaire is only acceptable for use in LZ3 or higher because both the UH and UL zonal lumen values are below 500 lumens, but greater than 50 lumens.

Comparing the glare zonal lumen values to Table 130.2-B for Type III luminaires, this luminaire is only acceptable for use in LZ2 or higher. Even though there are some angles that are less than the maximum zonal lumen limits, the FVH value moves this luminaire up to LZ2.

The final result is the larger of the two ratings. Therefore, combining both Uplight (LZ2) and Glare (LZ3), this luminaire can only be used in LZ3 or higher applications.

Example 6-5 Zonal Lumen Limits by Lighting Zone

Question

Do Uplight and Glare zonal lumen limits vary in the regulations?

Answer

Yes, they vary depending on lighting zone. Outdoor Lighting Zone 1 has more stringent zonal lumen requirements than Outdoor Lighting Zone 2. Refer to Table 130.2-A and 130.2-B in the Energy Standards for the zonal lumen maximums for each particular Lighting Zone.

Example 6-6 Zonal Lumen Limits for Luminaires in a Rail Yard

Question

Am I required to meet the uplight and glare zonal lumen limits for luminaires in a rail yard?

Answer

No, only luminaires in areas such as hardscape areas, building entrances, canopies, or outdoor sales areas are required to meet the uplight and glare zonal lumen limits. However, in this example, the parking lot for the employees outside the rail yard must meet the uplight and glare zonal lumen limits.

Example 6-7 Full Cut-Off Luminaires and Zonal Lumen Limits

Question

Can full cut-off luminaires be used to meet the zonal lumen limits of the Energy Standards?

Answer

Luminaires using light sources of 150W or greater, including full cut-off luminaires, must meet the Uplight zonal lumen limits in Table 130.2-A to meet the requirements of this section. Fully shielded luminaires have superior optics that can very effectively reduce or eliminate disability and discomfort glare, and other negative impacts of high intensity unshielded lighting. However, a traditional “full cut-off” style luminaire is not assured to meet the Uplight and Glare zonal lumen limits of Table 130.2-B, so verification will be required.

Example 6-8 Wallpacks and Zonal Lumen Limits

Question

A new parking lot adjacent to a building is being designed to be illuminated by 250W wall packs mounted on the side of the building. Do these wall packs have to meet the zonal lumen limits? The wall packs are also illuminating the façade of the building, but their main purpose is for parking lot illumination.

Answer

Yes, these 250W wall packs will have to meet the zonal lumen limits because their main purpose is for parking lot illumination. Luminaire mounting methods or locations do not necessarily determine the purpose of the illumination. Define the function of the luminaire by determining what the majority of the light is striking. In the case a typical wallpack, 80% or more of the light is likely striking the parking lot or sidewalk in front of the building, and only 20% or less on the façade, so this will be required for verification of the zonal limits.

Each luminaire must be appropriately assigned to the function area that it is illuminating, whether it is mounted to a pole, building, or other structure. Only luminaires that are 150W or less are not required to meet the Uplight and Glare limits in the Energy Standards.

Example 6-9 Wallpacks and Zonal Lumen Limits

Question

Can we use 250W, non-cut-off wall packs for building façade lighting?

Answer

Even though façade lighting is exempt from the zonal lumen limits, you cannot consider a traditional – wall pack installation as façade lighting because most of the light from these luminaires will not illuminate the façade to which they are attached. Most ‘wall pack’ style luminaires do not direct the majority of the light exiting the luminaire onto the façade. Only wall packs that are 150W or less are not required to meet the Uplight and Glare limits in the Energy Standards.

Example 6-10 Cut-Off Luminaires and Zonal Lumen Limits

Question

If a cut-off or full cut-off luminaire is mounted at a tilt does it still meet the zonal lumen limits?

Answer

It depends. Luminaires that meet the zonal lumen limits when mounted at 90° to nadir may or may not comply with the zonal lumen limits when they are mounted at a tilt. In order for a tilted luminaire to meet this requirement a photometric test report must be provided showing that the luminaire meets the zonal lumen limits at the proposed tilt, or other non-level mounting condition. This can be provided by the manufacturer or calculated by various lighting calculation software products available in the industry. A test will be required for each unique tilt situation (as the tilt angle changes, the BUG rating will also change).

6.3.3 Controls for Outdoor Lighting

§130.2(c)

Outdoor lighting controls shall be installed that meet the following requirements as applicable.

Controls are not required for outdoor lighting when a health or life safety statute, ordinance, or regulation does not permit the lighting to be turned OFF. Controls are also not required for lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

A. Automatic Shutoff Controls

§130.2(c) 1

All installed outdoor lighting must be controlled by a photocontrol or outdoor astronomical time-switch controls that automatically turns off the outdoor lighting when daylight is available. Also note for the automatic scheduling controls requirement for outdoor lighting to be turned off for a portion of the night and the day.

B. Independent Control

§130.2(c) 2

All installed outdoor lighting shall be independently controlled from other electrical loads by a time-based lighting control device or system that is capable of being programmed to turn off outdoor luminaires for a portion of the night and the day.

Example 6-11 Circuiting of Irrigation Controllers

Question

Can irrigation controllers be on the same circuit as lighting?

Answer

Yes, it is allowed but, if there is any outdoor lighting load on the circuit, the outdoor lighting load must be separately controlled from all other loads.

C. Controls for Luminaires Mounted below 24 Feet

§130.2(c) 3

All installed outdoor lighting, where the bottom of the luminaire is mounted 24 feet or less above the ground, shall be controlled with automatic lighting controls that meet all of the following requirements:

1. Include motion sensors or other lighting control systems that automatically control lighting in response to the area being vacated of occupants.
2. Be capable of automatically reducing the lighting power of each luminaire by at least 40 percent but not exceeding 90 percent, or provide continuous dimming through a range that includes 40 percent through 90 percent.
3. Employ auto-ON functionality when the area becomes occupied.
4. Ensure that no more than 1,500 watts of lighting power are controlled together.

This requires that lower wattage lighting mounted on shorter poles, be controlled to dim back during the time that the space is 'open for business', but does not have occupants present. An example might be a plaza on an office building, or an outdoor retail space.

The lighting may also have a time switch (time-based control) or other scheduling device so that the lighting will be turned off during the after-hours period. These may be combined into a single intelligent device, but it may also be accomplished through the use of two separate control mechanisms.

The lighting controller and lighting equipment as a system must be capable of dimming the lighting back from full power to a reduced power level that represents at least a 40% reduction, and at most a 90% reduction. This requirement does not insist that every lamp be capable of this setback, but that the luminaire is capable. The intent is that the lighting maintains a reasonable uniformity compared to the original design rather than employing a 'checker board' approach to meet the power reduction requirement.

The 1500 watt limit is intended to keep the size of the lighting zones small enough to ensure that the lighting will be setback enough to make the lighting controls cost effective.

However, not all lighting must be controlled in this manner. For the following applications, the motion controls requirements for outdoor luminaires mounted less than 24 feet above the ground are not mandatory, as discussed in greater detail below:

- Lighting for Outdoor Sales Frontage
- Lighting for Building Facades, Ornamental Hardscape and Outdoor Dining
- Outdoor lighting which meets one of the following conditions: pole mounted luminaires with a maximum rated wattage of 75 watts, non-pole mounted luminaires with a maximum rated wattage of 30 watts each, or linear lighting with a maximum wattage of 4 watts per linear foot of luminaire.

D. Application Specific Controls

§130.2(c) 4 & §130.2(c) 5

For Outdoor Sales Frontage lighting, an automatic lighting control shall be installed that meets the following requirements:

- A part-night outdoor lighting control to permit the lighting to be activated at sunset, and be programmed to turned OFF at some point in the night after the business has closed,

OR:

- Motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent, and which have auto-ON functionality.

Note that Sales Frontage lighting does not typically have an area where a motion sensor can be employed to create a viable occupancy-based control. This is the primary reason that this area is exempted from §130.2(c)3, and this alternate approach be employed. This area is still required to meet requirements for Automatic Shutoff Controls, and Automatic Scheduling Controls.

For Building Façade, Ornamental Hardscape and Outdoor Dining applications, an automatic lighting control shall be installed that meets one or more of the following requirements.

- A part-night outdoor lighting control as defined in §100.1.
- Motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent, and which have auto-ON functionality.
- A centralized time-based zone lighting control capable of automatically reducing lighting power by at least 50 percent.

These requirements essentially add part-night control and centralized lighting control options in addition to the occupancy-based control option. Some of these applications are done because occupancy-based control is not viable for these applications (façade and ornamental are examples of this), and others because it may be disturbing to the mood or the visual impact may be undesirable when lighting is changing. These areas are still required to employ the Automatic Shutoff Control from §130.2(c)1.

Note that outdoor wall mounted luminaires (often called ‘wallpacks’) where the bottom of the luminaire is mounted 24 feet or less above the ground must also be controlled by a motion sensor capable of shutting off between 40% and 90% of the load, as required by §130.2(c)3. The point of including this is to direct the reader to the appropriate section for that luminaire type, as this is a common misapplication of the Code.

Example 6-12 Mandatory Outdoor Requirements

Question

What are the mandatory outdoor lighting requirements?

Answer

The mandatory outdoor lighting requirements include:

• Motion sensing for incandescent luminaires rated over 100 watts

• BUG Uplight and Glare zonal lumen limits for luminaires ratings greater than 150 watts unless excluded by the code.

• Automatic controls to turn lighting OFF when daylight is available

• Separate circuiting and independently controlled from other electrical loads by an automatic scheduling control

• Motion sensing devices for luminaires mounted below 24 feet above ground that automatically reduce the lighting power of each luminaire by at least 40 percent, but not greater than 90 percent, auto-ON functionality when the area becomes occupied and no more than 1500 watts of lighting power on a single control zone.

• Outdoor Sales Frontage lighting shall have a part-night outdoor lighting control or motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent.

• Building Façade, Ornamental Hardscape, and Outdoor Dining shall have a part-night outdoor lighting control or motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent, or a centralized time-based zone lighting control capable of automatically reducing lighting power by at least 50 percent.

All lighting controls must meet the requirements of §110.9.

6.3.4 Requirements for Lighting Control Functionality

§110.9(b)

All Installed Lighting Control Systems listed in §110.9(b) shall comply with the requirements listed below; and all components of the system considered together as installed shall meet all applicable requirements for the application for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150.0(k).

A. Time-Switch Lighting Controls

1. Automatic Time-Switch Controls shall meet all requirements for Automatic Time Switch Control devices in the Title 20 Appliance Efficiency Regulations.
2. Astronomical Time-Switch Controls shall meet all requirements for Astronomical Time-Switch Control devices in the Title 20 Appliance Efficiency Regulations.
3. Multi-Level Astronomical Time-Switch Controls, in addition to meeting all of the requirements for Astronomical Time-Switch Controls, shall include at least 2 separately programmable steps per zone.
4. Outdoor Astronomical Time-Switch Controls, in addition to meeting all of the requirements for Astronomical Time-Switch Controls, shall have setback functions

that allow the lighting on each controlled channel to be switched or dimmed to lower levels. The setback functions shall be capable of being programmed by the user for at least one specific time of day.

B. Daylighting Controls

1. Automatic Daylight Controls shall meet all requirements for Automatic Daylight Control devices in the Title 20 Appliance Efficiency Regulations.
2. Photo Controls shall meet all requirements for Photo Control devices in the Title 20 Appliance Efficiency Regulations.

C. Dimmers shall meet all requirements for Dimmer Control devices in the Title 20 Appliance Efficiency Regulations.

D. Occupant Sensing Controls: Occupant, Motion, and Vacancy Sensor Controls shall meet the following requirements:

1. Occupant Sensors shall meet all applicable requirements for Occupant Sensor Control devices in the Title 20 Appliance Efficiency Regulations.
2. Motion Sensors shall meet all applicable requirements for Motion Sensor Controls devices in the Title 20 Appliance Efficiency Regulations.
3. Vacancy Sensors shall meet all applicable requirements for Vacancy Sensor Controls devices in the Title 20 Appliance Efficiency Regulations.
4. Partial-ON Sensors shall meet all applicable requirements for partial on sensing devices in the Title 20 Appliance Efficiency Regulations.
5. Partial-OFF Sensors shall meet all applicable requirements for partial off sensing devices in the Title 20 Appliance Efficiency Regulations.
6. All Occupant Sensing Control types shall be programmed to turn OFF all or part of the lighting no longer than 20 minutes after the space is vacated of occupants, except as specified by §130.1(c)8.

EXCEPTION to §110.9(b)4: Occupant Sensing Control systems may consist of a combination of single or multi-level Occupant, Motion, or Vacancy Sensor Controls, provided that components installed to comply with manual-on requirements shall not be capable of conversion by the user from manual-on to automatic-on functionality.

E. Part-Night Outdoor Lighting Controls, as defined in §100.1, shall meet all of the following requirements:

1. Have sunrise and sunset prediction accuracy within +/- 15 minutes and timekeeping accuracy within five minutes per year; and
2. Have the ability to setback or turn off lighting at night as required in §130.2(c), by means of a programmable timeclock or motion sensing device; and
3. When controlled with a timeclock, shall be capable of being programmed to allow the setback or turning off of the lighting to occur from any time at night until any time in the morning, as determined by the user.

Lighting control devices are required to have various types of functionality, depending on what type of control they are, and whether they are “devices” (consisting of a single component), or “systems” consisting of two or more components. Lighting control devices are regulated by Title 20 California Code of Regulations the Appliance Standards (California Code of Regulations, Title 20), whereas lighting control systems are regulated by §110.9 of the Energy Standards. See below for a more detailed explanation of lighting control devices and systems:

A. Self-contained lighting control devices are defined by the Energy Standards as unitary lighting control modules that require no additional components to be fully functional lighting controls. Most self-contained lighting controls are required to be certified by the manufacturer according to the Title 20 Appliance Efficiency Regulations; please see the Appliance Standards Manual for details of those requirements. The following lighting controls related to outdoor lighting control, are required to be certified to Title 20 as specified in §110.9(b):

1. Time-Switch Lighting Controls
   - Outdoor Astronomical Time-Switch Controls
2. Daylighting Controls
   - Photo Controls
3. Occupant Sensing Controls
   - Motion Sensors
4. Part-Night Outdoor Lighting Control

A Part-Night Outdoor Lighting Control is defined by the Energy Standards as a time or occupancy-based lighting control device or system that is programmed to reduce or turn off the lighting power to an outdoor luminaire for a portion of the night.

A part-night control device is not required to be certified to Title 20, but must meet the requirements as specified in §110.9(b)5. It must:

a. Be able to accurately predict sunrise and sunset within +/- 15 minutes and timekeeping accuracy within five minutes per year; and

b. Be able to setback or turn off lighting at night as required in §130.2(c), by means of a programmable timeclock or motion sensing device; and

c. When the setback or turning off is controlled with a timeclock, shall be capable of being programmed to allow the setback or turning off of the lighting to occur from any time at night until any time in the morning, as determined by the user.

B. Lighting Control Systems are defined by the Energy Standards as requiring two or more components to be installed in the building to provide all of the functionality required to make up a fully functional and compliant lighting control. Lighting control systems are not required to be certified to Title 20, and may be installed for compliance with lighting control requirements in the Energy Standards providing they meet all of the following requirements:

1. A lighting control system shall comply with all requirements listed below; and all components of the system considered together as installed shall meet all applicable requirements for the lighting control application for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150(k).
2. For all lighting control systems, including Energy Management Control Systems (EMCS), an installation certificate shall be signed by the licensee of record in accordance with §130.4(b) and Nonresidential Appendix NA7

3. If there are indicator lights that are integral to a lighting control system, they shall consume no more than one watt of power per indicator light.
4. A lighting control system shall meet all of the requirements in the Title 20 Appliance Efficiency Regulations for the identical self-contained lighting control device it is installed to function as. For example, if a lighting control system is installed to comply with the requirements for an occupancy sensor, then the system shall comply with all of the requirements for an occupancy sensor in Title 20.
5. If the system is installed to function as a partial-on or partial-off occupant sensor, the installation may be made up of a combination of single or multi-level Occupant, Motion, or Vacancy Sensor Controls, provided that the components installed to comply with manual-on requirements shall not be capable of conversion by the user from manual-on to automatic-on functionality.

Example 6-13 Manufacturer Responsibility for Certified Controls

Question

What is the responsibility of the manufacturer with regard to using lighting controls that are certified by the Energy Commission and listed in the Energy Commission directories?

Answer

It is the responsibility of the manufacturer to certify its specific controls and to present the data to the Energy Commission so that it can be listed in the Energy Commission directories.

Example 6-14 Designer Responsibility for Certified Controls

Question

What is the responsibility of the designer with regard to using lighting controls that are certified by the Energy Commission and listed in the Energy Commission directories?

Answer

It is the responsibility of the designer to specify only lighting controls that have been listed certified and listed in the Energy Commission directories.

Example 6-15 Installer Responsibility for Certified Controls

Question

What is the responsibility of the installer with regard to using lighting controls that are certified by the Energy Commission and listed in the Energy Commission directories?

Answer

It is the responsibility of the installer to install only controls that are certified by the Energy Commission and listed in the Energy Commission directories. It is also the responsibility of the installer to sign the Installation Certificate.

6.4 Prescriptive Measures

6.4.1 Lighting Zones

The basic premise of the Energy Standards is to base the outdoor lighting power that is allowed on how bright the surrounding conditions are. The Energy Standards contain lighting power allowances for newly installed equipment and specific alterations that are dependent on which Lighting Zone the project is located.

The technical basis for the differences in outdoor lighting zones described by the Illuminating Engineering Society of North America (IES) is that the eyes adapt to darker surrounding conditions and less light is required to properly see; when the surrounding conditions get brighter, more light is needed to see. The least power is allowed in Lighting Zone 1 and increasingly more power is allowed in Lighting Zones 2, 3, and 4. Lighting Zone 0 is intended for undeveloped spaces in parks and wildlife preserves and is very low ambient illumination. Providing greater power than is needed potentially leads to debilitating glare and an increasing spiral of brightness as over-bright projects become the surrounding conditions for future projects causing future projects to unnecessarily require greater power resulting in wasted energy.

For outdoor lighting design recommended practice documents, the IES has directed the various committees to incorporate the Lighting Zone concept into the design criteria. However, in 2014, the IES published a new Recommended Practice for Parking Facilities. In this document, the Lighting Zone concept has been effectively disregarded by establishing a single design criteria for Lighting Zones 1-4. As a result, the new Lighting Zone allowances for General Hardscape do not increment upward in the same manner as previous versions of the Code.

The Energy Commission defines the boundaries of Outdoor Lighting Zones based on the 2010 U.S. Census Bureau boundaries for urban and rural areas as well as the legal boundaries of wilderness and park areas (see Energy Standards Table 10-114-A). By default, government designated parks, recreation areas and wildlife preserves are Lighting Zone 0 and Lighting Zone 1. Lighting Zone 0 areas are undeveloped areas of government designated parks, recreation areas, and wildlife preserves; Lighting Zone 1 are developed portions of government designated parks, recreation areas and wildlife preserves.. Rural areas are Lighting Zone 2; and urban areas are Lighting Zone 3. Lighting Zone 4 is a special use district that may be created by a local government through application to the Energy Commission.

Table 6-3: Lighting Zone Characteristics and Rules for Amendments by Local Jurisdictions

Zone	Ambient Illumination	State wide Default Location	Moving Up to Higher Zones	Moving Down to Lower Zones
LZ0	Very Low	Undeveloped areas of government designated parks, recreation areas, and wildlife preserves.	Undeveloped areas of government designated parks, recreation areas, and wildlife preserves can be designated as LZ1 or LZ2 if they are contained within such a zone.	Not applicable
LZ1	Low	Developed portion of government designated parks, recreation areas, and wildlife preserves. Those that are wholly contained within a higher lighting zone may be considered by the local government as part of that lighting zone.	Developed portion of a government designated park, recreation area, or wildlife preserve, can be designated as LZ2 or LZ3 if they are contained within such a zone.	Not applicable.
LZ2	Moderate	Rural areas, as defined by the 2010 U.S. Census.	Special districts within a default LZ2 zone may be designated as LZ3 or LZ4 by a local jurisdiction. Examples include special commercial districts or areas with special security considerations located within a rural area.	Special districts and government designated parks within a default LZ2 zone maybe designated as LZ1 by the local jurisdiction for lower illumination standards, without any size limits.
LZ3	Moderately High	Urban areas, as defined by the 2010 U.S. Census.	Special districts within a default LZ3 may be designated as a LZ4 by local jurisdiction for high intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels.	Special districts and government designated parks within a default LZ3 zone may be designated as LZ1 or LZ2 by the local jurisdiction, without any size limits.
LZ4	High	None	Not applicable.	Not applicable.

Energy Standards Table 10-114-A

The options allowed under §10-114 are as follows:

A. Parks, Recreation Areas and Wildlife Preserves

The default for undeveloped portions of government designated parks, recreation areas, and wildlife preserves is Lighting Zone 0. The local jurisdiction having authority over the property will know if the property is a government designated park, recreation area, or wildlife preserve.

The default for developed portions of government designated parks, recreation areas, and wildlife preserves is Lighting Zone 1. The local jurisdiction having authority over the property will know if the property is a government designated park, recreation area, or wildlife preserve. However, when a park, recreation area, wildlife preserve, or portions thereof, are surrounded by urban areas (as defined by the U.S. Census Bureau), such areas may be designated as Lighting Zone 3 by adoption of the local jurisdiction. Similarly, a Lighting Zone 2 designation can be adopted if the area is surrounded by rural areas (as defined by the U.S. Census Bureau). All adjustments in LZ designation must be reviewed by the CEC for approval.

B. Rural Areas

The default for rural areas as defined by the U.S. Census Bureau is Lighting Zone 2. However, local jurisdictions having building permit authority may designate certain areas as either Lighting Zone 3 or Lighting Zone 4 if the local jurisdiction determines that ambient lighting levels are higher than typical for a rural area. Examples of areas that might be designated Lighting Zone 3 are special commercial districts or areas with special security considerations. All adjustments in LZ designation must be reviewed by the CEC for approval.

Local jurisdictions also may designate default Lighting Zone 2 areas as Lighting Zone 1, which would establish lower lighting power for outdoor areas with lower surrounding brightness. An example of an area that might be changed to Lighting Zone 1 would include an underdeveloped, environmentally sensitive or predominately residential area within a default Lighting Zone 2 area.

C. Urban Areas

Lighting Zone 3 is the default for urban areas, as defined by the U.S. Census Bureau. Local jurisdictions may designate areas to Lighting Zone 4 for high intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels. All adjustments in LZ designation must be reviewed by the CEC for approval.

Local jurisdictions also may designate areas as Lighting Zone 2 or even Lighting Zone 1 if they deem that this is appropriate.

6.4.1.1 **Determining the Lighting Zone for an Outdoor Lighting Project**

Permit applicants may determine the Lighting Zone for a particular property using the following steps:

- Local jurisdiction – Check with the local jurisdiction having authority over permitting of the property. The local jurisdiction will know if the property is a government designated park, recreation area, or wildlife preserve, and therefore in default Lighting Zone 0 or 1. The local jurisdiction also may know if the property is contained within the physical boundaries of a Lighting Zone for which a locally-adopted change has been made. However, verify through the California Energy Commission website whether or not a locally-adopted change has been submitted to the Energy Commission.
- U.S. Census – Look at the U.S. Census website to determine if the property is within a rural (statewide default Lighting Zone 2) or urban (statewide default Lighting Zone 3) census block.
    - According to the US Census Bureau, there are two types of urban area, Urbanized Areas (UAs) of 50,000 or more people and Urban Clusters (UCs) of at least 2,500 and less than 50,000 people. Furthermore, “Rural” encompasses all population, housing, and territory not included within an urban area.
    - There is an address search tool provided by US Census Bureau. Enter the address and look up for the geography results indicating whether the entered address is urban or rural under geography type.

      (http://factfinder.census.gov/faces/nav/jsf/pages/searchresults.xhtml?ref=addr&refresh=t)

  - A 'Geography Results' window will display a number of geographies within which the address is located. If you are in an urban area, one of the geographies will designate this; otherwise you are in a rural geography.

- Energy Commission website – Check the Energy Commission's website to determine if the property is contained within the physical boundaries of a Lighting Zone that has been changed through a local jurisdiction adoption process.

6.4.1.2 **Examples for Defining Physical Boundaries**

Using Metes and bounds is a good method to use for defining the physical boundaries of an adopted Lighting Zone.

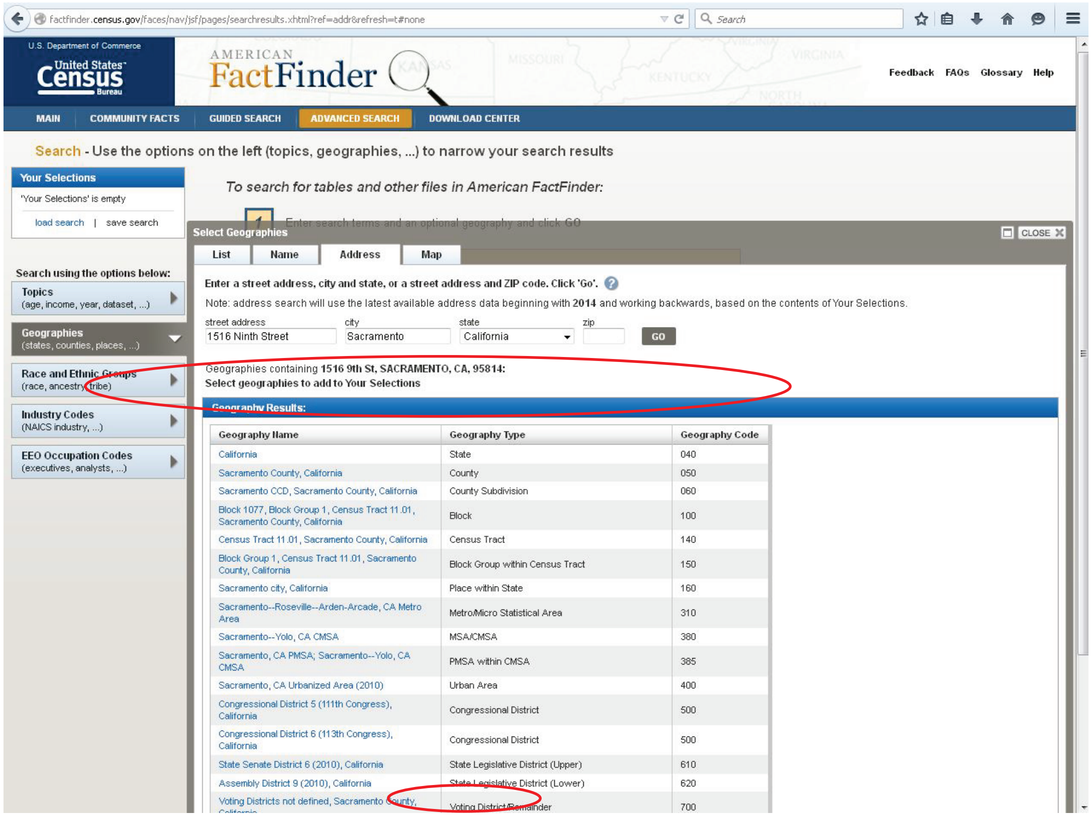
Metes and bounds is a system that uses physical features of the local geography, along with directions and distances, to define and describe the boundaries of a parcel of land. The boundaries are described in a running prose style, working around the parcel of the land in sequence, from a point of beginning, returning back to the same point. The term "metes" refers to a boundary defined by the measurement of each straight run, specified by a distance between the terminal points, and an orientation or direction. The term "bounds" refers to a more general boundary descriptions, such as along a certain watercourse or public road way.

Following are examples of using metes and bounds to define the physical boundaries of an adopted Lighting Zone:

- Properties with frontage on Kennedy Memorial Expressway, between First Avenue and Main Street to a depth of 50 ft from each frontage property line.
- The area 500 ft east of Interstate 5, from 500 ft north of Loomis Ave to 250 ft south of Winding Way.
- The area of the Sunrise Bike Trail starting at Colfax Avenue and going east to Maple Park, the width of a path which is from the edge of the South Fork of the American River on one side, to 100 ft beyond the paved bike trail, or to private property lines, whichever is shorter, on the other side.
- The area that is bounded by the Truckee River on the West, Grizzly Lane on the south, Caddis Road on the east, and the boundary of Placer County on the north.

Note: The physical boundaries of a changed Lighting Zone are not required to coincide with the physical boundaries of a census tract.

Figure 6-2: Example of US Census Bureau Information



Example 6-16 Changing the Default Lighting Zone

Question

I want to have the default outdoor Lighting Zone for a particular piece of property changed. How do I accomplish that?

Answer

Check with the local jurisdiction having authority over the property and ask them what you need to do to petition them to have the default outdoor Lighting Zone officially adjusted.

6.4.1.3 Lighting Zone Adjustments by Local Jurisdictions

§10-114

Energy Standards Table 10-114-A

The Energy Commission sets statewide default Lighting Zones. However, jurisdictions (usually a city or county), may change the zones to accommodate local conditions. Local governments may designate a portion of Lighting Zones 2 or 3 as Lighting Zone 3 or 4. The local jurisdiction also may designate a portion of Lighting Zone 3 to Lighting Zone 2 or even Lighting Zone 1. When a local jurisdiction adopts changes to the Lighting Zone boundaries, it must follow a public process that allows for formal public notification, review, and comment about the proposed change. The local jurisdiction also must provide the Energy Commission with detailed information about the new Lighting Zone boundaries, and submit a justification that the new Lighting Zones are consistent with the specifications in §10-114.

The Energy Commission has the authority to disallow Lighting Zone changes if it finds the changes to be inconsistent with the specification of §10-114 including Table 10-114-A.

6.4.2 Outdoor Lighting Power Compliance

An outdoor lighting installation complies with the Energy Standards if the actual outdoor lighting power is no greater than the allowed outdoor lighting power. This section describes the procedures and methods for complying with §140.7(a through d).

In some situations, more than one lighting designer designs the outdoor lighting. An example might be that one designer is designing the pole mounted lighting for the parking lot and another designs the lighting that is attached to the building. Final compliance documentation must be developed that accounts for all outdoor lighting power and calculates the allowable lighting power once.

Two separate sets of outdoor lighting compliance documentation may unintentionally double count the allowances for outdoor lighting. Therefore, this needs to be considered when evaluating the sum total of the actual installed outdoor lighting power.

The allowed lighting power is determined by measuring the area or length of the lighting application and multiplying this area (in W/ft²) or length (in W/ft²) times the Lighting Power Allowance (in W). The allowed lighting power must be calculated for the general hardscape lighting of the site and for specific applications if desired.

The area of the lighting application must be defined exclusive of any areas on the site that are not illuminated.

The actual power of outdoor lighting is the total watts of all of the non-exempt lighting systems (including ballast, driver or transformer loss) (See §140.7(c)).

The allowed outdoor lighting power is calculated by Lighting Zone as defined in §10-114. Local governments may amend Lighting Zones in compliance with §10-114. See Section 6.4.1 for more information about amending outdoor ordinances by local jurisdictions.

6.4.2.1 **Maximum Outdoor Lighting Power**

The Energy Standards establish maximum outdoor lighting power that can be installed. The allowed outdoor lighting power must be determined according to the Outdoor Lighting Zone in which the site is located. See Section 6.4.1 for more information about Outdoor Lighting Zones.

The wattage of outdoor luminaires must be determined in accordance with §130.0(c) or Reference Nonresidential Appendix NA8. See Section 5.3 for more information about determining luminaire wattage.

The total allowed lighting power is the combined total of all of the allowed lighting power layers. There are lighting power allowances for general hardscape lighting and lighting power allowances for specific applications. An outdoor lighting installation complies with the lighting power requirements if the actual outdoor lighting power installed is no greater than the allowed outdoor lighting power calculated under §140.7(d) and complies with certain stipulations associated with specific special application allowances. The allowed lighting power shall be the combined total of the sum of the general hardscape lighting allowance determined in accordance with §140.7(d)1, and the sum of the additional lighting power allowance for specific applications determined in accordance with §140.7(d)2.

See Section 6.4.3 for a detailed explanation in determining the total allowed lighting power.

6.4.2.2 **Illuminated Area**

With indoor lighting applications, the entire floor area is considered to be illuminated for the purpose of determining the allowed lighting power. However, for outdoor lighting applications, the number of luminaires, their mounting heights and their layout affect the presumed illuminated area and therefore the allowed lighting power.

The area of the lighting application may not include any areas on the site that are not illuminated. The area beyond the last luminaire is considered illuminated only if it is located within 5 mounting heights of the nearest luminaire.

In plan view of the site, the illuminated area is defined as any hardscape area within a square pattern around each luminaire or pole that is 10 times the luminaire mounting height, with the luminaire in the middle of the pattern. Another way to envision this is to consider an illuminated area from a single luminaire as the area that is 5 times the mounting height in four directions.

Illuminated areas shall not include any area that is obstructed by any other structure, including a sign or within a building, or areas beyond property lines.

The primary purpose for validating the illuminated area is to not include any areas that are not illuminated. Areas that are illuminated by more than one luminaire shall not be double counted. Either an area is illuminated or it is not illuminated.

When luminaires are located further apart (more than 10 times their mounting height apart), then the illuminated area stops at 5 times the mounting height of each luminaire.

Planters and small landscape areas are included within the general hardscape area as long as the short dimension of the inclusion is less than 10 ft wide, and the inclusion is bordered on at least three sides.

Landscape areas that are greater than 10 ft wide in the short dimension are excluded from the general hardscape area calculation, but the perimeter of these exclusions may be included in the linear wattage allowance (LWA) calculation.

6.4.3 General Hardscape Lighting Power Allowance

6.4.3.1 **Calculation of Allowed Lighting Power**

The allowed lighting power shall be the combined total of the sum of the general hardscape lighting allowance determined in accordance with §140.7(d)1, and the sum of the additional lighting power allowance for specific applications determined in accordance with §140.7(d)2.

A. General Hardscape Lighting Allowance

Hardscape is defined in §100.1 as an improvement to a site that is paved and has other structural features, including but not limited to, curbs, plazas, entries, parking lots, site roadways, driveways, walkways, sidewalks, bikeways, water features and pools, storage or service yards, loading docks, amphitheaters, outdoor sales lots, and private monuments and statuary.

General Hardscape lighting allowance = (Hardscape Area x AWA) + (Perimeter Length of Hardscape Area x LWA) + IWA

Determine the general hardscape lighting power allowances as follows:

1. The general hardscape area of a site shall include parking lot(s), roadway(s), driveway(s), sidewalk(s), walkway(s), bikeway(s), plaza(s), bridge(s), tunnel(s), and other improved area(s) that are illuminated. In plan view of the site, determine the

illuminated hardscape area, which is defined as any hardscape area that is within a square pattern around each luminaire or pole that is ten times the luminaire mounting height with the luminaire in the middle of the pattern, less any areas that are within a building, beyond the hardscape area, beyond property lines, or obstructed by a structure. The illuminated hardscape area shall include portions of planters and landscaped areas that are within the lighting application and are less than or equal to 10 feet wide in the short dimensions and are enclosed by hardscape or other improvement on at least three sides. Multiply the illuminated hardscape area by the Area Wattage Allowance (AWA) from Table 6-4 (Table 140.7-A) for the appropriate Lighting Zone.

2. Determine the perimeter length of the general hardscape area. The total hardscape perimeter is the length of the actual perimeter of the illuminated hardscape on the property. It shall not include portions of hardscape that is not illuminated according to §140.7(d)1A. Multiply the hardscape perimeter by the Linear Wattage Allowance (LWA) for hardscape from Table 6-4 (Table 140.7-A) for the appropriate lighting zone. Generally, if there is an enclosed exclusion in the area AWA calculation, the perimeter may be included in the LWA calculation.

   The perimeter length for hardscape around landscaped areas and permanent planters shall be determined as follows:

   i. Landscaped areas completely enclosed within the hardscape area, and which width or length is a minimum of 10 feet wide, the perimeter of the landscaped areas or permanent planter shall be added to the hardscape perimeter length.

   ii. Landscaped areas completely enclosed within the hardscape area, and which have a width or length less than 10 feet wide, shall not be added to the hardscape perimeter length.

   iii. Landscaped edges that are not abutting the hardscape shall not be added to the hardscape perimeter length.

3. Determine the Initial Wattage Allowance (IWA). The IWA is allowed to be used one time per site. The purpose is to provide additional watts for small sites, or for odd hardscape geometries. Add the IWA for general hardscape lighting from Table 6-4 (Table 140.7-A) for the appropriate lighting zone.

The general hardscape lighting allowance shall be the sum of the allowed watts determined from (1), (2) and (3) above.

Table 6-4: General Hardscape Lighting Power Allowance

Type of Power Allowance	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2[2]	Lighting Zone 3[2]	Lighting Zone 4
Area Wattage Allowance (AWA)	No allowance[1]	0.020 W/ft²	0.030 W/ft²	0.040 W/ft²	0.050 W/ft²
Linear Wattage Allowance (LWA)		0.15 W/lf	0.25 W/lf	0.35 W/lf	0.45 W/lf
Initial Wattage Allowance (IWA)		340 W	450 W	520 W	640 W

[1] Continuous lighting is explicitly prohibited in Lighting Zone 0. A single luminaire of 15 Watts or less may be installed at an entrance to a parking area, trail head, fee payment kiosk, outhouse, or toilet facility, as required to provide safe navigation of the site infrastructure. Luminaires installed in Lighting Zone 0 shall meet the maximum zonal lumen limits for Uplight and Glare specified in Table 130.2-A and 130.2-B.

[2] For lighting Zone 2 and 3, where greater than 50% of the paved surface of a parking lot is finished with concrete, the AWA for that area shall be 0.035 W/ft² for Lighting Zone 2 and 0.040 W/ft² for Lighting Zone 3, and the LWA for both lighting zones shall be 0.70 W/lf. This does not extend beyond the parking lot, and does not include any other General Hardscape areas.

Table 140.7-A from the Energy Standards

The allowed lighting power for general hardscape lighting is calculated using the following components:

- Area Wattage Allowance (AWA), which is the area of the illuminated hardscape, and is expressed in watts per square foot.
- Linear Wattage Allowance (LWA), which is the length of the perimeter of the illuminated hardscape, and is expressed in watts per linear foot.
- Initial Wattage Allowance (IWA), which is a flat allowance for each property, and is expressed in watts.

To determine the total allowed power for general hardscape lighting, use the equation: (Hardscape area x AWA) + (Hardscape perimeter x LWA) + (IWA).

Example 6-17 Power Allowance for Parking Lots

Question

In a parking lot in front of a retail store, we are not using the full lighting power allowance values from Table 140.7-A for the parking lot. Can we use the remaining allowance to illuminate the building entrance and the walkways near the store to a higher level?

Answer

Yes, because hardscape power densities are tradable, you may use the unused portion of the power allowance in the parking lot to increase the illumination levels for other lighting applications, including building entrance and walkway areas.

Example 6-18 Illumination for Stairs

Question

Lighting for stairs is exempt from the requirements of §140.7, so is a pole-mounted luminaire that is located at the stairs considered exempt, even though some of the light serves hardscape areas that are not exempt?

Answer

In this example, the luminaire is not regulated by the Energy Standards if the primary purpose for that luminaire is to illuminate the stairs (or other unregulated areas), and a majority of the light coming from a luminaire falls on stairs. However, the luminaire is regulated by the Energy Standards if the majority of the light coming from the luminaire falls on regulated areas, such as hardscape areas other than the stairs. For example, if the luminaire is equipped with optics that directs more than 50 percent of the light towards the stairs, then the luminaire may be considered stair lighting and therefore exempt. Conversely, the luminaire must be considered hardscape lighting if the lack of proper optical controls results in more than 50 percent of the light falling on the adjacent hardscape areas.

Example 6-19 Calculating the Illuminated Area of a Parking Lot

Question

A parking lot is only illuminated from a series of 5 cut-off wall packs mounted on an adjacent building. The parking lot extends 100 ft from the building. The luminaires are mounted at a height of 15 ft above the ground and spaced 50 ft apart. How large is the illuminated area?

Answer

The illuminated area extends a distance equal to 5 times the mounting height in three directions (the fourth direction is not counted because it is covered by the building). The illuminated area therefore extends from the building a distance of 75 ft. The total illuminated area is 75 ft x 350 ft or 26,250 ft².

Example 6-20 Calculating the Illuminated Area

Question

If a pole has a height of 15 ft, what are the dimensions of the square pattern used for power calculations?

Answer

The illuminated area is defined as any area within a square pattern around each luminaire or pole that is 10 times the luminaire mounting height, with the luminaire in the middle of the pattern. It does not include any area that is within a building, under a canopy, beyond property lines, or obstructed by a sign or structure. Therefore, for a 15 ft pole, the area will be described by a square that is 150 ft (15 ft x 10) on each side, or 22,500 ft² (150 ft x 150 ft), minus areas that are beyond the property line or other obstructions.

Example 6-21 Calculating the Illuminated Area

Question

If two poles in the center of an illuminated area are a greater distance than 10 times the mounting height, will all of the square footage between them be included in the area?

Answer

In most applications, for example parking lots, these square patterns will typically overlap, so the entire area of the parking lot between poles will typically be included when determining the lighting power budget. However, if the poles are so far apart that they exceed 10 times the mounting height of the luminaires on the poles, the coverage squares do not overlap and the non-illuminated areas between poles cannot be included in determining illuminated hardscape area.

Example 6-22 Calculating the Power Allowance for a Roadway

Question

A 300 ft long, 15 ft wide roadway leads through a wooded area to a hotel entrance in Lighting Zone 2, and the owner wants to light the roadway with luminaires mounted at a height of 20 ft. What is the allowed lighting power for this roadway?

Answer

The hardscape area for the roadway must first be calculated. If the entire roadway will be lighted, then the 20 ft poles will not be spaced more than 200 ft apart and not more than 100 ft from the ends of the roadway. (Lighted area is 10 times the pole height.) The hardscape area then is 15 ft x 300 ft or 4500 ft². The linear perimeter of this hardscape is the sum of the sides (not including the side that connects to the larger site) 300 ft + 15 ft + 300 ft or 615 ft.

Three allowances make up the total power allowance: Area, Linear, and Initial. However, the initial wattage allowance applies one time to the entire site. It is not considered for usage for this roadway piece which would only be one small part of the site. All allowances are based on Lighting Zone 2 and found in Table 6-4 (Table 140.7-A of the Energy Standards). The area wattage allowance is equal to 135 W (0.03 W/ft² x 4500 ft²).

The linear wattage allowance is equal to 153.75 W (0.25 W/lf x 615 lf).

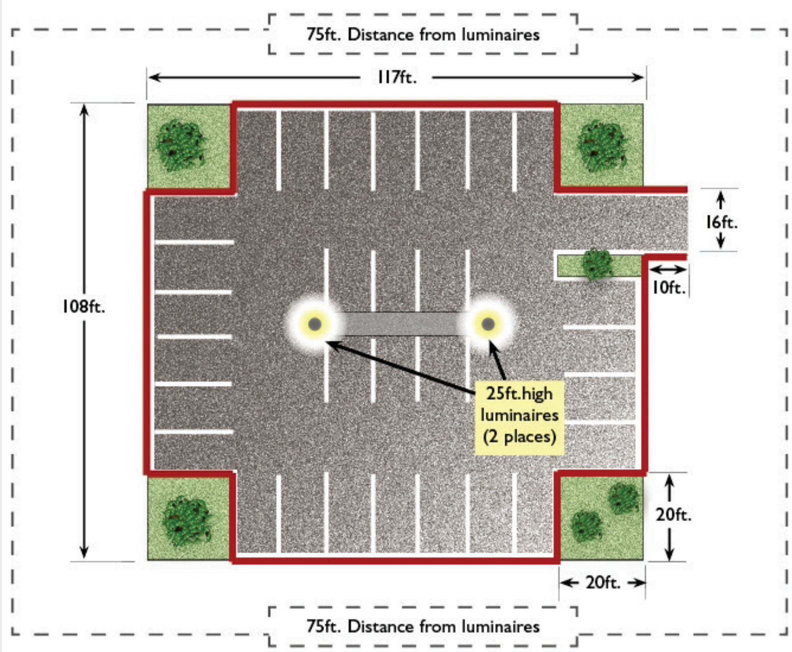
Finally, the sum of these allowances gives a total wattage allowance for the roadway of 288.75 W (135 W + 153.75 W).

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Initial	450W	-	not used
Area	0.030 W/ft^2	4500 ft^2	135 W
Perimeter	0.25 W/LF	615 ft	153.75 W
TOTAL POWER ALLOWANCE			**288.75 W**

Example 6-23 Calculating the Power Allowance for a Parking Lot

Question

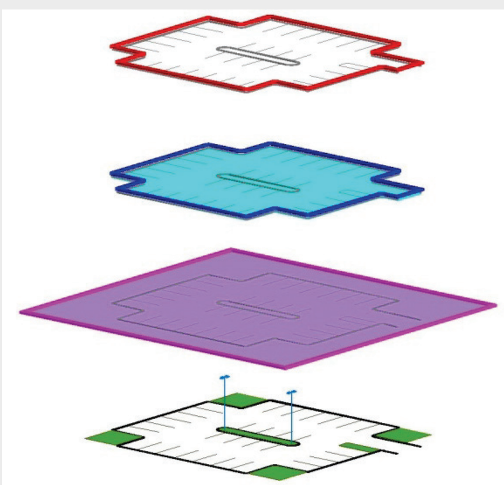
The parking lot illustrated below has two luminaires that are mounted at a height of 25 ft. What is the illuminated hardscape area and what is the allowed lighting? The lot is located in Lighting Zone 3.



Poles are 40 feet apart

Answer

The poles are 40 ft apart, and using the 10 times mounting height rule, the illuminated area can be as large as 250 ft by 290 ft. The boundary of this maximum illuminated area extends beyond the edges of the parking lot as well as the entrance driveway, so the entire paved area is considered illuminated. The landscaped island in middle and peninsula below the entrance driveway are less than 10 ft wide, so they are included as part of the illuminated area, but not part of the hardscape perimeter. The landscaped cutouts (20 x 20 ft) in the corners of the parking lot are bound by pavement on only two sides so they are not included. The total paved area is 11,196 ft². [(12,636 ft² + 160 ft² (driveway) – 1,600 ft² (cutouts)]. The perimeter of the hardscape is 470 ft [(2 x 77 ft) + (2 x 68 ft) + (8 x 20 ft) + (2 X10 ft)].



Perimeter

Area

Illuminated Area

Site Plan

Three allowances make up the total power allowance: Area, Linear, and Initial. All allowances are based on lighting zone 3 and found in Table 6-4 (Table 140.7-A of the Energy Standards). The area wattage allowance is equal to 447.84 W (0.040 W/ft² x 11,196 ft²).

The linear wattage allowance is equal to 164.5W (0.35W/lf x470 lf). The initial wattage allowance (IWA) is 520 W for the entire site.

Finally, the sum of these three allowances gives a total wattage allowance for the site of 1132.34 W (447.84 W + 164.5W+ 520 W).

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Initial	520W	-	520 W
Area	0.040 W/ft^2	11,196 ft^2	447.84 W
Perimeter	0.35 W/LF	470 ft	164.5 W
TOTAL POWER ALLOWANCE			**1132.34 W**

Example 6-24 Calculating the Illuminated Area of a Parking Lot

Question

In the parking lot layout shown above, what would the illuminated area be and what would the maximum allowed lighting power be if much smaller pedestrian style poles were used at 8 ft high and placed 30 ft apart?

Answer

If the mounting height is reduced to 8 ft, and the spacing to 30 ft and using the 10 times mounting height rule, the illuminated area can be a rectangle as large as 80 ft by 110 ft. The hardscape area that intersects the maximum allowed illuminated area is now 8,524 ft² [(80 ft x (80 ft + 30 ft) - 2 x (6 ft x 6 ft cutouts) -2 x (6 ft x 17 ft cutouts)]. The new hardscape perimeter is 380 ft [(2 x 88 ft) + (2 x 68 ft) + (4 x 6 ft) + (2 x 6 ft) + (2 x 16 ft)].

Using the same allowances as in the previous example, the total wattage allowance for the site is 993.96 W (340.96 area W + 133 perimeter W + 520 initial W).

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Initial	520W	-	520 W
Area	0.040 W/ft^2	8524 ft^2	340.96 W
Perimeter	0.35 W/LF	380 ft	133 W
TOTAL POWER ALLOWANCE			**993.96 W**

6.4.4 Additional Light Power Allowances and Requirements, by Application

The lighting power for Specific Applications provides additional lighting power that can be layered in addition to the General Hardscape lighting power allowances as applicable.

Most of a site will be classified as ‘General Hardscape’ and will be calculated using Table 6-4 (Table 140.7-A of the Energy Standards) as the only source of allowance.

Some portions of the site may fit use categories that permit the inclusion of an additional lighting allowance for that portion of the site. These Specific Applications are detailed in Table 6-5 (Table 140.7-B of the Energy Standards). Not all of these allowances are based on area.

The single exception to this is the allowance for Hardscape Ornamental Lighting, which is calculated independent of the rest of the Specific Applications, and no regard to the overlap of this Application is made. See Section E for more information about the Hardscape Ornamental Lighting allowance.

Table 6-5: Additional Lighting Power Allowance for Specific Applications

Lighting Application	Lighting Zone 0	Lighting Zone 1	Lighting Zone 2	Lighting Zone 3	Lighting Zone 4
WATTAGE ALLOWANCE PER APPLICATION. Use all that apply as appropriate.					
Building Entrances or Exits. Allowance per door. Luminaires must be within 20 feet of the door.	Not applicable	15 watts	25 watts	35 watts	45 watts
Primary Entrances to Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities. Allowance per primary entrance(s) only. Primary entrances are entrances that provide access for the general public. This allowance is in addition to the building entrance or exit allowance above. Luminaires must be within 100 feet of the primary entrance.	Not applicable	45 watts	80 watts	120 watts	130 watts
Drive Up Windows. Allowance per customer service location. Luminaires must be within 2 mounting heights of the sill of the window.	Not applicable	40 watts	75 watts	125 watts	200 watts
Vehicle Service Station Uncovered Fuel Dispenser. Allowance per fueling dispenser. Luminaires must be within 2 mounting heights of the dispenser.	Not applicable	120 watts	175 watts	185 watts	330 watts
ATM Machine Lighting. Allowance per ATM machine. Luminaires must be within 50 feet of the dispenser.	Not applicable	250 watts for first ATM machine, 70 watts for each additional ATM machine.			
WATTAGE ALLOWANCE PER UNIT LENGTH (w/linear ft). May be used for one or two frontage side(s) per site.					
Outdoor Sales Frontage. Allowance for frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires must be located between the principal viewing location and the frontage outdoor sales area.	Not applicable	No Allowance	22.5 W/linear ft	36 W/linear ft	45 W/linear ft
WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/ft²). May be used for any illuminated hardscape area on the site.					
Hardscape Ornamental Lighting. Allowance for the total site illuminated hardscape area. Luminaires must be rated for 100 watts or less and be post-top luminaires, lanterns, pendant luminaires, or chandeliers.	Not applicable	No Allowance	0.02 W/ft²	0.04 W/ft²	0.06 W/ft²
WATTAGE ALLOWANCE PER SPECIFIC AREA (W/ft²). May be used as appropriate provided that only one is used for a given area (i.e., provided that two allowances are not applied to the same area).					
Building Facades. Only areas of building façade that are illuminated qualify for this allowance. Luminaires must be aimed at the façade and capable of illuminating it without obstruction or interference by permanent building features or other objects.	Not applicable	No Allowance	0.18 W/ft²	0.35 W/ft²	0.50 W/ft²
Outdoor Sales Lots. Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non-sales areas are considered hardscape areas even if these areas are completely surrounded by sales lots on all sides. Luminaires must be within 5 mounting heights of the sales lot area.	Not applicable	0.164 W/ft²	0.555 W/ft²	0.758 W/ft²	1.285 W/ft²
Vehicle Service Station Hardscape. Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires must be illuminating the hardscape area and must not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.	Not applicable	0.014 W/ft²	0.155 W/ft²	0.308 W/ft²	0.485 W/ft²
Vehicle Service Station Canopies. Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy.	Not applicable	0.514 W/ft²	1.005 W/ft²	1.300 W/ft²	2.200 W/ft²
Sales Canopies. Allowance for the total area within the drip line of the canopy. Luminaires must be located under the canopy.	Not applicable	No Allowance	0.655 W/ft²	0.908 W/ft²	1.135 W/ft²
Non-sales Canopies and Tunnels. Allowance for the total area within the drip line of the canopy or inside the tunnel. Luminaires must be located under the canopy or tunnel.	Not applicable	0.084 W/ft²	0.205 W/ft²	0.408 W/ft²	0.585 W/ft²

Table 140.7-B from the Energy Standards

Assigned lighting applications must be consistent with the actual use of the area. Outdoor lighting definitions in §100.1 must be used to determine appropriate lighting applications.

Specific Applications that are based on specific instances on the site are the cumulative total of those instances on the site, with the allowance being accumulated per instance.

Specific Applications that are based on the length of an instance on the site are calculated as the product of the total length of the instance and the allowance per linear foot for the Application.

A. General Hardscape Power Trade-Offs

Allowed lighting power determined according to §140.7(d)1 for general hardscape lighting may be traded to specific applications in §140.7(d)2, as long as the hardscape area from which the lighting power is traded continues to be illuminated in accordance with §140.7(d) 1A.

B. Specific Allowances Power Trade-Offs Not Allowed

Allowed lighting power for specific applications shall not be traded between specific applications, or to hardscape lighting in §140.7(d)1. This means that for each and every specific application, the allowed lighting power is the smaller of the allowed power determined for that specific application according to Table 140.7-B, or the actual installed lighting power that is used in that specific application.

C. Wattage Allowance per Application

The applications in this category are provided with additional lighting power, in watts (W) per instance, as defined in Table 6-5 (Table 140.7-B of the Energy Standards). Use all that apply as appropriate. Wattage allowances per application are available for the following areas:

- Building Entrances or Exits.
- Primary Entrances of Senior Care Facilities, Police Stations, Hospitals, Fire Stations, and Emergency Vehicle Facilities.
- Drive-Up Windows. See Section 6.4.5F for additional information about drive-up windows
- Vehicle Service Station Uncovered Fuel Dispenser. See Section 6.4.5C for additional information about vehicle service stations.
- ATM Machine Lighting

D. Wattage Allowance for Outdoor Sales Frontage Application

The wattage allowance per linear foot is available only for outdoor sales frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor. The outdoor sales frontage allowance is calculated as the product of the total length of qualifying sales frontage times the outdoor sales frontage lighting allowance in Table 6-5 (Table 140.7-B of the Energy Standards). See Section 6.4.5B for additional information about sales frontage.

E. Wattage Allowance per Hardscape Ornamental Lighting Application

The ornamental lighting allowance on the site is calculated as the product of the total illuminated hardscape for the site times the hardscape ornamental lighting allowance in

Table 6-5 (Table 140.7-B of the Energy Standards), in watts per square foot (W/ft^2). Luminaires qualifying for this allowance shall be rated for 100 W or less as determined in accordance with §130.0(c), and shall be post-top luminaires, lanterns, pendant luminaires, or chandeliers. This additional wattage allowance may be used for any illuminated hardscape area on the site. See Section 6.4.5E, Ornamental Lighting, for additional information about ornamental lighting.

F. Wattage Allowance per Specific Area

Applications in this category are provided with additional lighting power, in watts per square foot (W/ft^2), as defined in Table 140.7-B of the Energy Standards (Table 6-5). Wattage allowances per specific area are available for the following areas:

1. Building Facades

Only areas of building façade that are illuminated shall qualify for this allowance. Luminaires qualifying for this allowance shall be aimed at the façade and shall be capable of illuminating it without obstruction or interference by permanent building features or other objects. See Section 6.4.5A for additional information about building facades.

2. Outdoor Sales Lots

Allowance for uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale. Driveways, parking lots or other non-sales areas shall be considered hardscape areas, not outdoor sales lots, even if these areas are completely surrounded by sales lot on all sides. Luminaires qualifying for this allowance shall be within 5 mounting heights of the sales lot area. See 6.4.5B for more information.

3. Vehicle Service Station Hardscape

Allowance for the total illuminated hardscape area less area of buildings, under canopies, off property, or obstructed by signs or structures. Luminaires qualifying for this allowance shall be illuminating the hardscape area and shall not be within a building, below a canopy, beyond property lines, or obstructed by a sign or other structure.

4. Vehicle Service Station Canopies

Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy. See Section 6.4.5C for additional information about vehicle service stations.

5. Sales Canopies

Allowance for the total area within the drip line of the canopy. Luminaires qualifying for this allowance shall be located under the canopy. See Section 6.4.5D for additional information about lighting under canopies.

6. Non-sales Canopies and Tunnels

Allowance for the total area within the drip line of the canopy or inside the tunnel. Luminaires qualifying for this allowance shall be located under the canopy or tunnel. See Section 6.4.5D for additional information about lighting under canopies.

7. Guard Stations

Allowance up to 1,000 ft^2 per vehicle lane. Guard stations provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants, including identification, documentation, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse. See Section 6.4.5G for additional information about guarded facilities.

8. Student Pick-up/Drop-off zone

Allowance for the area of the student pickup/drop-off zone, with or without canopy, for preschool through 12th grade school campuses. A student pick-up/drop off zone is a curbside, controlled traffic area on a school campus where students are picked up and dropped off from vehicles. The allowed area shall be the smaller of the actual width or 25 ft, times the smaller of the actual length or 250 ft. Qualifying luminaires shall be within 2 mounting heights of the student pick-up/drop-off zone.

9. Outdoor Dining

Allowance for the total illuminated hardscape of outdoor dining. Outdoor dining areas are hardscape areas used to serve and consume food and beverages. Qualifying luminaires shall be within 2 mounting heights of the hardscape area of outdoor dining.

10. Special Security Lighting for Retail Parking and Pedestrian Hardscape

This additional allowance is for illuminated retail parking and pedestrian hardscape identified as having special security needs. This allowance shall be in addition to the building entrance or exit allowance.

6.4.5 Further Discussion about Additional Lighting Power Allowance for Specific Applications

6.4.5.1 **Building Facades**

Building façade is defined in §100.1 as the exterior surfaces of a building, not including horizontal roofing, signs, and surfaces not visible from any public viewing location. Only areas of building façade that are illuminated should qualify for this allowance. Luminaires qualifying for this allowance should be aimed at the façade and should be capable of illuminating it without obstruction or interference by permanent building features or other objects.

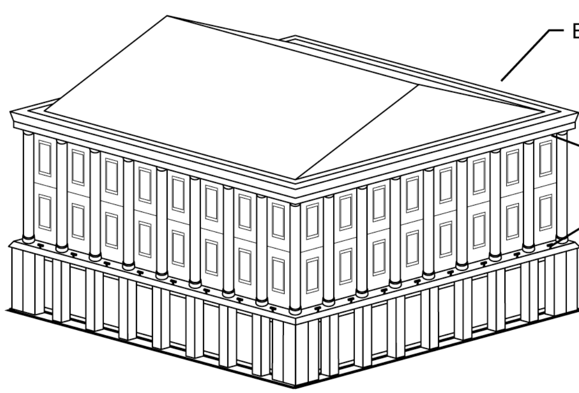
Building façades and architectural features may be illuminated by flood lights, sconces or other lighting attached to the building. Building façade lighting is not permitted in Lighting Zone 0 and Lighting Zone 1. Façade orientations that are not illuminated and façade areas that are not illuminated because the lighting is obstructed shall not be included. General site illumination, sign lighting, and/or lighting for other specific applications can be attached to the side of a building and not be considered façade lighting. Wall packs mounted on sides of the buildings are not considered façade lighting when most of the light exiting these luminaires lands on areas other than the building façade.

Figure 6-3: Façade Lighting

Courtesy of Horton Lees Brogden Lighting Design, Inc of San Francisco
Photographer: Jay Graham

Example 6-25 Calculating the Allowance for a Projected Area

Question



(Lighting Zone 3) A city wants to illuminate its city hall on two sides. The structure is a three-story building with a colonnade on the second and third floors and a cornice above. The columns are considered important architectural features and the principal goal of the lighting project is to highlight these features. The columns are 30 ft tall x 3 ft in diameter and are spaced at 8 ft. For the purposes of determining the lighting power allowance for the building, what is the surface area to be illuminated? What is the lighting power allowance? The columns will be illuminated by downlights at the cornice and uplights above the first floor.

Answer

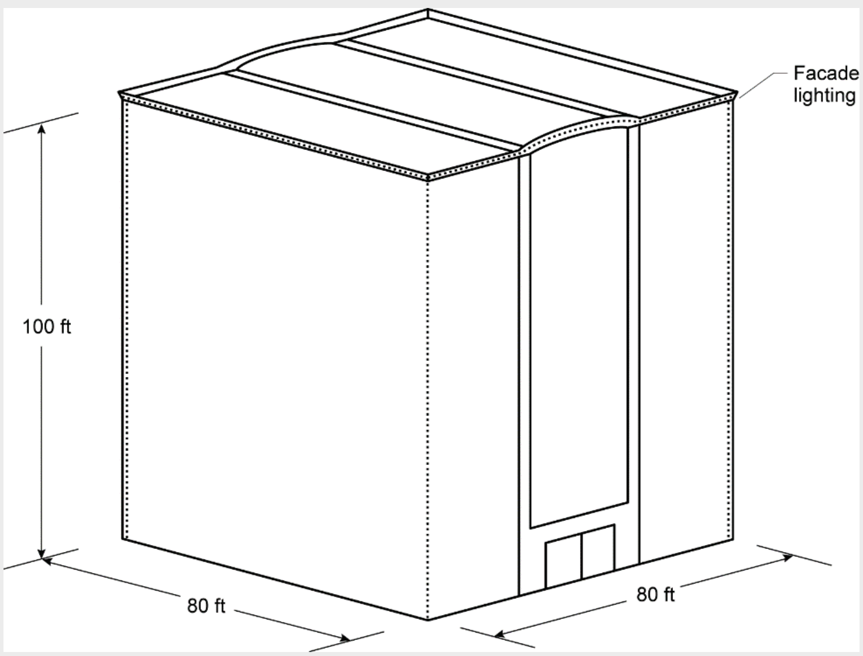
The area of the façade for the purposes of calculating the lighting allowance is the projected area of the illuminated façade. Architectural features such as columns, recesses, facets, etc. are ignored. The illuminated area for each façade is therefore 30 ft x 150 ft or 4,500 ft². The façade allowance for Lighting Zone 3 is 0.35 W/ft², so the total power allowed is 1,575 W per façade, or 3,150 W total.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.35 W/^{ft2}	A. 4,500 ft^2	1,575 W
	TOTAL POWER ALLOWANCE		**1,575 W**

Example 6-26 Permanent vs. Temporary Façade Lighting

Question

I am designing a high-rise building and permanently mounted marquee lights will be installed along the corners of the building. The lights will be turned on at night, but only for the holiday season, roughly between mid-November and mid-January. The lights consist of a series of 9 W compact fluorescent luminaires spaced at 12 inches on-center (OC) along all the corners of the building and along the top of the building. Essentially, the lights provide an outline of the building. For the purposes of the Outdoor Lighting Standards, are these considered façade lighting? Because they will only be used for about two months of the year, are they considered temporary lighting and exempt?



Answer

The lighting is permanent lighting and must comply with the Energy Standards. Temporary lighting is defined in §100.1 as is a lighting installation with plug-in connections that does not persist beyond 60 consecutive days or more than 120 days per year. Anything that is permanently mounted to the building is considered permanent lighting, and the hours of intended use do not affect its status as permanent lighting.

Because this lighting is primarily used to accent the architectural outline of the building, it may be considered façade lighting. And because all corners of the building are illuminated, all four facades may be considered to be illuminated. The area on each façade is 80 ft x 100 ft or 8,000 ft². The total illuminated area is four times 8,000 ft² or 32,000 ft². The Lighting Zone 3 allowance for façade lighting is 0.35 W/ft² and the total power allowance for façade lighting is 11,200 W.

There are 100 ft x 4 plus 80 ft x 4 lamps (a total of 720 lamps) on the building. Each lamp is 13 W (including the ballast). This data is taken from Reference Nonresidential Appendix NA8. The installed power is 720 lamps times 13 W/lamp or 9,360 W. The installed power is less than the allowance so the façade lighting complies. If this building were in Lighting Zone 2, the allowance would be 0.18 W/ft² or a total of 5,760 W. The lighting design would not comply in Lighting Zone 2.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.35 W/ft²	32,000 ft²	11,200 W
	TOTAL POWER ALLOWANCE		**11,200 W**

Example 6-27 Power Allowance for Facades

Question

Portions of the front façade of a proposed wholesale store in Lighting Zone 3 are going to be illuminated. The front wall dimensions are 120 ft by 20 ft. There is 250 ft² of fenestration in the front wall that is illuminated by the façade lighting. Signs cover another 500 ft² of the front wall, and another 400 ft² is not illuminated at all. What is the allowed front façade lighting power?

Answer

The gross wall area is 2,400 ft² (120 x 20). However we must subtract all those areas that are not illuminated. Note that because the 250 ft² of fenestration is intended to be illuminated by the façade lighting, this area may be included in the total area eligible for power calculations.

The areas not eligible for power calculations include:

500 ft² of signs + 400 ft² of unlighted façade = 900 ft²

Net wall area used for façade lighting: 2,400 ft² – 900 ft² = 1,500 ft²

From Table 6-5 (Table 1407-B of the Energy Standards), the allowed façade lighting power density in Lighting Zone 3 is 0.35 W/ft²

The calculated allowed power based on net wall area is 1,500 ft² x 0.35 W/ft² = 525 W.

The allowed power is therefore the smaller of actual wattage used for façade lighting or 525 W.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.35 W/ft²	1,500 ft²	525 W
	TOTAL POWER ALLOWANCE		**525 W**

Example 6-28 Sign Lighting

Question

Is sign lighting part of my façade lighting?

Answer

The sign area must be subtracted from the façade area so that the area is not double counted. The sign lighting must meet the requirements of the Energy Standards for sign lighting. See Chapter 7 for more information about sign lighting.

Example 6-29 Oranamental vs. Façade Lighting

Question

Is the lighting of my parapet wall with small wattage decorative lighting considered ornamental or façade lighting?

Answer

In this example, the lamps attached to the building façade are considered façade lighting. This cannot be considered ornamental lighting because ornamental lighting is defined in Table 140.7-B of the Energy Standards as post-top luminaires, lanterns, pendant luminaires, chandeliers.

Example 6-30 Hardscape vs. Façade Lighting

Question

If I mount a luminaire on the side of my building to illuminate an area is it considered façade lighting or hardscape lighting?

Answer

It depends on the primary intent of the luminaire. For example, if the luminaire is primarily illuminating the walls (such as a sconce), then it should be considered part of the building façade lighting. If on the other hand, the luminaire is primarily illuminating the parking lot beyond (most wall packs), then it should be part of the hardscape lighting. It should be noted that lighting power tradeoffs are not allowed between building façade and hardscape areas.

6.4.5.2 **Sales Frontage**

This additional allowance is intended to accommodate the retailers need to highlight merchandise to motorists who drive by their lot. Outdoor sales frontage includes car lots, but can also include any sales activity.

Outdoor sales frontage must be immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. Luminaires qualifying for this allowance shall be located between the principal viewing location and the frontage outdoor. The outdoor sales frontage allowance is calculated as the product of the total length of qualifying sales frontage times the outdoor sales frontage lighting allowance in Table 147-B of the Energy Standards.

When a sales lot qualifies for the sales frontage allowance, the total sales lot wattage allowance is determined by adding the following three layers:

- General hardscape lighting power allowance
- Outdoor sales frontage
- Outdoor sales lot

6.4.5.3 **Vehicle Service Stations**

According to the definition in §100.1, vehicle service station is a gasoline, natural gas, diesel, or other fuel dispensing station. In addition to allowances for building entrances and exits, hardscape ornamental lighting, building façade, and outdoor dining allowances, as appropriate; the total wattage allowance specifically applying to vehicle service station hardscape is determined by adding the following layers, as appropriate:

- General hardscape lighting power allowance
- Vehicle service station uncovered fuel dispenser (allowance per fuelling dispenser, with 2 mounting heights of dispenser)
- Vehicle service station hardscape (less area of buildings, under canopies, off property, or obstructed by signs or other structures)
- Vehicle service station canopies (within the drip line of the canopy)

The lighting power allowances are listed in Table 140.7-B of the Energy Standards.

Figure 6-4: Service Station Hardscape Areas

Source: AEC Photographer: Tom Bergstrom

Source: AEC Photographer: Tom Bergstrom

Example 6-31 Calculating Canopy Lighting Area and Hardscape Area

Question

Where does canopy lighting area end and hardscape area start?

Answer

The horizontal projected area of the canopy on the ground establishes the area for under canopy lighting power calculations. This area also referred to as the "drip line" of the canopy.

6.4.5.4 **Under Canopies**

According to the definition in §100.1, a canopy is a permanent structure, other than a parking garage, consisting of a roof and supporting building elements, with the area beneath at least partially open to the elements. A canopy may be freestanding or attached to surrounding structures. A canopy roof may serve as the floor of a structure above.

The definition of a canopy states that a canopy is not a parking garage. A parking garage is classified as an unconditioned interior space, whereas a canopy is classified as an outdoor space.

The lighting power allowance for a canopy depends on its purpose. Service station canopies are treated separately (see the previous section). The two types of canopies addressed in this section are those that are used for sales and those that are not. Non-sales canopies include covered walkways, and covered entrances to hotels, office buildings, convention centers and other buildings. Sales canopies specifically cover and protect an outdoor sales area, including garden centers, covered automobile sales lots, and outdoor markets with permanent roofs. The lighting power allowances are listed in Table 140.7-B of the Energy Standards.

The area of a canopy is defined as the horizontal projected area, in plan view, directly underneath the canopy. This area is also referred to as the "drip line" of the canopy. Canopy lighting, either sales or non-sales shall comply separately, e.g. trade-offs are not permitted between other specific lighting applications or with general site illumination.

General site lighting or other specific applications lighting, and/or sign lighting that are attached to the sides or top of a canopy, cannot be considered canopy lighting. For example, internally illuminated translucent panels on the perimeter of a canopy are considered sign lighting, while the lighting underneath the canopy and directed towards the ground is canopy lighting.

Figure 6-5: Canopy Lighting

Source: AEC Photographer: Tom Bergstrom

Example 6-32 Power Allowance Under Canopies

Question

The first floor of an office tower in Lighting Zone 3 is setback 20 ft on the street side. The width of the recessed façade is 150 ft. The primary purpose of the setback (and canopy) is to provide a suitable entrance to the office tower; however, space under the canopy is leased as news-stand, a flower cart and a shoe shine stand. These commercial activities occupy about half of the space beneath the canopy. What is the allowed lighting power?

Answer

The total canopy area is 20 ft x 150 ft or 3,000 ft². The General Hardscape allowance for the site will need to be separately determined. The canopy allowance is an additional layer allowed only for the canopy area. The 1,500 ft² used for the flower cart, news-stand and shoe shine stand is considered a sales canopy and the allowance is 0.908 W/ft² or a total of 1,362 W. The other 1,500 ft² is a non-sales canopy and the allowance is 0.408 W/ft² or a total of 612 W. Trade-offs are not permitted between the sales portion and the non-sales portions.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Non-Sales Canopy	0. 408W/^{ft2}	1,500 ft^2	612 W
Sales Canopy	0.908 w/ft^2	1,500 ft^2	1,362 W
	TOTAL POWER ALLOWANCE		**1,575 W**

6.4.5.5 **Ornamental Lighting**

Ornamental lighting is defined in §100.1 as post-top luminaires, lanterns, pendant luminaires, chandeliers, and marquee lighting. However, marquee lighting does not qualify for the ornamental lighting allowance. The allowances for ornamental lighting are listed in Table 140.7-B of the Energy Standards.

The ornamental lighting allowance on the site is calculated as the product of the total illuminated hardscape for the site times the hardscape ornamental lighting allowance in Table 140.7-B. This allowance is calculated separately, and is not accumulated into the other allowances. This additional wattage allowance may be used for any illuminated hardscape area on the site.

Luminaires used for ornamental lighting as defined in Table 140.7-B shall have a rated wattage, as listed on a permanent, pre-printed, factory-installed label, of 100 W or less.

Figure 6-6: Ornamental Lighting

Source: Ted Walson Photographer

(The cobra head luminaires shown in the above figure are not ornamental lighting. However, if the post-top acorn luminaires are rated 100 watts r less, they qualify as ornamental lighting)

Example 6-33 Bollard Luminaires

Question

Are bollard luminaires considered ornamental lighting?

Answer

No, Ornamental lighting is defined in Table 140.7-B of the Energy Standards as post-top luminaires, lanterns, pendant luminaires, chandeliers.

6.4.5.6 Drive-up Windows

Drive-up windows are common for fast food restaurants, banks, and parking lot entrances. In order to qualify, a drive-up window must have someone working behind the "window". Automatic ticket dispensers at parking lots do not count.

The lighting power allowances are listed in Table 140.7-B of the Energy Standards as a wattage allowance per application.

The wattage allowance in Lighting Zone 3 is 125 W for each drive-up window.

Luminaires qualifying for this allowance must be within 2 mounting heights of the sill of the window.

Figure 6-7: Drive-up Windows

Source: AEC Photographer: Tom Bergstrom

Example 6-34 Power Allowance for Drive-up Window

Question

A drive-up window in Lighting Zone 2 has width of 7 ft. What is the allowed lighting power for this drive-up window?

Answer

The width of a drive-up window in not used for determining the allowed wattage. In Lighting Zone 2, 75 W is allowed for each drive-up window.

6.4.5.7 Guarded Facilities

Guarded facilities, including gated communities, include the entrance driveway, gatehouse, and guardhouse interior areas that provide access to secure areas controlled by security personnel who stop and may inspect vehicles and vehicle occupants including, identification documentation, vehicle license plates, and vehicle contents.

There is an allowance of up to 1,000 ft² per vehicle lane. Qualifying luminaires shall be within 2 mounting heights of a vehicle lane or the guardhouse.

The power allowances for guarded facilities are listed in Table 140.7-B of the Energy Standards.

Example 6-35 Power Allowance for Guard Stations

Question

A guard station to the research campus of a defense contractor consists of a guard station building of 300 ft². Vehicles enter to the right of the station and exit to the left. What is the outdoor lighting power allowance? The guard station is located in Lighting Zone 2.

Answer

Since there are two vehicle lanes, the allowance for Lighting Zone 2 is two times of 300 ft² times 0.355 W/ft² is 213 W, in addition to the general hardscape lighting power allowance.

Example 6-36 Residential Guarded Facilities

Question

Is the guarded facility at the entrance to a residential gated community covered by the Energy Standards?

Answer

Yes, residential guarded facilities are covered by the Energy Standards.

Example 6-37 Outdoor Lighting for Hospitals

Question

Is the parking lot outside of a hospital (“I” occupancy) regulated by the Energy Standards?

Answer

No. Hospitals are “I” type occupancies and are not covered by the Energy Standards. This includes all outdoor areas. The same is true for all other “I” type occupancies such as detention facilities.

Example 6-38 Parking Garage Standards

Question

We have a 5 story parking garage. The top level is uncovered. What are the lighting Standards requirements for this garage?

Answer

Because the lower 4 floors have a roof, they are considered indoor unconditioned buildings and must comply with the requirement of Energy Standards Table 140.6-C. For these levels, indoor compliance documents will be required. The uncovered top floor is considered a parking lot and therefore must comply with the hardscape requirements of Table 140.7-A in the Energy Standards. Outdoor lighting compliance documents will be required for the top level.

Example 6-39 Hardscape Materials for Parking Lots

Question

Our overflow parking lot is covered with gravel. Is this parking lot considered “hardscape” and must it comply with the Energy Standards?

Answer

Yes, parking lots covered with gravel, or any other material used to enhance the surface to accommodate parking or travel, such as pavers, asphalt, cement, or other pervious or non-pervious materials are considered hardscape and must comply with the requirements for hardscape areas.

6.5 Alterations and Additions for Outdoor Lighting

§141.0(b)2J

The Energy Standards apply to alterations and additions to outdoor lighting systems. In general, additions are treated the same as newly constructed buildings, and must comply with all mandatory measures and lighting power density requirements. The application of the Energy Standards to alterations depends on the scope of the proposed improvements.

For alterations that increase the connected lighting load in a lighting application listed in Table 140.7-A or 140.7-B, the added or altered luminaires in the application zone must meet all the applicable requirements of §130.2(c) and §140.7.

For alterations in parking lots or outdoor sales lots that do not increase connected lighting load, but do replace the larger of 5 luminaires or 10 percent of the existing luminaires where the luminaire is mounted less than 24 feet above the ground, the replaced luminaires are required to meet the applicable controls requirements of §130.2(c)1 and §130.2(c)3. For applications where the luminaire is mounted greater than 24 feet above the ground, the replaced luminaires are required to meet the applicable controls requirements of §130.2(c)1 and either comply with §130.2(c)2 or be controlled by lighting control systems (including motion sensors).

For alterations that do not increase connected lighting load, but do replace the larger of 5 luminaires or 50 percent of the existing luminaires in a lighting application listed in Table 140.7-A or 140.7-B, the replaced luminaires must also meet the requirements of §140.7 in addition to the control requirements mentioned in the previous paragraph.

Some or all mandatory measures may apply to altered components. The mandatory requirements include certification of any new lamps, ballasts and drivers that are installed if they are the type regulated by the Appliance Efficiency Regulations. Any new lighting controls must meet minimum performance requirements.

Lighting alterations generally refers to replacing the entire luminaire.

6.5.1 Outdoor Lighting Additions and Alterations – Mandatory and Lighting Power Density Requirements

§141.0(a)1. §130.0, §130.2

A. Mandatory Requirements

Additions to existing outdoor lighting must meet all of the mandatory measures for the added luminaires. The mandatory requirements include certification of any new lamps, light sources, ballasts and drivers that are installed if they are the type regulated by the Appliance Efficiency Regulations. Any new lighting controls must meet minimum performance requirements. In addition, control and circuiting requirements apply as follows:

- Motion sensing for incandescent luminaires rated over 100 watts.
- Maximum zonal lumens for uplight and glare for luminaires with lamps rated greater than 150 watts.
- Automatic controls to turn lighting OFF when daylight is available.
- Independently controlled from other electrical loads by an automatic scheduling control.
- Motion sensing devices for luminaires mounted below 24 feet above ground that automatically reducing the lighting power of each luminaire by at least 40 percent, but not greater than 90 percent, auto-ON functionality when the area becomes occupied and no more than 1,500 watts of lighting power shall be controlled together.
- Outdoor Sales Frontage shall have a part-night control or motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent, along with auto-ON functionality.
- Building Façade, Ornamental Hardscape, and Outdoor Dining shall have a part-night control or motion sensors capable of automatically reducing lighting power by at least 40 percent but not exceeding 90 percent, along with auto-ON functionality, or a centralized time-based zone lighting control capable of automatically reducing lighting power by 50 percent.
- All lighting controls must meet the requirements of §110.9.

B. Lighting Power Density Requirements

The outdoor lighting additions must also comply with lighting power allowances of §140.7, Energy Standards Tables 140.7-A and 140.7-B. These requirements are the same as for newly constructed buildings, as discussed earlier in this Chapter.

Example 6-40 Requirements for Parking Lot Additions

Question

I am adding a new 20,000 ft² section to our parking lot. What are the outdoor lighting requirements for the new addition?

Answer

§141.0(a)1 specifies that all additions to existing outdoor lighting systems must comply with applicable requirements of §110.9, §130.0, §,130.2, §130.4, and §140.7.

Example 6-41 BUG Requirements for Parking Lot Lighting Replacement

Question

We are replacing 20 percent of the existing 250 W luminaires in a parking lot. Does the BUG requirement apply to the new and existing luminaires?

Answer

Yes, new luminaires may be required to meet the Uplight and Glare lumen limits; however, luminaires that are not being replaced are not required to be upgraded to meet the Uplight and Glare lumen limits. §141.0 (b) specifies that all altered components must meet applicable mandatory requirements, including Uplight and Glare lumen limits for replacements luminaires. Therefore, replacement luminaires that are greater than 150 W must meet the Uplight and Glare limits of the Standards, even if less than 5 luminaires or 10 percent of the luminaires on site are replaced.

However, there is an exception to §130.2(b) where replacement of existing pole mounted luminaires in hardscape areas meeting all of the following conditions are not required to comply with the Uplight and Glare lumen limits:

- Where the existing luminaire does not meet the luminaire Uplight and Glare lumen limits in §130.2(b); and
- Spacing between existing poles is greater than 6 times the mounting height of the existing luminaires; and
- Where no additional poles are being added to the site; and
- Where new wiring to the luminaires is not being installed; and
- Provided that the connected lighting power wattage is not increased.

Example 6-42 Requirements for Replacing Existing Luminaires

Question

In a service station we are replacing more than 50 percent of under canopy luminaires. Does this trigger the alteration requirements for outdoor lighting? Do we need to bring non-canopy lighting such as hardscape lighting up to code as well?

Answer

Yes, §141.0(b)2Liii specifies that when more than 5 luminaires or 50 percent of luminaires are replaced in a given lighting application included in Energy Standards Tables 140.7-A and 140.7-B, the alteration requirements apply. So, in this example, all of the under canopy luminaires must meet the requirements of §140.7 and the applicable control requirements of Section 130.2. Hardscape and other outdoor Lighting Applications other than the canopy need not meet these requirements even if they are included in the permit along with the canopy lighting.

Example 6-43 Requirements for Adding New Luminaires in a Parking Lot

Question

We are adding new luminaires to the existing lighting systems in a parking lot. Which Standards requirements are triggered by this alteration?

Answer

Because additional load is being added to the parking lot, which is part of the general hardscape lighting, the entire general hardscape area must comply with the lighting power density requirements for the given Lighting Zone. However, only the newly installed lighting system must comply with the applicable mandatory requirements, including control requirements and Uplight and Glare lumen limits.

Example 6-44 Requirements for Replacing Ballasts

Question

I am going to change the ballasts in my façade lighting system. Will I be required to meet the new Outdoor Lighting Standards for façade lighting?

Answer

No, the replacement of only lamps or ballasts in outdoor lighting systems is not considered an alteration and does not trigger compliance with Outdoor Lighting Standards. Replacing entire luminaires will trigger mandatory requirements for the altered (replaced) luminaires only. Replacing more than 5 luminaires or 50 percent of the existing luminaires or adding to the connected lighting load for any outdoor lighting application will trigger the lighting power density requirements of the Energy Standards.

Example 6-45 Requirements for LED Retrofits

Question

I am going to retrofit all of my HID parking lot lights with an LED retrofit kit. What requirements do I need to follow for the LED retrofits?

Answer

For outdoor lighting alterations that reduce lighting power such as LED retrofits, there are two options for demonstrating compliance with the Energy Standards. You can either use NRCC-LTO-02 to calculate the lighting power allowance for the hardscape area, or you can use NRCC-LTO-04 to list the number and wattage of the existing luminaires in the hardscape area.

In both cases, the requirements are the same: if fewer than 5 luminaires are being retrofitted, or the number of luminaires being retrofitted is less than 10 percent of the total number of luminaires in the hardscape area, then the requirements of the Energy Standards are not triggered and no compliance documentation is required. If more than 10 percent and less than 50 percent of the luminaires in the hardscape area are being retrofitted, then control requirements apply. If 50 percent or more of the luminaires in the hardscape area are being retrofitted, then control requirements apply and the lighting must either meet current lighting power allowances per Section 140.7 (using NRCC-LTO-02) or must achieve a 40 percent reduction in lighting power (using NRCC-LTO-04).

Example 6-46 Exemption from lighting power allowance requirements

Question

50 HID exterior pole fixtures in a parking lot are being replaced with 50 new LED fixtures. However, to improve poor coverage in one end of the lot an additional 3 pole fixtures are added, bringing the total new fixture count to 53. Despite the addition of 3 fixtures, the total connected load for the 53 fixtures was reduced by 42 percent compared to the original 50. Does this project have to meet the Outdoor LPAs in §140.7?

Answer

No, the project does not have to meet the lighting power allowances in §140.7. Even though the number of fixtures is increased, the total wattage of the project is less than before so the connected lighting load has decreased, not increased. Since the overall connected load was reduced by 40 percent or more compared to the original luminaires, Exception to §141.0(b)2Liii applies and the new fixtures are not required to comply with the LPAs in §140.7.

6.5.2 Outdoor Lighting Alterations – Adding Outdoor Lighting to Existing Sites

In many cases, the general lighting for a site will be designed for a shopping center or a strip mall and stores or restaurants may be added later with additional lighting needs. In general, if one has a new outdoor lighting application (more doors, outdoor dining, retail sales) one can add the amount of lighting associated with the additional lighting allowances for specific applications contained in Table 140.7-B of the Energy Standards. If this amount of lighting allowance is not enough, one can either re-design the proposed lighting system or re-calculate the hardscape lighting allowances for the entire site to identify if savings somewhere else on site can be used to add light for this application.

Outdoor lighting power allowances are based upon a "layering" of specific application allowances on top of general hardscape allowances. The general hardscape allowance has three components: the initial wattage allowance (IWA) which is available once per site, the linear wattage allowance (LWA) which is available for the perimeter of the hardscape and the area wattage allowance (AWA) which is available for the field of the illuminated hardscape area. For an outdoor lighting alteration, the LWA shall be applied only to the perimeter of altered portions of the site hardscape. When the outdoor lighting is designed all at the same time, the outdoor lighting allowance is calculated as described in Section 6.4 of this chapter.

Example 6-47 Power Allowance for Additional Outdoor Dining (Inside Illuminated Area)

Question

A strip mall in Lighting Zone 3 with a common parking lot has its lighting system already designed and installed. A restaurant moves into one of the buildings and designates 400 ft² as outdoor dining. The outdoor dining area is within the illuminated area (5 mounting heights) of the pre-existing lighting. How is the allowable lighting calculated?

Answer

The allowable lighting power can be calculated in two ways:

Method 1

Calculate only the additional allowance layer for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B of the Energy Standards. In this case the allowance is 0.240 W/ft². Multiplying this allowance by 400 ft² yields 96 W.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Outdoor Dining	0.240 W/ft^2	400 ft^2	96 W
TOTAL POWER ALLOWANCE			96 W

Method 2

One could have the permit cover all of the site lighting including the outdoor dining area. (This second compliance path would provide a greater power allowance, but would require more work in the application process.) This only yields a higher allowance if the current lighting system serving hardscape areas for the rest of the site has less wattage than the calculated total site hardscape wattage allowance. Additional allowances would be possible if one upgraded to the current hardscape system for other parts of the site and reduced its wattage.

Example 6-48 Power Allowance for Additional Outdoor Dining (Outside Illuminated Area)

Question

A strip mall in Lighting Zone 3 with a common parking lot has the parking lot lighting system designed and installed. A restaurant moves into one of the buildings and designates 400 ft² as outdoor dining. The outdoor dining area is outside of the illuminated area of the pre-existing parking lot lighting. How is the allowable lighting calculated?

Answer

In addition to adding outdoor dining area, which is a specific application that is allowed more light, the illuminated general hardscape lighting area is also increasing in size by 400 ft². Adding illuminated hardscape area results in increased general hardscape area wattage allowances (AWA) and increased linear wattage allowances (LWA) but it does NOT add an additional initial wattage allowance (IWA) because only one initial wattage allowance is allowed per site. The allowable lighting power can be calculated in two ways:

Method 1

Calculate the general hardscape area wattage allowances (AWA) and the increase to the general hardscape linear wattage allowances (LWA) and the additional allowance layer for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B of the Standards. As discussed above, it is not permissible to also claim the general hardscape initial wattage allowance (IWA) as this is calculated only once per site. The linear wattage allowance applies only to the new perimeter length, which is not adjacent to previously illuminated area that is part of the site.

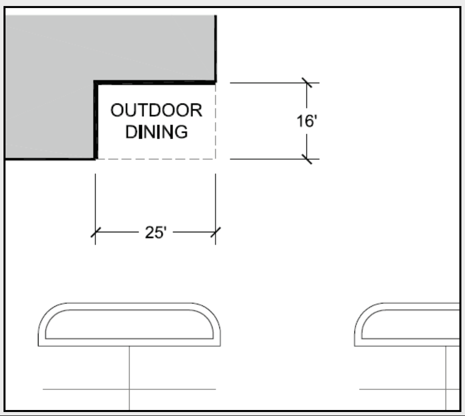
As shown in the figure below, the perimeter length is 41 ft (25 ft + 16 ft). In LZ 3 the AWA is 0.040 W/ft² and the LWA is 0.35 W/ft. The additional allowance for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B is 0.240 W/ft². Thus for a perimeter length of 41 ft and an area of 400 ft², the total lighting wattage allowance is:

Hardscape LWA of 0.35 W/ft x 41 ft = 14 W

Hardscape AWA of 0.040 W/ft² x 400 ft² = 16 W

Specific Allowance Outdoor Dining 0.240 W/ft². x 400 ft² = 96 W

Total allowance = 126 W



Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Outdoor Dining	0.240 W/ft2	400 ft^2	96 W
Area	0.040 W/ft2	400 ft^2	16 W
Perimeter	0.35 W/LF	41 ft	14 W
TOTAL POWER ALLOWANCE			126 W

Method 2

One could have the permit cover all of the site lighting including the outdoor dining area. (This second compliance path would provide a greater power allowance, but would require more work in the application process.) This only yields a higher allowance if the current lighting system serving hardscape areas for the rest of the site has less wattage than the calculated total site hardscape wattage allowance.

Example 6-49 Power Allowance for Outdoor Dining

Question

A restaurant moves in next door to a strip mall and the strip mall has its own parking lot lighting. Although the restaurant is adjacent to the outdoor parking lot lighting of the mall, this restaurant has its own parking lot and is not on the same site as the mall. The restaurant is adding 400 ft² of outdoor dining. How is the outdoor lighting allowance calculated?

Answer

This restaurant is on its own site and is able to take the all of the general hardscape lighting power allowances (IWA, LWA, and AWA). This lighting system is also allowed to take the additional specific application wattage allowance for the 400 ft² of outdoor dining.

6.6 Outdoor Lighting Compliance Documents

This section contains information about required outdoor lighting documentation, including outdoor lighting plan check documents, Installation Certificate, and Certificate of Acceptance.

6.6.1 Overview

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the compliance documentations needed for compliance with the nonresidential outdoor lighting requirements of the Energy Standards.

This section is addressed to the person preparing construction and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance with the Energy Standards.

6.6.2 Compliance Documentation and Numbering Scheme

Nonresidential outdoor lighting Certificate of Compliance documents are listed below:

- NRCC-LTO-01-E; Certificate of Compliance: Outdoor Lighting
- NRCC-LTO-02-E; Certificate of Compliance: Outdoor Lighting Controls
- NRCC-LTO-03-E; Certificate of Compliance: Outdoor Lighting Power Allowances

Nonresidential outdoor lighting Certificate of Installation documents are listed below:

- NRCI-LTO-01-E; Certificate of Installation; Outdoor Lighting
- NRCI-LTO-02-E; Certificate of Installation: Energy Management Control System or Lighting Control System

Nonresidential outdoor lighting Certificate of Acceptance document:

- NRCA-LTO-02-A: Certificate of Acceptance, Outdoor Lighting Controls

The Energy Standards use the following numbering scheme for the nonresidential lighting compliance documents:

NRCC	Nonresidential Certificate of Compliance
NRCI	Nonresidential Certificate of Installation
NRCA	Nonresidential Certificate of Acceptance
LTI	Lighting, Indoor
LTO	Lighting, Outdoor
LTS	Lighting, Sign
01	The first set of compliance documents in this sequence
E	Primarily used by enforcement authority
A	Primarily used by acceptance tester

The paper prescriptive compliance documents have a limited number of rows per section for entering data. Some designs may need fewer rows, and some designs may need additional rows. If additional rows are required for a particular design, then multiple copies of that page may be used.

6.6.3 Certificate of Installation Documents

The Certificates of Installation are primarily used to declare that what was installed matches the plans on the Certificates of Compliance. The Certificate is signed by a person with an approved license.

A copy of the completed signed and dated Installation Certificate must be posted at the building site for review by the enforcement agency in conjunction with requests for final inspection for the building. See Section 2.2.3 for more information about the Installation Certificate.

6.6.4 Certificate of Acceptance

Before an occupancy permit is granted for a new building or space, or a new lighting system serving a building, space, or site is operated for normal use, all outdoor lighting controls serving the site shall be certified as meeting the Acceptance Requirements for Code Compliance. A Certificate of Acceptance shall be submitted to the enforcement agency under Administrative Regulations §10-103(a).

The acceptance requirements that apply to outdoor lighting controls include the following:

- Certifies plans, specifications, installation certificates, and operating and maintenance information meet the requirements of the Energy Standards.
- Certified that outdoor lighting controls meet the applicable requirements of §110.9 and §130.2.

Acceptance testing must be conducted, and a Certificate of Acceptance must be completed and submitted before the enforcement agency can issue the certificate of occupancy. The procedures for performing the acceptance tests are documented in Reference Nonresidential Joint Appendix NA7.8. See the following chapters for more information about outdoor lighting control acceptance requirements.

- Chapter 2 - Compliance and Enforcement
- Chapter 13 - Acceptance Requirements
- Reference Nonresidential Joint Appendix NA7.8, Outdoor Lighting Controls Acceptance Test

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7. Sign Lighting

7.1 Overview

This chapter discusses the requirements for sign lighting in the Building Energy Efficiency Standards (Energy Standards). They set minimum control requirements, maximum allowable power levels and minimum efficacy requirements. They conserve energy, reduce peak electric demand, and are technically feasible and cost effective.

The Energy Standards do not allow trade-offs between sign lighting power allowances and other end uses including outdoor lighting, indoor lighting, HVAC, building envelope, or water heating.

7.1.1 History and Background

Regulations for lighting have been in effect in California since 1977. However, until the adoption of the 2005 Energy Standards, they only addressed indoor lighting, inside spaces that were air conditioned or heated, and outdoor lighting that was connected to a lighting panel when the lighting panel was located inside a conditioned building. The 2005 Standards expanded the scope to include most outdoor lighting applications, indoor and outdoor sign lighting applications, and indoor lighting applications in unconditioned buildings. After the 2005 Standards, the Sign Lighting Standards were updated with the 2008 Energy Standards.

The 2016 Sign Lighting Standards evolved over a three year period through a dynamic and open public process. The Energy Commission solicited ideas, proposals, and comments from a number of interested parties. The Energy Commission encouraged all interested persons to participate in a series of public hearings and workshops through which it gathered information and viewed presentations on energy efficiency possibilities from a variety of perspectives. A consulting team was hired, which included a number of nationally recognized lighting experts to assist in the development of the Energy Standards.

7.1.2 Scope and Application

The 2016 Sign Lighting Standards address both indoor and outdoor signs. The Energy Standards include control requirements for all illuminated signs (§130.3) and establish lighting power requirements for internally illuminated and externally illuminated signs (§140.8).

The Sign Lighting Standards are the same throughout the state and are independent of outdoor Lighting Zones.

The Sign Lighting Standards are the same in conditioned and unconditioned spaces.

7.1.3 Summary of Requirements

§110.9, §130.0, §130.3, §140.8 and §141.0

7.1.3.1 **Mandatory Measures**

The Energy Standards require that indoor and outdoor sign lighting be automatically controlled.

In brief, the mandatory sign lighting requirements include:

- Automatic shutoff controls.
- Dimming controls.
- Demand responsive controls for electronic message centers.

All lighting controls must meet the requirements of §110.9 as applicable. Most lighting controls must be certified by the manufacturer to the Energy Commission and are required to be listed in the Energy Commission directories. Additionally, self-contained lighting control devices are now regulated by the Title 20 Appliance Efficiency Regulations. More details on the mandatory measures are provided in Section 7.2 of this chapter.

7.1.3.2 **Sign Lighting Power**

Sign Lighting Standards apply to both indoor and outdoor signs and contain two different prescriptive compliance options:

1. The watt per square foot approach specifies a maximum lighting power that can be installed, expressed in W/ft² of sign area.
2. The specific technology approach specifies that the signs shall be illuminated with efficient lighting sources (electronic ballasts, high efficacy lamps, efficient power supplies and efficient transformers).

More details on the sign lighting power requirements are provided in Section 7.3 of this chapter.

7.2 Mandatory Measures

The mandatory features and devices are required for all sign lighting projects as applicable. The mandatory measures require that lighting controls are certified by the manufacturers to the Energy Commission, and that sign lighting systems have controls for efficient operation. Mandatory features also set requirements for how lighting systems are classified according to technology, and how to calculate installed wattage.

Mandatory measures for signs are specified in §110.9, §130.0, and §130.3. These mandatory measures for signs are similar to the mandatory measures for the other indoor and outdoor lighting Standards.

Note: For projects that involve building plans, the person with overall responsibility must ensure that the Mandatory Measures that apply to the project are listed on the plans. The format of the list is left to the discretion of the Principal Designer.

7.2.1 Certification Requirements for Lighting Control Devices

§110.0(b)

The Energy Standards limit the installation of lighting control devices and systems as follows:

A. For all lighting control devices that are within the scope of Section 1601 of the Appliance Efficiency Regulations, installation shall be limited to those that have been certified to the Energy Commission by the manufacturer, pursuant to the provisions of Title 20 California Code of Regulations, §1606.

B. For lighting control devices required to be certified to the Energy Commission that are not regulated by Title 20, installation shall be limited to those certified by the manufacturer in a declaration that is executed under penalty of perjury under the laws of the State of California that states:

- All the information provided pursuant to the certification is true, complete, accurate and in compliance with all applicable requirements of the Energy Standards.
- The equipment, product, or device was tested using the applicable test method specified in the Energy Standards.

See Chapter 5 of this manual for additional information about the requirements for lighting control devices and lighting control systems.

7.2.2 Title 20 Certification Requirements for Lighting Control Devices

§110.1

Any lighting control device regulated by the Appliance Efficiency Regulations, Title 20 California Code of Regulations, §1601 et seq., may be installed only if the appliance fully complies with Section 1608(a) of those regulations. The Title 20 regulations apply to appliances that are sold or offered for sale in California, except those sold wholesale in California for final retail sale outside the state and those designed and sold exclusively for use in recreational vehicles or other mobile equipment.

Once a device is certified, it will be listed in the Directory of Lighting Control Devices, which is available here: http://www.energy.ca.gov/appliances/database/

Call the Energy Hotline at 1-800-772-3300 to obtain more information.

Self-contained lighting control devices are defined by the Energy Standards, and by the Appliance Efficiency Regulations, as unitary lighting control modules that require no additional components to be fully functional lighting controls.

Self-contained lighting controls required for compliance with the Energy Standards are required to be certified by the manufacturer according to the Title 20 Appliance Efficiency Regulations. The following are types of lighting controls that are required to be certified to the Energy Commission in accordance with Title 20:

A. **Time-Switch Lighting Controls**

- Automatic Time-Switch Controls
- Astronomical Time-Switch Controls
- Multi-Level Astronomical Time-Switch Controls
- Outdoor Astronomical Time-Switch Controls

B. **Daylighting Controls**

- Automatic Daylight Controls
- Photo Controls

C. **Dimmers**

D. **Occupant Sensing Controls**

- Occupant Sensors
- Motion Sensors
- Vacancy Sensors

7.2.2.1 Demand Responsive Lighting Controls

The following information is for Electronic Message Centers when they are required to have demand responsive controls according to §130.3(a)3.

A. Definitions - The following are definitions from §100.1:

1. DEMAND RESPONSE is short-term changes in electricity usage by end-use customers, from their normal consumption patterns. Demand response may be in response to:
   - Changes in the price of electricity; or
   - Participation in programs or services designed to modify electricity use.
     - In response to wholesale market prices.
     - When system reliability is jeopardized.
2. DEMAND RESPONSE PERIOD is a period of time during which electricity loads are modified in response to a demand response signal.
3. DEMAND RESPONSE SIGNAL is a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator, to a customer, indicating a price or a request to modify electricity consumption, for a limited time period.
4. DEMAND RESPONSIVE CONTROL is a kind of control that is capable of receiving and automatically responding to a demand response signal.

B. Demand Responsive Controls and Equipment.

§130.5(e)

Demand responsive controls and equipment shall be capable of receiving and automatically responding to at least one standards-based messaging protocol which enables demand response after receiving a demand response signal.

7.2.3 Using Lighting Control Systems to Comply with the Energy Standards

Lighting Control Systems are defined by the Energy Standards as requiring two or more components to be installed in the building to provide all of the functionality required to make up a fully functional and compliant lighting control. Compliant lighting control systems are those that meet all of the applicable requirements.

A. A lighting control system shall comply with all requirements listed below, and all components of the system considered together as installed shall meet all applicable requirements for the lighting control application for which they are installed:

- Before a lighting control system, including an energy management control system (EMCS), can be recognized for compliance with the lighting control requirements in the Energy Standards, the person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit an Installation Certificate (§130.4(b) 1 and 2).
- If any of the requirements in the Installation Certificate fail the installation tests, the Lighting Control System (or EMCS) shall not be recognized for compliance with the Energy Standards.
- If there are indicator lights that are integral to a lighting control system, they shall consume no more than one watt of power per indicator light (§110.9(a)5).
- A lighting control system shall meet all of the requirements in the Title 20 Appliance Efficiency Regulations for each of the identical self-contained lighting control devices that it is installed to function as.

B. The following are the Title 20 requirements for lighting control devices that lighting control systems installed to comply with the Energy Standards must meet:

1. **Automatic Time-Switch Controls**. Commercial automatic time-switch controls labeled for use with lighting shall:
    - Have program backup capabilities that prevent the loss of the device’s schedule for at least 7 days, and the device’s date and time for at least 72 hours if power is interrupted.
    - Be capable of providing manual override to each connected load and shall resume normally scheduled operation after manual override is initiated within 2 hours for each connected load.
    - Incorporate an automatic holiday shutoff feature that turns off all connected loads for at least 24 hours and then resumes normally scheduled operation.
2. **Astronomical Time-Switch Controls**. Astronomical time-switch controls shall:
    - Meet the requirements of an automatic time-switch control.
    - Have sunrise and sunset prediction accuracy within plus-or-minus 15 minutes and timekeeping accuracy within 5 minutes per year.
    - Be capable of displaying date, current time, sunrise time, sunset time, and switching times for each step during programming.
    - Have an automatic daylight savings time adjustment.
    - Have the ability to independently offset the on and off for each channel by at least 99 minutes before and after sunrise or sunset.

3. **Automatic Daylight Controls.** Automatic daylight controls shall:
   - Be capable of reducing the power consumption in response to measured daylight either directly or by sending and receiving signals.
   - Comply with Section 1605.3(I)(2)(F) of Title 20 if the day lighting control is capable of directly dimming lamps.
   - Automatically return to its most recent time delay settings within 60 minutes when put in calibration mode.
   - Have a set point control that easily distinguishes settings to within 10 percent of full scale adjustment.
   - Have a light sensor that has a linear response within 5 percent accuracy over the range of illuminance measured by the light sensor.
   - Have a light sensor that is physically separated from where the calibration adjustments are made, or is capable of being calibrated in a manner that the person initiating the calibration is remote from the sensor during calibration to avoid influencing calibration accuracy.
   - Comply with Section 1605.3(I)(2)(E) of Title 20 if the device contains a photo control component.
4. **Photo Controls**. Photo controls shall not have a mechanical device that permits disabling of the control.
5. **Dimmer Controls.** All dimmer controls shall:
   - Be capable of reducing power consumption by a minimum of 65 percent.
   - Include an off position which produces a zero lumen output.
   - Not consume more than 1 watt per lighting dimmer switch leg when in the off position.
   - Dimmer controls that can directly control lamps shall provide electrical outputs to lamps for reduced flicker operation through the dimming range so that the light output has an amplitude modulation of less than 30 percent for frequencies less than 200 Hz without causing premature lamp failure.
   - Wall box dimmers and associated switches designed for use in three way circuits shall be capable of turning lights off, and to the level set by the dimmer if the lights are off.

7.2.4 Determining Sign Lighting Installed Power

§130.0(c)

The lighting wattage of signs shall be determined in accordance with the applicable provisions of §130.0(c). Note that the installed wattage of sign lighting is not considered when using the Alternate Lighting Source compliance option in §140.8(b). See Section 7.4 of this chapter for more information about sign lighting energy requirements.

Following are the most common sign lighting requirements for determining luminaire classification and power:

1. The wattage of luminaires with line voltage lamp holders not containing permanently installed ballasts or transformers shall be the maximum relamping rated wattage of the luminaire, and for recessed luminaires with line-voltage medium screw base sockets, wattage shall not be less than 50 watts per socket.
2. Screw-based adaptors shall not be used to convert an incandescent luminaire to any type of non-incandescent technology. Screw-based adaptors, including screw-base adaptors classified as permanent by the manufacturer, shall not be recognized for compliance with the Energy Standards.
3. The wattage of luminaires with permanently installed or remotely installed ballasts or drivers shall be the operating input wattage of the rated lamp/ballast combination published in ballast manufacturer's catalogs based on independent testing lab reports as specified by UL 1598.
4. The wattage of luminaires and lighting systems with permanently installed or remotely installed transformers shall be the rated wattage of the lamp/transformer combination.
5. The wattage of light emitting diode (LED) luminaires, and LED light engines shall be the maximum rated input wattage of the system when tested in accordance with IES LM-79-08.
    - An LED lamp, integrated or non-integrated type in accordance with the definition in ANSI/IES RP-16-2010, shall not be classified as a LED lighting system for compliance with Part 6. LED modules having screw-bases including, but not limited to, screw based pig-tails, screw-based sockets, or screw-based adaptors shall not be recognized as a LED lighting system for compliance with Part 6.

The rules for determining lighting wattage are discussed in greater detail in Chapter 5 of this manual.

7.3 Required Sign Lighting Controls

7.3.1 Indoor Sign Lighting Controls

§130.3(a)1

All indoor sign lighting is required to be controlled with an automatic time-switch control or astronomical time-switch control.

These controls are required to meet the minimum requirements in §110.9. See Section 7.2 of this chapter for information on the minimum requirements for lighting controls.

7.3.2 Outdoor Sign Lighting Controls

§130.3(a)2

Outdoor sign lighting is required to meet the following requirements as applicable:

A. All outdoor sign lighting is required to be controlled with one of the following two options:
    1. A photocontrol in addition to an automatic time-switch control.
    2. An astronomical time-switch control.

These controls are required to meet the minimum requirements in §110.9. See Section 7.2 of this chapter for information on the minimum requirements for lighting controls.

EXCEPTION to §130.3(a)2A: Lighting for outdoor signs in tunnels, and for signs in large permanently covered outdoor areas that are intended to be continuously lit for 24 hours per day and 365 days per year.

B. All outdoor sign lighting that is ON both day and night shall be controlled with a dimmer that provides the ability to automatically reduce sign lighting power by a minimum of 65 percent during nighttime hours.

Signs that are illuminated at night and for more than 1 hour during daylight hours shall be considered ON both day and night.

EXCEPTION to §130.3(a)2B: Lighting for outdoor signs in tunnels and large covered areas that are intended to be illuminated both day and night.

7.3.3 Demand Responsive Lighting Controls for Electronic Message Centers

An Electronic Message Center (EMC) that has a new connected lighting power load of greater than 15 kW shall have a control installed that is capable of reducing the lighting power by a minimum of 30 percent when receiving a demand response signal.

EXCEPTION to §130.3(a)3: Lighting for an EMC that is not permitted by a health or life safety statute, ordinance, or regulation to be reduced by 30 percent is not required to be capable of reducing the lighting power when receiving a demand response signal.

Example 7-1

Question

Because the Energy Standards require sign lighting to be controlled by an automatic time switch control, will a sign on the inside of a mall be required to be turned off during the day?

Answer

No, the signs will not be required to be turned off during the day. The automatic time switch control will allow the owner/occupant to program their signs to be automatically turned on and off in accordance with their particular needs.

7.4 Sign Lighting Energy Requirements

7.4.1 Scope of Sign Lighting Energy Requirements

The Sign Lighting Energy Requirements apply to all internally illuminated signs, externally illuminated signs, unfiltered light emitting diodes (LEDs), and unfiltered neon, whether used indoors or outdoors. Examples include cabinet signs, channel letters, lightboxes, backlit signs, illuminated billboards, and electronic message centers.

7.4.2 Applications Excluded from Sign Lighting Energy Requirements

§140.8

The following sign lighting applications are not required to comply with the sign lighting energy requirements:

1. Unfiltered incandescent lamps that are not part of an electronic message center (EMC), an internally illuminated sign, or an externally illuminated sign.

   This exception applies only to portions of a sign that are unfiltered incandescent lamps. An unfiltered sign is defined in the Energy Standards as a sign where the viewer perceives the light source directly as the message, without any colored filter between the viewer and the light source. Although internally illuminated signs are mentioned in this exception, it is only those portions of a hybrid sign consisting of unfiltered incandescent lamps that are excluded from the sign lighting energy requirements

2. Exit signs.

   However, exit signs are required to meet the requirements of the Appliance Efficiency Regulations.

3. Traffic Signs.

   However, traffic signs are required to meet the requirements of the Appliance Efficiency Regulations.

7.4.3 Lighting Energy Compliance Options

There are two options available for complying with the sign lighting energy requirements:

Option 1 - Maximum Allowed Lighting Power (Watts per square foot Approach).

Option 2 - List of Compliant Alternate Lighting Sources.

7.4.3.1 Option 1: Maximum Allowed Lighting Power

§140.8(a)

This option for complying with the sign lighting energy requirements is also known as the watts per square foot approach. When using this option, there are rules in the Energy Standards for classifying the lighting technology used, and for determining sign lighting power. Additional information about Sign Lighting Installed Wattage is in Section 7.2.4 of this chapter.

The maximum allowed lighting power is different for internally illuminated signs and for externally illuminated signs, as follows:

A. For internally illuminated signs, the maximum allowed lighting power shall not exceed the product of the illuminated sign area and 12 watts per square foot of the illuminated sign area (see Figures 7-1 and 7-2 below). For double-faced signs, only the area of a single face shall be used to determine the allowed lighting power (see Figure 7-3 below).

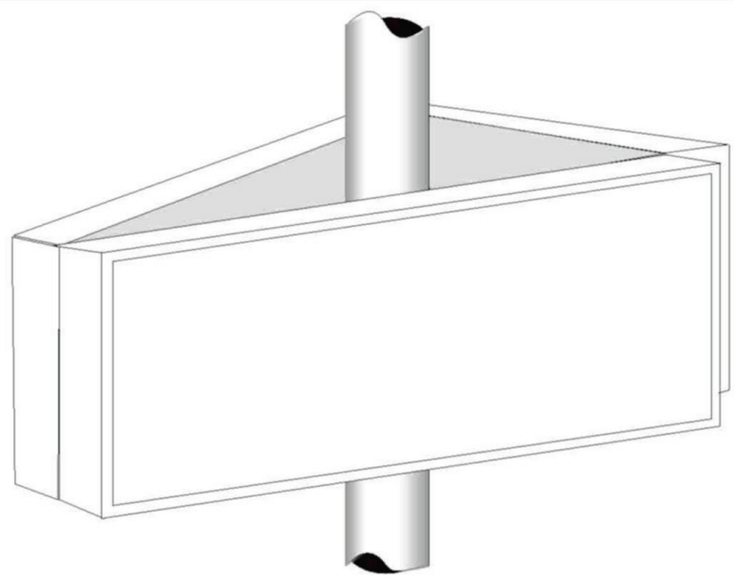
   Internally illuminated signs are defined in the Energy Standards as signs that are illuminated by a light source that is contained inside a sign where the message area is luminous, including cabinet signs and channel letter signs.

B. For externally illuminated signs, the maximum allowed lighting power shall not exceed the product of the illuminated sign area and 2.3 watts per square foot of the illuminated sign area. Only areas of an externally lighted sign that are illuminated without obstruction or interference, by one or more luminaires, shall be used.

Externally illuminated signs are defined in the Energy Standards as any sign or a billboard that is lit by a light source that is external to the sign directed towards and shining on the face of the sign.

C. Lighting for unfiltered light emitting diodes (LEDs) and unfiltered neon are not required to comply with the maximum allowed lighting power option, but are required to comply with the alternate lighting source compliance method.

Figure 7-1: Multi-faced Sign



Include area from each face when separated by an opaque divider

Figure 7-2: Single-faced Internally Illuminated Cabinet Sign with Fluorescent Lamps and Translucent Face

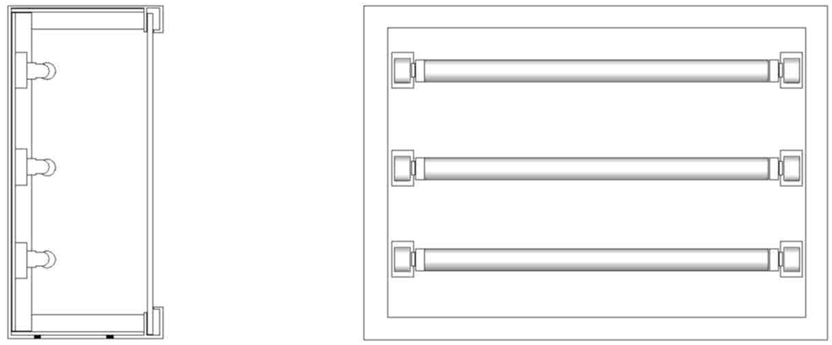
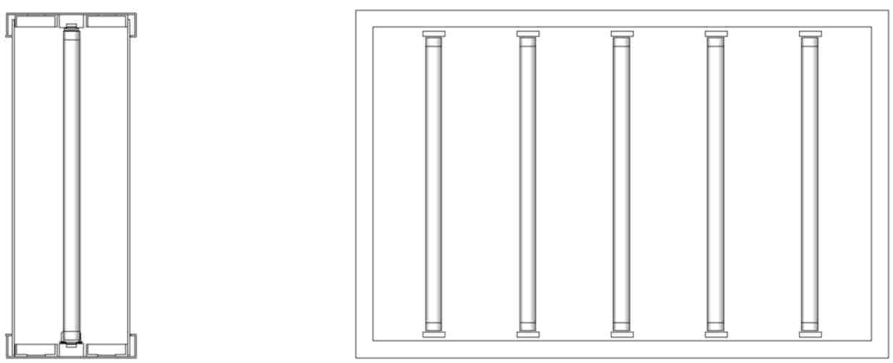


Figure 7-3: Double-faced Internally Illuminated Cabinet Sign with Fluorescent Lamps and Translucent Faces



7.4.3.2 Option 2 – List of Compliant Alternate Lighting Sources

§140.8(b)

This option for complying with the sign lighting energy requirements is to use only lighting technologies on the list of compliant lighting sources. When using this option for compliance, there is no requirement to calculate lighting power.

A. **List of Compliant Alternate Lighting Sources** - A sign complies if it is equipped only with one or more of the following light sources:

1. High pressure sodium lamps.
2. Metal halide lamps that are:
   - Pulse start or ceramic served by a ballast that has a minimum efficiency of 88 percent or greater, or

- Pulse start that are 320 watts or smaller, are not 250 watts or 175 watts, and are served by a ballast that has a minimum efficiency of 80 percent.

  Ballast efficiency is the measured output wattage to the lamp divided by the measured operating input wattage when tested according to ANSI C82.6-2005.

3. Neon or cold cathode lamps with transformer or power supply efficiency greater than or equal to one of the following:
   - A minimum efficiency of 75 percent when the transformer or power supply rated output current is less than 50 mA.
   - A minimum efficiency of 68 percent when the transformer or power supply rated output current is 50 mA or greater.

     The ratio of the output wattage to the input wattage is at 100 percent tubing load.
4. Fluorescent lighting systems meeting one of the following requirements:
   - Use only lamps with a minimum color rendering index (CRI) of 80.
   - Use only electronic ballasts with a fundamental output frequency not less than 20 kHz.
5. Light emitting diodes (LEDs) with a power supply having an efficiency of 80 percent or greater.

   EXCEPTION to §140.8(b)5: Instead of requiring a power supply with an efficiency of 80 percent or greater, single voltage external power supplies that are designed to convert 120 volt AC input into lower voltage DC or AC output, and which have a nameplate output power less than or equal to 250 watts, shall be certified to comply with the applicable requirements for external power supplies in the Appliance Efficiency Regulations
6. Compact fluorescent lamps that do not contain a medium screw base sockets (E24/E26).

7.4.4 Hybrid Signs

A sign may consist of multiple components, where some components are regulated, and some components are not regulated. For example, a single sign structure may have a regulated internally illuminated cabinet, plus regulated externally illuminated letters which are attached to a brick pedestal, plus unregulated unfiltered incandescent “chaser” lamps forming an illuminated arrow. For example, Figure 7-4 shows an arrow which is not part of an electronic message center (EMC) using unfiltered incandescent lamps.

If the lamps are not covered by a lens, then only the control regulations (§130.3) apply to the sign. This type of unfiltered incandescent sign is not regulated by §140.8.

Figure 7-4: Unfiltered Incandescent Sign

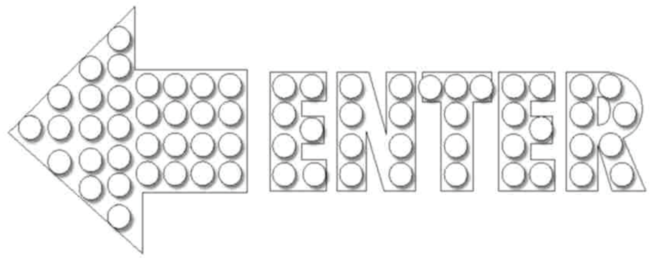
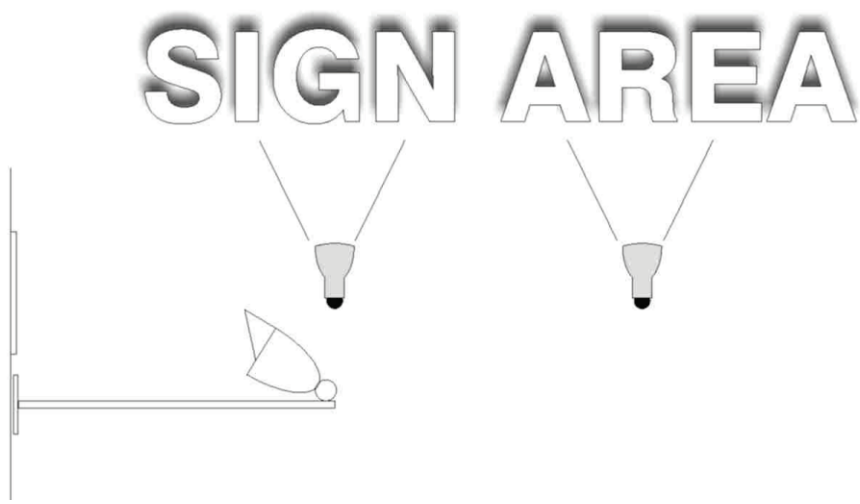


Figure 7-5 shows an externally illuminated sign using flood lighting, which is regulated by the Energy Standards. The power (wattage) used for these lighting components must comply with the watts per square foot approach, or use only lighting technologies approved according to §140.8(b).

Figure 7-5: Externally Illuminated Sign Using Flood Lighting



Example 7-2

Question

Can I use neon or cold cathode lights in my sign and comply with the Energy Standards under Option 2 (Compliant Alternate Lighting Sources)?

Answer

Yes, neon and cold cathode lights are allowed under the alternate light source compliance option, provided that the transformers or power supplies have an efficiency of 75 percent or greater for output currents less than 50 mA and 68 percent or greater for output currents 50 mA or greater.

Example 7-3

Question

Do signs inside a theater lobby or other indoor environments need to comply with the sign requirements?

Answer

Yes, all internally and externally illuminated signs whether indoor or outdoor must comply with either the Maximum Allowed Lighting Power or Compliant Alternate Lighting Sources compliance option.

Example 7-4

Question

My sign is equipped with both hardwired compact fluorescent lamps and incandescent lamps. Can my sign comply under the Compliant Alternate Lighting Sources option?

Answer

No. Since your sign is not exclusively equipped with energy efficient technologies allowed under the Compliant Alternate Lighting Sources option (incandescent sources are not allowed), it therefore must comply under the Maximum Allowed Lighting Power compliance option. Your other option is to replace the incandescent sources with an energy efficient option that is permitted under the specific technology approach, such as compliant LED, pulse start or ceramic metal halide, or fluorescent.

Example 7-5

Question

My sign has three parts: an internally illuminated panel sign equipped with electronic ballasts, and two unfiltered 30 mA neon signs on top and bottom of the panel sign displaying an illuminated arrow and lettering having power supplies with an efficiency of 76 percent. Does this sign comply with the Compliant Alternate Lighting Sources option?

Answer

Yes, as long as the internally illuminated panel portion is illuminated with a compliant technology. This sign is essentially made up of three different signs; an internally illuminated panel sign and two unfiltered neon signs with efficient power supplies that comply with the Compliant Alternate Lighting Sources option. Therefore the entire sign complies with the Energy Standards as long as the separate parts comply.

Example 7-6

Question

Are signs required to comply with Outdoor Lighting Zone requirements?

Answer

No. Outdoor Lighting Zones do not apply in any way to signs. The Sign Lighting Standards are the same throughout the state; they do not vary with Outdoor Lighting Zones.

7.5 Additions and Alterations

§141.0(a)1, §141.0(b)2H

All new signs, regardless of whether they are installed in conjunction with an indoor or outdoor addition, or an alteration to a building or outdoor lighting system, must meet the requirements for newly installed equipment in §110.9, §130.0, §130.3 and §140.8.

7.5.1 Sign Alterations

§141.0(b)2M

Existing indoor and outdoor internally illuminated and externally illuminated signs that are altered as specified by §141.0(b)2M are required to meet the requirements of §140.8. Altered components of existing indoor and outdoor internally and externally illuminated signs must also meet the requirements of §130.0.

These requirements (either Maximum Allowed or Compliant Alternate Lighting Sources) are triggered by alterations to existing internally or externally illuminated signs when any of the following occurs as result of the alteration, as specified in §141.0(b)2M:

- The connected lighting power is increased.
- More than 50 percent of the ballasts are replaced and rewired.
- The sign is relocated to a different location on the same site or on a different site.

The requirements for signs are not triggered when just the lamps are replaced, the sign face is replaced or the ballasts are replaced (without rewiring).

Sign ballast rewiring that triggers the alterations requirements generally involves rewiring from parallel to series or vice versa, or when a ballast(s) is relocated within the same sign requiring relocating the wires. This does not include routine in-place ballast replacements.

Example 7-7

Question

We are replacing 60 percent of the ballasts in a sign. Must we replace the remaining ballasts in the sign in order to comply with the Energy Standards?

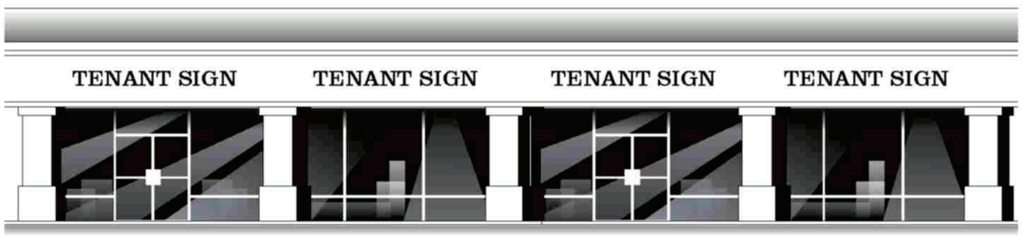
Answer

It depends. If more than 50 percent of the ballasts are being replaced, and the replacement involves rewiring the ballasts, then the requirements of §140.8 apply to the whole sign. If more than 50 percent of the ballasts are being replaced during regular maintenance, and the ballasts are not being rewired, then the sign is not required to meet the Energy Standards requirements. However, when existing wiring will allow the direct replacement of a magnetic ballast with a high efficiency high frequency electronic fluorescent ballast, even though the Energy Standards do not require the electronic ballast, the sign owner is encouraged to replace the magnetic ballasts with an electronic ballast.

Example 7-8

Question

I have a strip mall full of signs. Must I immediately bring all of these signs into compliance even if I'm not going to alter them?



Answer

No, only those signs in which at least 50 percent of the ballasts are replaced and rewired, or those signs that are moved to a new location (on the same property or different property) must comply with the sign lighting energy requirements. Also, all newly installed signs must also comply with the sign lighting energy requirements.

7.6 Energy Compliance Documentation

7.6.1 Overview

This section describes the required documentation for compliance with the sign lighting energy requirements. At the time the sign permit application is submitted to the enforcement agency, the applicant must also submit the sign lighting energy compliance documentation.

The sign lighting energy compliance documentation is located in Appendix A of this manual and are designated as "NRCC-LTS".

Sign lighting compliance documents for compliance with the 2016 Energy Standards will be required starting on January 1, 2017.

See Chapter 2 of this manual for additional information about the data registry.

7.6.2 Sign Lighting Inspection

The electrical building inspection process for sign lighting energy compliance is carried out along with the other building inspections performed by the enforcement agency. The inspector relies upon the plans (when required for signs) and upon the NRCC-LTS-01-E Certificate of Compliance documentations.

7.6.3 Two Combined SLTG Documents

There are two compliance documents required for compliance with the sign lighting Standards:

1. Certificate of Compliance.
2. Installation Certificate.

For convenience of the sign lighting industry, these two documents have been combined into one multi-use compliance document with the sign lighting Standards. See Section 5.10.6 of this manual for information about the Certificate of Compliance, and Section 5.10.7 for information about the Installation Certificate.

7.6.4 Explanation of Compliance Document Numbering System

The following is an explanation of the Compliance Document Numbering System:

NRCC	Nonresidential (NR) Certificate of Compliance (CC)
LTS	Lighting (LT), Signs (S)
01	The sequential number of sets. For signs, there is only one set of documents
E	Enforcement Document. Developed primarily for the Enforcement Agency

7.6.5 Lighting Control Systems Installation Certificate

There is another installation certificate required when a lighting control system or an EMCS is installed to comply with the sign lighting control requirements. They are as follows:

1. The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the construction or installation of features, materials, components, or manufactured devices shall sign and submit the Installation Certificate.
2. If any of the requirements in the Installation Certificate fail the installation tests, that application shall not be recognized for compliance with the Energy Standards.

For lighting control systems and EMCS, there are Certificates of Installation for nonresidential indoor lighting (LTI), and for nonresidential outdoor lighting (LTO). However there is no similar document for sign lighting (LTS). Therefore, if sign lighting is controlled by a lighting control system or by an EMCS, the NRCI-LTI-02-E or the NRCI-LTO-02-E, shall be used as a Certificate of Installation submitted for signs.

Table of Contents

8. Electrical Power Distribution

This chapter describes the Title 24, Part 6, Building Energy Efficiency Standards (Energy Standards) requirements in §130.5 for energy efficiency measures used for electrical power distribution systems of nonresidential, high-rise residential, and hotel/motel occupancy buildings.

8.1 Overview

8.1.1 Summary of Changes in 2016

The changes for electrical power distribution systems in the 2016 update to the Energy Standards include:

- New definitions for Electrical Metering, Service, Service Equipment, Equipment, Plug Load, and Low Voltage Dry-Type Distribution Transformer are added to §100.1.
- New mandatory requirement for low-voltage dry-type distribution transformers as specified in new §110.11.
- Clarifications for the Service Metering requirement of §130.5(a).
- Clarifications for the Separation of Electrical Circuits requirement of §130.5(b) to allow flexible approaches for providing the ability to measure the separate loads of the building.
- Clarifications for the Voltage Drop requirement of §130.5(c) to allow a 5% overall voltage drop rather than split requirements for feeders and branch circuits.
- Clarifications for the Circuit and Receptacle Control for 120-Volt Receptacles requirement of §130.5(d).
- Relocation of the Energy Management of Control System (EMCS) requirement to §130.0.
- Clarification for alteration requirements for electrical power distribution systems in §141.0(b)2P.

8.1.2 Scope and Applications

The following requirements for electrical power distribution systems apply to all non-residential, high-rise residential, and hotel/motel buildings. All the requirements in §130.5 of Electrical Power Distribution Systems are mandatory, and therefore are not included in the energy budget for the performance compliance approach.

A. New Construction and Additions

The requirements of §130.5 apply to all newly constructed buildings and additions.

B. Alterations

The requirements for alterations to electrical power distribution systems are covered in §141.0(b)2P of the Energy Standards.

For alterations with entirely new or complete replacements of electrical power distribution systems, the requirements of §130.5(a) through (d) must be met; §130.5(e), relating to demand response controls, is not required for alterations.

For alterations of feeders and branch circuits, which includes adding, modifying, or replacing either feeders or branch circuits, the voltage drop requirements of §130.5(c) must be met. See Section 8.6 of this manual and §141.0(b)2P of the Energy Standards for details of the requirements for alterations to electrical power distribution systems.

C. Acceptance Testing, Commissioning, and Installation Certificates

The requirements of §130.5 and §141.0(b)2P are not subject to acceptance testing or commissioning requirements under the Energy Standards.

See Section 8.8 for more information on compliance and installation documentation.

8.2 Service Electrical Metering Requirements

§130.5(a)

Projects are required to provide an electrical metering system that measures the instantaneous power usage and the cumulative electrical energy being used by the building. For metering systems that are not provided by the serving utility company, requirements apply based on the service kVA as specified in Table 130.5-A and stated below:

- For electrical service rated at any kVA, the meter must be able to indicate instantaneous kW demand and KWh for a user-defined period.
- For electrical service rated more than 250 kVA, the meter must be able to measure historical peak demand in kilowatts.
- For electrical services rated more than 1000kVA, the meter must also be able to measure historical peak demand in kilowatts and kWh per rate period.

Utility-provided meters that indicate instantaneous kW demand and kWh for a utility-defined period are sufficient to meet this Section's requirements, and are not required to measure historical peak demand. If the utility-provided meter does not indicate instantaneous kW demand and kWh for a utility-defined period, then a separate meter must also be installed that provides the full functionality required by § 130.5(a) and Table 130.5-A of the Energy Standards.

Each electrical service or feeder must have a permanently installed metering system that complies with these requirements. The terms "service" and "feeder" are both defined in regulation, the first in the Energy Standards and the latter in the California Electrical Code, as follows:

- "Service is the conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premise served", as defined in §100.1 of the Energy Standards.
- "Feeder - All circuit conductors between the service equipment, the source of a separately derived system, or other power supply source and the final branch-circuit overcurrent device", as defined in Article 100 of the 2016 California Electrical Code.

This is not a requirement to install meters both at the service and at each feeder. Rather, this requirement simply prevents unmetered service or feeder circuits from being installed within a building by requiring that a meter be installed at either the service level or, if not at the service level, at the feeder level, whatever is appropriate for the installation in question.

Example 8-1

Question:

There is one service to my building and the building fire pump is installed with the power connection tapped to the same service.

Do I need to install another meter for the fire pump, in addition to the service metering already provided by the local utility?

Answer:

No, it is not mandatory to provide another meter for the fire pump if it is using a service that is already connected to a meter. If it is not using a service that is already metered, then a separate meter may be required.

Example 8-2

Question:

There are two services provided by the local utility company to my building.

Do both services require meeting the service electrical metering requirement?

Answer:

Yes, it is mandatory to have one service electrical metering for each service in accordance with §130.5(a).

Example 8-3

Question:

I own a nonresidential building with four tenant units. The building has one service and there are four sets of meters and disconnect switches, one set for each tenant unit. The meters are provided by a local utility company, they provide the required kW and kWh information, and I intend to utilize the meters to meet the §130.5(a) requirement. Is this allowed by the regulations?

Answer:

Yes, metering each feeder instead of metering the service is allowed, and is intended to address situations where one service feeds to multiple tenants.

Example 8-4

Question:

I have a building with multiple tenant spaces and each individual tenant space is served by separate and individual feeders. There is an individual meter for each feeder. Do I have to install a separate meter at the building service to fulfill the §130.5(a) requirement?

Answer:

No, it is not necessary to install a separate metering system for the service if a) there are individual meters for all the feeders and b) all the meters meet the metering functionality requirements, based on the building service size, in Table 130.5-A of the Energy Standards.

8.3 Separation of Electrical Circuits for Electrical Energy Monitoring

§130.5(b)

The purpose of the Separation of Electrical Circuits requirement is to set up a backbone for monitoring the specific contributions of separate loads to the overall energy use of the building. By designing the electrical distribution system with separation of electrical loads in mind, energy monitoring can be readily setup and implemented without significant physical changes to the electrical installations. The end goal is to be able to monitor the electrical energy usage of each load type specified in Table 130.5-B of the Energy Standards: building owners, facility management, and others can make use of such energy usage information to better understand how much energy has been used by each building system during a certain period of time. Further analysis of such energy information can help facilitate energy efficiency measures to improve building energy performance for building owners and operators.

Example 8-5

Question:

My new nonresidential building is served by a single panel with a service less than 50 kVA.

What is the required separation of electrical circuit requirement for this building?

Answer:

Since the service is smaller than 50kVA, renewable power sources and electric vehicle charging stations shall be separated from other electrical load types and from each other, in accordance with the “Electrical Service rated 50kVA or less” column of Table 130.5-B and §130.5(b).

The renewable power source shall be separated by group. All electric charging vehicle loads can be in aggregate.

If there are no renewable power sources or electric vehicle charging stations in this building, it is not required to separate the electrical circuits for electrical energy monitoring purposes.

8.3.1 Compliance Methods

Electrical power distribution systems shall be designed so that measurement devices can monitor the electrical energy usage of load types according to Table 130.5-B. However, for each separate load type, up to 10 percent of the connected load may be of any other load type. Also, note that the 2016 requirements have moved to become more flexible than the 2013 requirements: where the 2013 Energy Standards prescribed specific methods for ensuring separation of electrical loads, the 2016 Energy Standards allow any approach that provides the ability to measure the separate loads of the building.

The separation of electrical circuit requirement of §130.5(b), may be accomplished by any of the following example methods:

A. **Method 1:** Switchboards, motor control centers, or panelboards loads can be disaggregated for each load type, allowing their independent energy measurement. This method must permit permanent measurement and determination of actual interval demand load value for each disaggregated load in the system.

   This is a straightforward approach, as each distribution equipment serves a single load type. Summation of the kVA measurement of the distribution equipment in accordance with the respective load type can result in the energy usage of each load type. This method is simple and straightforward in terms of the effort required in compiling the measurement data.

B. **Method 2:** Switchboards, motor control centers, or panelboards may supply other distribution equipment with their loads disaggregated for each load type. The measured interval demand load for each piece of distribution equipment must be able to be added or subtracted from other distribution equipment supplying them. This method must permit permanent measurement and determination of actual interval demand load value for each disaggregated load in the system.

   This method allows distribution equipment to serve more than one load type while still allowing the separate energy use of each load to be determined. More effort may be required in terms of treatment of the measured energy data in order to obtain the energy usage of each load type.

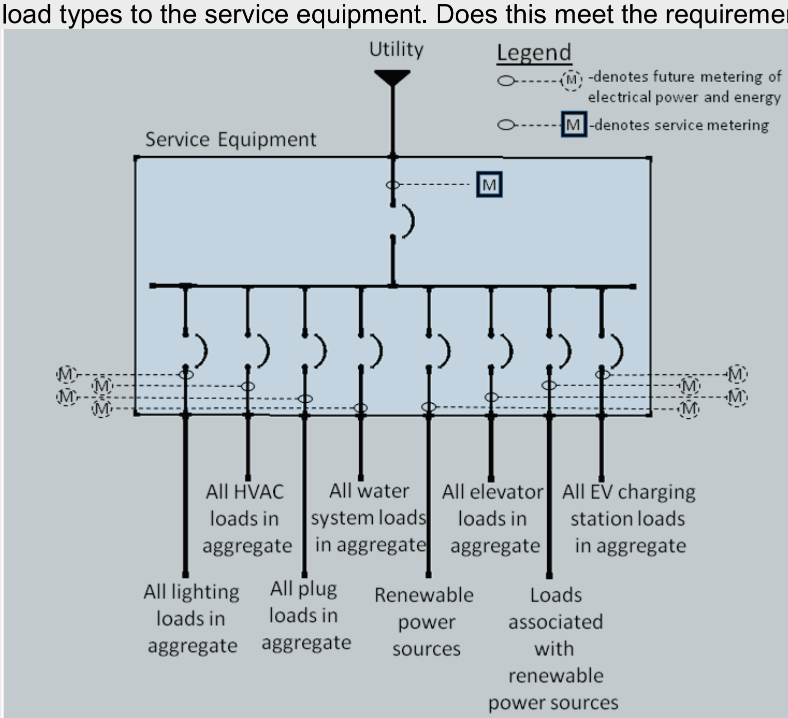
C. **Method 3:** Buildings for which a complete metering and measurement system is provided that at a minimum, measures and reports the loads by type.

   This method allows a complete metering system to be used to meet the requirements of §130.5(b), provided that at a minimum measures and reports the loads called for in Table 130.5-B of the Energy Standards. Such an installation goes beyond the requirement of the Energy Standards as it meters and measures the power and energy usage of each load type.

Example 8-6

Question:

I am working on a new building project of a nonresidential building with a service less than 250 kVA but more than 50kVA. Following is the proposed concept layout of separation of circuits for connecting different load types to the service equipment. Does this meet the requirements of the Energy Standards?



Answer:

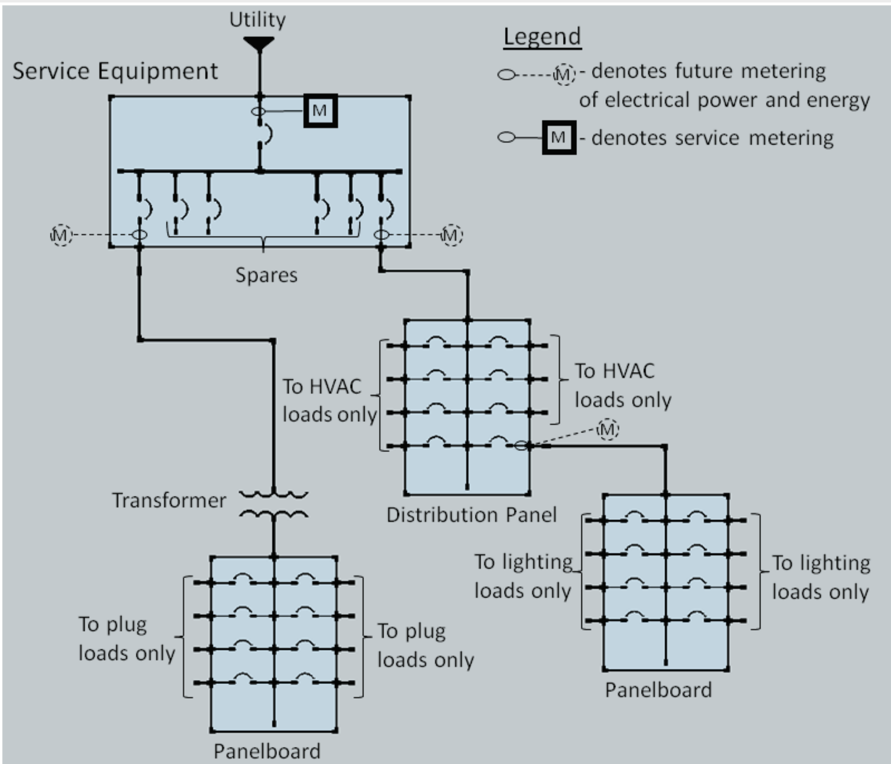
The proposed design meets the separation of electrical circuit requirement of §130.5(b) as there are separations of circuits for connecting different load types to the service equipment. There should be provisions including physical spaces for future setup of measurement devices for energy monitoring at each electrical installation location.

Example 8-7

Question:

Part of my proposed design is to use a distribution panel serving HVAC loads, with the panel also feeding a lighting panelboard. There is another, separate panelboard serving plug loads only.

Does this design meet the requirements of the Energy Standards?



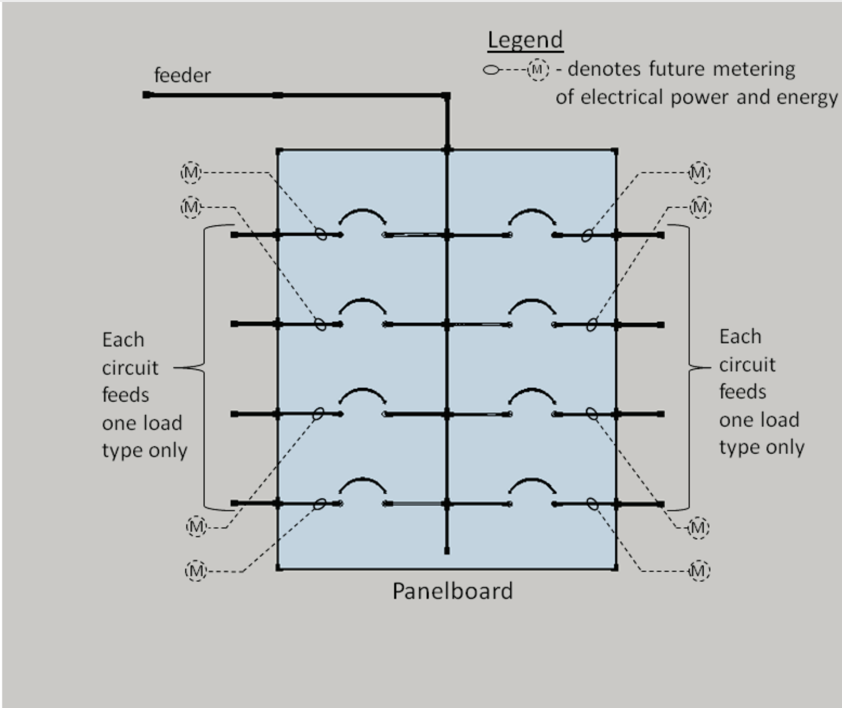
Answer:

The proposed design meets the separation of electrical circuit requirement of §130.5(b) as each load type of load in the building can be accounted for by addition and subtraction of the measured energy data as indicated in Method 2.

Example 8-8

Question:

Can a panelboard with provisions allowing branch circuit energy monitoring be used to meet the separation of electrical circuits requirement? Each circuit would serve no more than one load type. Does this design meet the requirements of the Energy Standards?



Answer:

The proposed design allows each load type to be separately measured for energy usage, and therefore meets the requirements of §130.5(b).

8.3.2 Application Considerations

The Energy Standards envision the use of conventional panelboards, motor control centers, panelboards, and other standard wiring methods for meeting the requirement to separate electrical loads. The requirement may also achieved by a well-planned wiring approach, such as connecting all HVAC units to a single feeder from the service using a combination of through feeds and taps. The regulations are intentionally written to specify the “what” without prescribing the “how”, and thus provide as much flexibility as possible.

In a “typical” small building with a service less than 50kVA, separation of electrical loads is not required at all. Slightly larger buildings are able to comply by using carefully laid-out panelboards.

In larger buildings, separate risers for lighting, receptacles/equipment, and HVAC are allowed to be used for meeting the separation of electrical circuits requirement. Single large loads or groups of loads, such as an elevator machine room, or a commercial kitchen, may be connected to panelboards or motor control centers served by a dedicated feeder and the electrical power and energy of the entire group of loads can be measured by metering the feeder.

For services rated more than 250 kVA, lighting and plug loads are required to be separated “*by floor, type or area*”. So, in a single-story building, all the lighting loads could be fed from a single panel, and all the plug loads could be fed from another panel (or, alternatively, both types of loads could be fed from one panel with a split bus).

In a multi-story building, a simple way to comply would be to install a separate lighting panel and a separate plug-load panel for each floor of the building. However, it would be equally acceptable (and may be more useful) to divide the load according to which area of the building it serves (office, warehouse, corridors etc.), or by the type of light fixture (metal halide vs. fluorescent, dimmable vs. fixed output, etc.). So, for instance, both the first and second floor office lights could be fed from the same panel, while the warehouse lights would be fed from a second panel. Dividing the load by area or by type instead of by floor is more likely to yield useful information when the loads are analyzed in an energy audit. All of these approaches are available to designers and installers, and are acceptable methods of complying with the Energy Standards.

8.4 Voltage Drop Requirements

§130.5(c)

The voltage drop requirement, which has been clarified and revised in the 2016 update of the Energy Standards, is as follows:

Voltage drop of feeder + Voltage drop of branch circuit ≤ 5%

The maximum combined voltage drop on both installed feeder conductors and branch circuit conductors to the farthest connected load or outlet must not exceed five percent. This is the steady-state voltage drop under normal load conditions.

The voltage drop requirements of the following California Electrical Code (CEC) sections are exempted from the requirement of §130.5(c):

1. Article 647, Sensitive Electronic Equipment, Section 647.4 Wiring Methods.
2. Article 695, Fire Pump, Section 695.6, Power Wiring.
3. Article 695, Fire Pump, Section 695.7, Voltage Drop.

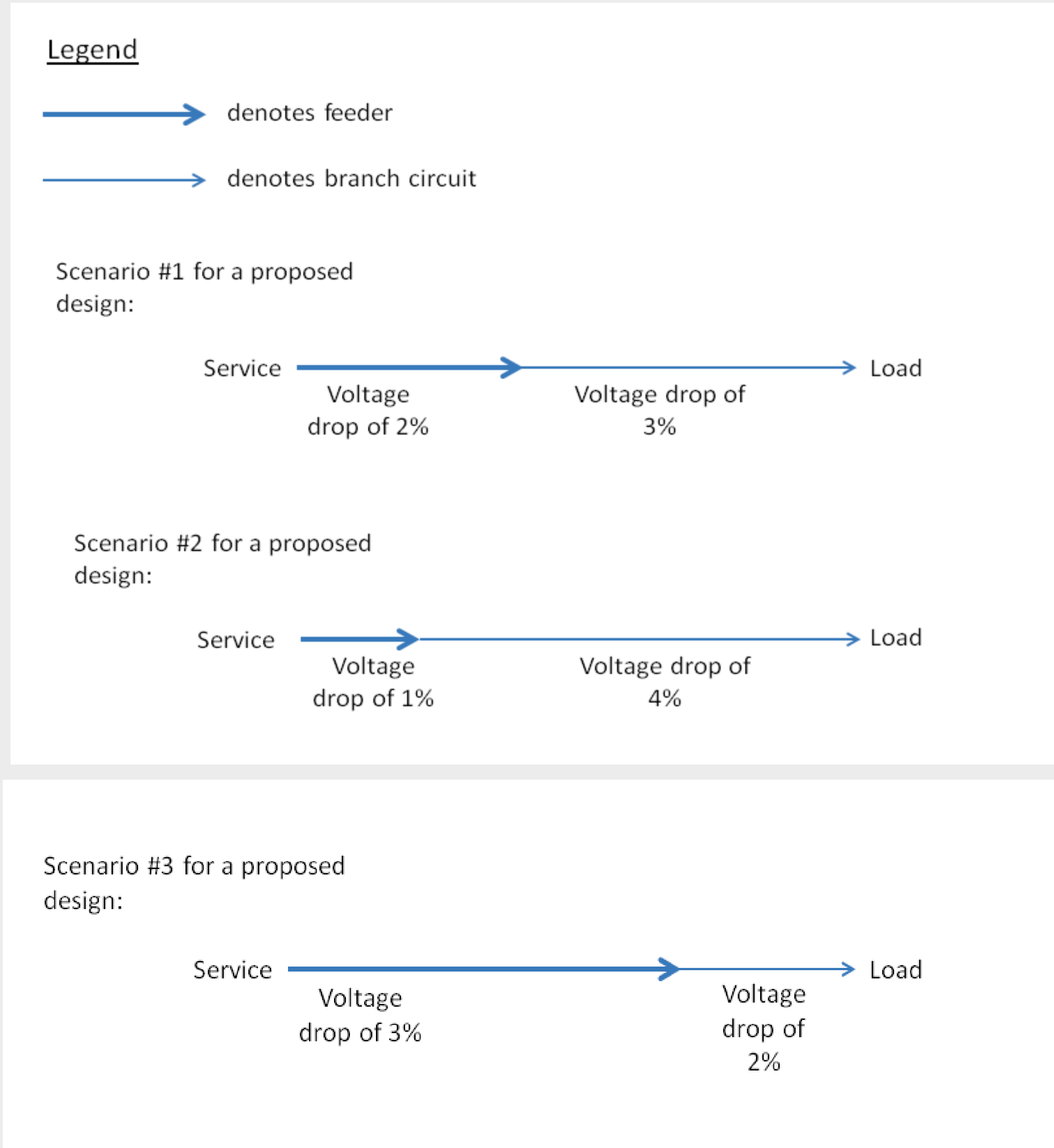
However, the informational note about voltage drop in Article 210, Branch Circuits, of the CEC is not part of the requirements of California Electrical Code, nor is the informational note about voltage drop in Article 215, Feeders.

Voltage drop represents energy lost as heat in the electrical conductors. The loss is called "I^2R" (I-squared-R) loss, meaning that the loss is directly proportional to both the conductor resistance and to the current squared. Because of I^2R loss, it is advantageous to distribute utilization power at the highest practical voltage to reduce the amount of current into each load.

Voltage drop losses are cumulative, so voltage drop in feeders and voltage drop in branch circuits add up to the load at the end of the branch circuit. Excessive voltage drop in the feeder conductors and branch circuit conductors can result in inefficient operation of electrical equipment.

Example 8-9

Do the following proposed designs meet the voltage drop requirement of §130.5(c)?



Answer:

All of the above proposed design scenarios meet the voltage drop requirement of §130.5(c), as the combined voltage drop of the feeder and the branch circuit does not exceed 5 percent.

8.5 Circuit Controls and Controlled Receptacles for 120-Volt Receptacles

§130.5(d)

Office plug loads are the loads with the largest power density (W/ft^2) in most office buildings. The Energy Standards require both controlled and uncontrolled 120-volt receptacles in lobbies, conference rooms, kitchen areas in office spaces, copy rooms, and hotel/motel guest rooms. The requirement of the Energy Standards for controlled receptacles allows these plug loads to be turned off when the space is unoccupied, resulting in energy savings.

In the 2016 update to the Energy Standards the requirements for circuit and receptacle level controls for 120-Volt receptacles have been clarified. Either approach can be used, provided that controlled receptacles are marked to differentiate them from uncontrolled receptacles.

Methods for meeting requirements include:

1. For any uncontrolled outlets, ensure that at least one controlled outlet is located within 6 feet of the uncontrolled outlet.
2. Using split wired receptacles that provide at least one controlled outlet.

The requirement does not mean that one controlled outlet must exist for each uncontrolled outlet.

In open office areas where receptacles are installed in modular furniture, at least one controlled receptacle must be provided for each workstation. Alternatively, any controlled circuits already built into the building system can be used to meet the requirement.

The controlled receptacles must be automatically switched off when the space is not occupied. An automatic time switch with manual override may also be used for meeting the requirement.

Plug-in strips and other plug-in devices CANNOT be used to meet this requirement. A hardwired power strip controlled by an occupant sensing control may be used for meeting the requirement, but a plug-in power strip cannot be used: the intent is for the controlled receptacles to be permanently available, not removable.

There are important exceptions where an uncontrolled outlet is not required to be matched with a controlled outlet. They include:

1. Receptacles in kitchen areas that are specifically for refrigerators and water dispensers.
2. Receptacles specifically for clocks (note that the receptacle must be mounted 6’ or more above the floor to meet this exception).
3. Receptacles in copy rooms specifically for <u>network</u> copiers, fax machines, A/V and data equipment other than personal computers.
4. Receptacles on circuits rated more than 20 amperes.
5. Receptacles connected to an uninterruptible power supply (UPS) that are intended to be in continuous use, 24 hours per day/365 days per year and are marked to differentiate the receptacles from other uncontrolled receptacles or circuits.

8.5.1 Application Considerations

The following are example approaches:

A. Private Offices, Conference Rooms, and other Spaces with Periodic Occupancy

Occupancy sensing controls that are part of a lighting control system may be used to control both general lighting and receptacles. For example, a common occupancy sensor can control general lighting and receptacles, with auxiliary relays connected to the lights and the controlled receptacles to provide the needed functionality.

B. Lobbies, Break Rooms, and other Spaces with Frequent Occupancy During Business Hours

Astronomic time-switch controls, with either a vacancy sensor or switch override, can switch the controlled receptacles. Programmable relay panels or controllable breakers can be used, or, for simpler projects, a combination of vacancy sensors and programmable time switches can accomplish the same task. Note that if vacancy sensing is used, controls will likely need to be room-by-room or space-by-space, but if time-of-day with manual override is used, whole circuits may be controlled together.

C. Open Office Areas

Receptacles in open office areas can be controlled by the building's automatic shut-off system or by controls integrated into the modular furniture systems. If the building provides controls, relays or controllable breakers with manual override switches for zones within an open office space may be used. A system using vacancy sensors might also be considered if sensors can be added as needed to address partitioning of the workstations (thus ensuring proper operation). Systems contained within workstation systems are an acceptable alternative provided that they are hardwired as part of the workstation wiring system.

D. Networked Control Systems and Building Automation Systems

Most advanced lighting and energy control systems can be easily designed to accommodate receptacle controls.

The Energy Standards recognize that certain office appliances, such as computers, need to be powered continuously during office hours to provide uninterrupted services. These would be connected to the uncontrolled receptacles. Other appliances, such as task lamps, personal fans and heaters, and monitors, do not need to be powered without the presence of occupants. These controllable loads would be plugged into the controlled receptacles to ensure they are automatically shut off and to prevent any unnecessary standby power draw. Ultimately, providing controlled receptacles allows building occupants to determine which appliances to be controlled.

In open office areas, it is advisable to implement vacancy sensor control at each workstation or cubicle to maximize the opportunities of shutoff controls. Modular office system furniture is usually equipped with more than one internal electrical circuit, and some of these circuits can be dedicated for controllable plug loads.

8.5.2 Demand Response

§130.5(e)

The demand response (DR) requirements of §130.5(e) specify that any controls or equipment for DR shall be capable of receiving and automatically responding to at least one standards-based messaging protocol. This ensures that any DR equipment that is installed is able to receive and respond appropriately to demand response signals.

To explain, the Energy Standards provide definitions for both "Demand Response Control" and "Demand Response Signal":

- Demand Responsive Control is defined in §100.1 of the Energy Standards as "a kind of control that is capable of receiving and automatically responding to a demand response signal".
- Demand Response Signal is defined in §100.1 as "a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator, to a customer, indicating a price or a request to modify electricity consumption, for a limited time period."

Demand response controls can be effectively employed in many circumstances and for several different building systems. The Energy Standards require demand response controls for lighting systems in two circumstances, per the requirements of the following sections:

- §130.1(e) requires the lighting in buildings over 10,000 square feet, excluding spaces with a lighting power density of 0.5 W/ft^2 or less, to be capable of automatically reducing lighting power in response to a Demand Responsive Signal; so that the total lighting power of non-excluded spaces can be lowered by a minimum of 15 percent below the total installed lighting power when a Demand Response Signal is received.
- §130.3(a)3 requires electronic message centers over 15 kW to have a control installed that is capable of reducing the lighting power by a minimum of 30 percent when receiving a Demand Response Signal.

The above requirements do NOT mean that a building has to respond to real time price signals; the requirement is to ensure that the building is DR ready (i.e., *capable* of responding to a DR signal). The decision to employ demand response is up to the building owner or manager, the utility company, and/or a governing authority. A building that is capable of responding to a request to reduce load when grid reliability is threatened (for instance with black outs) is sufficient to meet the requirements of the Energy Standards.

Demand response is becoming increasingly important as it permits the temporary reduction of electric load on the grid when extreme weather or supply constraints cause electricity demand to come close to the grid's maximum supply capabilities. It is also seen as a means to allow building operators to control electricity costs, as future prices are expected to change constantly as a function of overall system demand.

Because mandatory demand response ("DR") is relatively new, standards and systems are still being developed and evolving. For this reason, §130.5(e) does not specify a particular protocol or system, but rather lets it be specified by the utility company or other authority.

8.6 Additions and Alterations

Additions are like newly constructed buildings and all requirements of §130.5 apply to additions. For additions, the discussions in the previous sections of this chapter apply.

For alterations, the 2016 update of the Energy Standards included several edits to clarify the requirements that apply to alterations of electrical power distribution systems. A summary of these clarifications follows:

1. **Service Electrical Metering -** New or replacement electrical service equipment shall meet the requirements of §130.5(a). Alterations that do not install new service equipment or replace existing service equipment are not held to these requirements.

   Note that this requirement applies only to the service and does not apply to new or replaced feeders.

2. **Separation of Electrical Circuits for Electrical Energy Monitoring -** For entirely new or complete replacement of electrical power distribution systems, the entire system shall meet the applicable requirements of §130.5(b). Alterations that do not install an entirely new power distribution system, or completely replace an existing power distribution system, are not held to these requirements.
3. **Voltage Drop -** Alterations of feeders and branch circuits that include any addition, modification, or replacement of both feeders and branch circuits must meet the requirements of §130.5(c). Alterations that do not include both the feeder and branch circuit are not held to these requirements. For example, if a branch circuit is replaced but the feeder to the panel board is not touched, the feeder and branch circuit would not need to meet the 5 percent maximum voltage drop requirement.

   Note that the same exceptions for voltage drop permitted by the California Electric Code apply for alterations.
4. **Circuit Controls for 120 - Volt Receptacles and Controlled Receptacles -** For entirely new or complete replacement of electrical power distribution systems, the entire system shall meet the applicable requirements of §130.5(d).

Example 8-10

Question:

I have an existing building with multiple tenant spaces and each individual tenant space is served by separate and individual feeders. I am breaking up one large tenant space into two smaller ones. I plan to reuse the existing feeder and also to add a new feeder. Is it mandatory to provide a meter for the new feeder?

Answer:

No, this requirement is limited to new or replacement electrical service equipment, and does not apply to feeders. For alterations involving only new or replacement feeders, there is no requirement to install a meter for the newly added or replaced feeder.

Example 8-11

Question:

Does the language “entirely new or complete replacement” in §141.0(b)2Pii and iv refer to the entire building or just the altered areas of the building?

Answer:

This language applies to the electrical power distribution system within the building and therefore effectively refers to the entire building. A modification of only part of the electrical power distribution system does not trigger the requirement. For example, the scope of work for a tenant improvement project or for finishing an undeveloped space does not typically involve installing or replacing the entirety of the electrical power distribution system, and therefore separation of electrical circuits would not typically be required.

8.7 Equipment Requirements - Electrical Power Distribution Systems

The Energy Standards specify in §110.11 that low-voltage dry-type distribution transformers may be installed only if the manufacturer has certified model information to the Commission as required by the Title 20 Appliance Efficiency Regulations. In addition, §110.1 specifies that appliances regulated by the Title 20 Appliance Efficiency Regulations may be installed only if the appliance fully complies with those regulations, and both medium-voltage dry-type and liquid immersed transformers are included in the Appliance Efficiency Regulations.

Products that are successfully certified as complying with Title 20 are listed in the Appliance Efficiency Database along with their efficiency.

This means that builders, building design team engineers, or owners who wish to install a distribution transformer will generally need to check the Appliance Efficiency Database to confirm that the model they are selecting has been certified by its manufacturer as required by law. A link to the Database is below:

https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx

The following types of transformers are exempt from certification requirements, and are not required to be listed in the Database:

1. autotransformers;
2. drive (isolation) transformers;
3. grounding transformers;
4. machine-tool (control) transformers;
5. nonventilated transformers;
6. rectifier transformers;
7. regulating transformers;
8. sealed transformers;
9. special-impedance transformers;
10. testing transformers;
11. transformers with tap range of 20 percent or more;
12. uninterruptible power supply transformers; and
13. welding transformers.

8.8 Electrical Power Distribution Systems Compliance Documents

8.8.1 Overview

This section describes the compliance documentation (compliance form(s)) recommended for compliance with the requirements of the 2016 Energy Standards in regards to electrical power distribution systems.

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation.

This section is addressed to the person preparing construction and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance with the Energy Standards.

8.8.2 Compliance Documentation and Numbering

List of compliance documents for electrical power distribution systems:

- NRCC-ELC-01-E, Certificate of Compliance, Electrical Power Distribution Systems.
- NRCI-ELC-01-E, Certificate of Installation, Electrical Power Distribution Systems.

There are no acceptance test forms for electrical power distribution systems because there are no required acceptance tests for electrical power distribution systems under the Energy Standards.

The following is the numbering scheme of the compliance documentation forms:

NRCC	Nonresidential Certificate of Compliance
NRCI	Nonresidential Certificate of Installation
ELC	Electrical power distribution systems
E	Primarily used by enforcement authority
A	Primarily used by acceptance tester

Use a single compliance form for each building for the permit application; this is to ensure clarity of information for the permit and plan check process.

The paper prescriptive compliance documents have a limited number of rows per section for entering data. If additional spaces are required on the form in order to include the required information about the project, multiple copies of that page(s) may be used.

Table of Contents

9. Solar Ready

§110.10

This chapter of the nonresidential compliance manual addresses nonresidential solar-ready buildings requirements. These requirements (§110.10 and §141.0) are mandatory for newly constructed nonresidential buildings, hotels/motels, and high-rise multifamily buildings. They are also mandatory for additions where the total roof area is increased by at least 2,000 square feet.

Surveys of the existing building stock indicate that fewer than 30 percent of existing nonresidential buildings have suitable locations to install solar photovoltaic (PV) or solar water-heating (SWH) systems. The intent of the solar-ready building requirements is to integrate design considerations that affect the feasibility of installing solar energy systems into the original building design. The Energy Standards require buildings to have an allocated solar zone that is free of obstructions and is not shaded. The solar zone would be a suitable location to install PV or SWH collection panels. In addition, the Energy Standards require that the construction documents depict a plan for connecting a PV and SWH system to the electrical or plumbing system of a building. For areas of the roof designated as a solar zone, the plans must also clearly indicate the structural design loads for roof dead load and roof live load.

There are no infrastructure related requirements in the Energy Standards. Equipment such as solar modules, inverters, and metering equipment do not need to be installed, nor does conduit, piping, or pre-installed mounting hardware. The building structural design does not need to be modified to accommodate the additional loads from solar equipment that might be installed at a future date.

9.1 Overview

The requirements for solar ready buildings are all mandatory. There are no prescriptive and performance compliance paths for solar-ready buildings. Since the provisions are mandatory, there are no tradeoffs allowed, and applicants must demonstrate compliance with each measure. Exceptions to the mandatory measures are described in Section 9.5.

This chapter is organized as follows:

9.2 Covered Occupancies

§110.10(a)

The nonresidential solar-ready requirements apply to:

- Hotel/motel occupancies with 10 stories or fewer.
- High-rise multifamily buildings with 10 stories or fewer.
- All other nonresidential buildings with three stories or fewer.

9.3 Solar Zone

§110.10(b)

The *solar zone* is an allocated space that is unshaded and free of obstructions. It serves as a suitable place that solar panels can be installed at a future date.

The solar zone can be located at any of the following locations:

- Roof of building.
- Overhang of the building.
- Roof of another structure located within 250 feet (75 meters) of the primary building.
- Overhang of another structure within 250 feet (75 meters) of the primary building.
- Covered parking installed with the building project.

Other structures include, but are not limited to, trellises, arbors, patio covers, carports, gazebos, and similar accessory structures.

The solar zone design must comply with the access, pathway, smoke ventilation, and spacing requirements as specified in Title 24, Part 9 or in any requirements adopted by a local jurisdiction. These additional requirements are located in other parts of Title 24, including Parts 2, 2.5, and 9 that are adopted by the California Building Standards Commission as part of the California Building Standards Code.

9.3.1 Minimum Area

§110.10(b)1

The minimum solar zone area should be calculated using one of the following methods. Method 1 is described in §110.10(b)1B and should be used if shading is not a concern. Method 2 is described in Exception 3 to §110.10(b)1B and should be used if the site has significant shading.

A. Method 1: Minimum Solar Zone Area Based on Total Roof Area

The solar zone must have a total area that is no less than 15 percent of the total roof area after subtracting any area of the roof that is covered by a skylight.

The total area of the solar zone may be composed of multiple subareas. No dimension of a subarea can be less than 5 feet. If the total roof area is equal to or less than 10,000 square feet (1,000 square meters), each subarea must be at least 80 square feet (8 square meters). If the total roof area is greater than 10,000 square feet (1,000 square meters), each subarea must be at least 160 square feet (16 square meters).

B. Method 2: Minimum Solar Zone Area Based on Potential Solar Zone

The minimum required solar zone area may be reduced if the building site is shaded by objects that are not part of the building itself and there is no unshaded area that could accommodate the full solar zone.

For the Energy Standards, the *potential solar zone* is defined as the total area on an eligible space (that is, roof, overhang, roof or overhang of a structure within 250 feet (75 meters) of the building, or on a covered parking structure installed with the building) that has annual solar access of 70 percent or greater. If the potential solar zone is smaller than the minimum solar zone area specified in §110.10(b)1B (15 percent of the roof area of the building, excluding any skylights), then the solar zone can be reduced to half the area of the potential solar zone. If the roof is shaded such that there is no potential solar zone area, then no solar zone is required

For the solar-ready requirements, *solar access* is the ratio of solar insolation, including shading from objects that are excluded from the building project, to the solar insolation without shading.

$$Solar\ Access = \frac{Solar\ Insolation\ Including\ Shading}{Solar\ Insolation\ Without\ Shading}$$

Objects that are excluded from the building project are objects that will not be moved or modified as part of the building project and include existing buildings, telephone poles, communication towers, trees, or other objects. Objects that are included in the building project are objects that will be constructed as part of the building project and include the building itself, HVAC equipment on the building, parking lot lights, and other similar objects. As mentioned, solar access does not take shading from objects that are included in the building project as the designer has control of the location of these potential obstructions.

Annual solar access is most easily determined using an instrument that is equipped with a camera with a fisheye lens and specialized imagery processing software. The instrument can calculate the annual solar access of any point on a proposed site based on the location of the building and information that is captured in the digital photograph. Since this type of instrument relies on photographs, their most appropriate use is to determine solar access on existing buildings. The instruments are not as useful in the design phase for newly constructed buildings when capturing a digital photograph from the proposed solar zone location is not feasible.

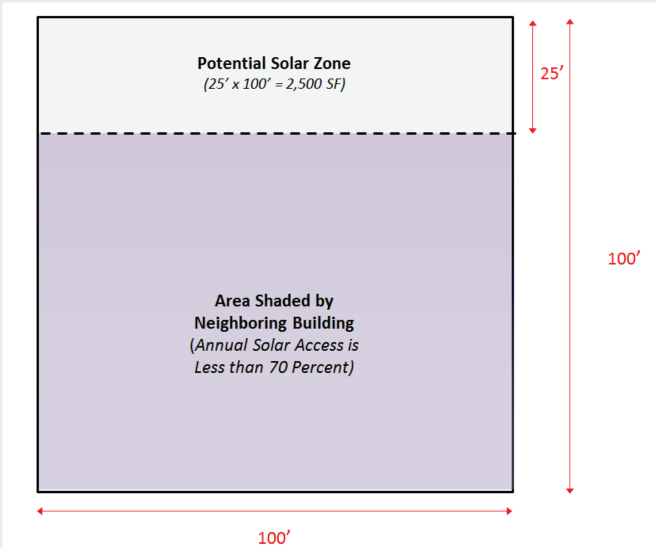
To determine the annual solar access during the design phase, designers will first evaluate whether there are any objects outside the building project that will shade the rooftop (or other prospective solar zone areas such as overhangs or parking shade structures). If an existing object is located to the north of all potential solar zones, the object will not shade the solar zone. Similarly, if the horizontal distance ("D") from the object to the solar zone is at least two times the height difference ("H") between the highest point of the object and the horizontal projection of the nearest point of the solar zone, then the object will not shade the solar zone. (See Figure 9.2.)

If objects outside the building project could shade the solar zone, annual solar access can be quantitatively determined using several computer-aided design (CAD) software packages that can import a CAD file of the building and perform a shading analysis, or several online solar quoting tools that make use of both overhead and orthogonal aerial imagery. Annual solar access can be qualitatively determined using several three-dimensional modeling programs.

Example 9-1

Question:

A roof with no skylights has an area of 10,000 ft^2 A neighboring building shades the roof, so 7,500 SF of the roof has less than 70 percent annual solar access. How big does the solar zone have to be?



Answer:

If the entire roof had an annual solar access of 70 percent or greater, the minimum solar zone would be 1,500 SF, or 15 percent of the total roof area (10,000 SF). However, the since the potential solar zone is 2,500 SF, the minimum solar zone can be reduced to half the area of the potential solar zone, or 1,250 SF.

Example 9-2

Question:

The total roof area is less than 10,000 SF, but the potential solar zone is less than the minimum size requirements for any subarea (less than 80 SF or narrower than 5 feet in the smallest dimension). Does the building still need to comply with the solar-ready requirements?

Answer:

No. If half the potential solar zone is less than 80 SF (if roof is less than or equal to 10,000 SF) or 160 SF (if roof is greater than 10,000 SF), then the building does not need to comply with the solar zone requirements.

Example 9-3

Question:

A portion of an office building will have six stories, and a portion of the building will have two stories. Is the new building subject to the solar zone requirements?

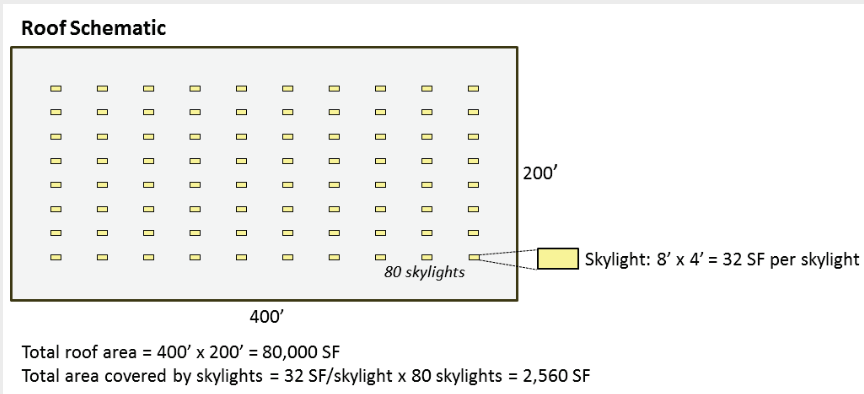
Answer:

No, the solar-ready requirements do not apply to office buildings that have more than three stories. The solar-ready requirements apply only to hotel/motel occupancies and high-rise multifamily buildings with 10 or fewer stories and all other nonresidential buildings with 3 or fewer stories.

Example 9-4

Question:

A new warehouse has a total roof area of 80,000 square feet (SF). Skylights cover 2,560 SF of the total roof area. What is the minimum solar zone area?



Answer:

The minimum solar zone area would be 11,616 SF

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{11,616\ SF} = 15\%\ x\ (80{,}000\ SF - 2{,}560\ SF)$$

Example 9-5

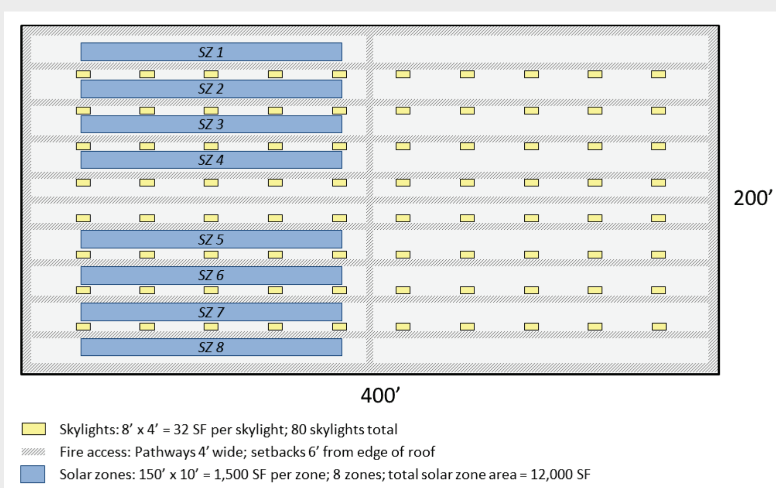
Question:

Does the solar zone have to be one contiguous area?

Answer:

No, the solar zone does not have to be one contiguous area. The total solar zone can be composed of multiple smaller areas. A subarea cannot be narrower than 5 feet in any dimension. If the total roof area is 10,000 SF or less, each subarea must be at least 80 SF. If the total roof area is greater than 10,000 SF, each subarea must be at least 160 SF.

The image below illustrates a solar zone layout that is composed of eight smaller subareas. The sum of all the smaller areas must equal the minimum total solar zone area. In this case, the sum of all areas must be at least 11,616 SF. The solar zones must also comply with fire code requirements, including, but not limited to, setback and pathway requirements. Current fire code requirements can be found in Ttile 24 Part 2 § 3111, Title 24 Part 2.5 §R331, and Title 24 Part 9 § 903.3.

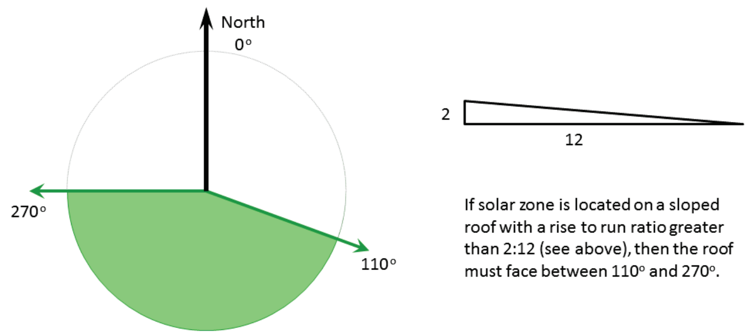


9.3.2 Orientation

§110.10(b)2

If the solar zone is located on a steep-sloped roofs (that is, the roof has ratio of rise to run of greater than 2:12), then the roof must be oriented between 110 degrees and 270 degrees of true north (not magnetic north). The orientation is important because it ensures a reasonable solar exposure if a solar energy system is installed in the future.

Figure 9-1: Orientation of Roof If Solar Zone Is Located on Steep-Sloped Roof



If a solar zone is located on a low-sloped roof (that is, the roof has a ratio of rise to run less than 2:12), the orientation requirements do not apply.

9.3.3 Shading

§110.10(b)3

Obstructions such as vents, chimneys, architectural features, or roof-mounted equipment cannot be located in the solar zone. This requirement is in place so the solar zone remains clear and open for the future installation of a solar energy system.

Any obstruction located on the roof or any other part of the building that projects above the solar zone must be located at a sufficient horizontal distance away from the solar zone such that the obstruction will not shade the solar zone. Equation 9-1 and Figure 9.2 describe the allowable distance between any obstruction and the solar zone. For each obstruction, the horizontal distance (“D”) from the obstruction to the solar zone has to be at least two times the height difference (“H”) between the highest point of the obstruction and the horizontal projection of the nearest point of the solar zone.

Equation 9-1: $D \geq 2H$

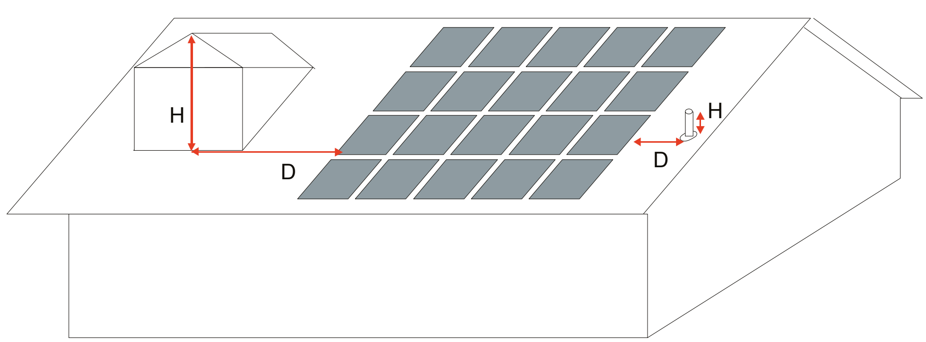


Figure 9-2: Schematic of Allowable Setback From Rooftop Obstructions

Source: California Energy Commission

Obstructions located north of all points of the solar zone are not subject to the horizontal distance requirements. Obstructions not located on the roof or another part of the building, such as landscaping or a neighboring building, are not subject to the horizontal distance requirements.

9.4 Construction Documents

Construction documents must include information about the as-designed structural loads and plans for interconnecting a PV and SWH system to the electrical or plumbing systems of the building.

9.4.1 Structural Design Loads

§110.10(b)4

The structural design load requirements apply if any portion of the solar zone is located on the roof of the building. For the areas of the roof designated as the solar zone, the structural design loads for roof dead load and roof live load shall be clearly indicated on the construction documents. This is required so that the structural loads are known if a solar energy system is installed in the future.

The Energy Standards do not require the roof on which the solar zone is located to be designed taking the loads of the solar equipment into consideration. In other words, there are no requirements for the inclusion of any collateral loads for future solar energy systems.

9.4.2 Interconnection Pathways

§110.10(c)

All buildings that must include a solar zone must also include a plan for connecting a PV or SWH system to the electrical or plumbing system of the building. The construction documents must indicate:

1. A location for inverters and metering equipment for future solar electric systems. The allocated space should be appropriately sized for a PV system that would cover the entire solar zone.
2. A pathway for routing conduit from the solar zone to the point of interconnection with the electrical service. There is no requirement to install conduit. Rather, the design drawings must show where the conduit would be installed if a system were installed at a future date.
3. A pathway for routing of plumbing from the solar zone to the water-heating system. There is no requirement to install piping.

9.4.3 Documentation

§110.10(d)

A copy of the construction documents that show the solar zone, the structural design loads, and the interconnection pathways must be provided to the building occupant. The building occupant must also receive a copy of compliance documents number NRCC-SRA-01-E and NRCC-SRA-02-E. Providing information to the building occupant is required so that the solar-ready information is available if the occupant decides to install a solar energy system in the future.

9.5 Exceptions

There are five exceptions to the solar zone area requirement described in §110.10(b)1B of the Energy Standards. Four of these five exceptions are described below. Although the language in the Standards implies that these four exceptions only apply to the solar zone requirements, the intent of the Energy Standards is for the exceptions to apply to the solar zone requirement, as well as the interconnection pathway requirements described in §110.10(c), and the documentation requirements described in §110.10(d).

1. **PV System Is Permanently Installed (Exception 1 to §110.10(b)1B):** Buildings are exempt from solar zone, interconnection pathway, and documentation requirements if a solar PV system with a nameplate direct current (DC) power rating of no less than 1 watt per square foot of roof area is permanently installed at the time of construction. The nameplate rating must be measured under standard test conditions. The permanently installed solar PV system can be installed anywhere on the building site. To verify compliance with this exception, document *NRCI-SPV-01-E Certificate of Installation: Solar Photovoltaic System* must be submitted.
2. **SWH System Is Permanently Installed (Exception 2 to §110.10(b)1B):** Buildings are exempt from solar zone, interconnection pathway, and documentation requirements if a domestic SWH system is permanently installed at the time of construction. The SWH system must comply with §150.1(c)8Ciii, the prescriptive solar water-heating system requirements when installing a water-heating system serving multiple dwelling units. The permanently installed domestic SWH collectors can be installed anywhere on the building site. To verify compliance with this exception, document *NRCI-STH-01-E Certificate of Installation: Solar Water Heating System* must be submitted.
3. **High-Rise Multifamily Building With Occupant-Controlled Smart Thermostats (OCST) and Efficient Equipment Installations:** High-rise multifamily buildings that comply with Items 1 and 2 below are exempt from solar zone, interconnection pathway, and documentation requirements.
    1. All thermostats in each dwelling unit are *occupant-controlled smart thermostats (OCST)* with communications capabilities enabled to receive and respond to demand response signals. An OCST is a setback thermostat with communication capabilities that enable the occupant to receive demand response-related messages and respond to those signals by automatic adjustment of the thermostat setpoint as described in Joint Appendix JA5 (subject to occupant participation). Enabling communications capabilities requires that the OCST has one of the following: onboard communications capabilities, an installed communications module for OCSTs with removable communications module(s), or an installed communications gateway for an OCST where an external gateway is required for communications.

       OCST must be certified by the Energy Commission to meet the requirements described in Joint Appendix JA5.
    2. One of the following additional measures is followed:
        a. Efficient Appliances: Install, in each dwelling unit, a dishwasher that meets or exceeds ENERGY STAR® requirements, along with either a refrigerator that also meets or exceeds ENERGY STAR requirements or a whole-house fan that is driven by an electronically commutated motor.

        b. Home Automation: Install, in each dwelling unit, a home automation system that can (at a minimum) control either the appliances or the lighting and can respond to demand response signals. This measure can be met by the same device that performs the OCST functions if that device is also capable of controlling lighting or appliances.

c. Graywater Irrigation: Install alternative plumbing (piping) to permit the discharge from any clothes washers (whether in individual dwelling units or communal laundry rooms) and all showers and bathtubs to be used for an irrigation system. This graywater system must comply with the California Plumbing Code and any applicable local ordinances.

d. Rainwater Catchment: Install a rainwater catchment system that is able to capture water flowing from at least 65 percent of the roof area of the building. This catchment system must comply with the California Plumbing Code and any applicable local ordinances.

4. **Roof Designed for Vehicle Traffic or Heliport (Exception 5 to §110.10(b)1B):** Buildings are exempt from solar zone interconnection pathway and documentation requirements if the roof is designed for vehicle traffic (parking lot) or if the roof is designed as a helicopter landing zone.

5. **Exception:** Exception 3 to §110.10(b)1B allows the minimum solar zone area to be reduced if the solar access at the building site is limited. Exception 3 to §110.10(b)1B is detailed above in the minimum solar zone area section of this chapter (Section 9.3.1).

Example 9-6

Question:

An office building has a total roof area of 5,000 SF. The total roof area covered by skylights is 200 SF. A solar PV system with a DC power rating (measured under standard test conditions) of 4 kilowatts (kW) will be installed. The collection panels for the 4 kW system will cover 400 SF. Does the building have to have to include a solar zone in addition to the installed solar PV system?

Answer:

Yes. To be exempt from the solar zone requirement, the solar PV system must have a power rating equal to 1 watt for every square foot of roof area, or in this case 5 kW (see equation below).

$$Minimum\ PV\ System\ Power\ Rating\ = Total\ Roof\ \ Area\ x\ 1\ Watt\ per\ SF$$

$$\mathbf{5,000}\boldsymbol{W} = \ 5000\ SF\ \times\ 1W/SF$$

The minimum solar zone for this building is 720 SF. (See calculation below.) The 400 SF on which the solar PV system is installed does count toward the minimum solar zone area, so an additional 320 SF would need to be allocated to complete the minimum solar zone requirement.

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ \ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{720}\ \boldsymbol{SF} = \ 15\%\ x\ (5,000\ SF \times 200\ SF)$$

9.6 Additions

§141.0(a)

The solar-ready requirements for additions are covered by the Energy Standards in §141.0(a). Additions do not need to comply with the solar-ready requirements unless the addition increases the roof area by more than 2,000 square feet (200 square meters).

9.7 California Fire Code Solar Access Requirements

Following regulations established by the Office of the State Fire Marshal, the 2016 version of Parts 2, 2.5, and 9 of Title 24 include requirements for installing rooftop solar photovoltaic systems. These regulations cover the marking and location of DC conductors, and access and pathways for photovoltaic systems. They apply to residential and nonresidential buildings regulated by Title 24 of the California Building Standards Codes. Provided below is a summary of the fire code requirements for nonresidential buildings.

PV arrays shall not have dimensions in either axis that exceed 150 feet. Nonresidential buildings shall provide a 6-foot wide access perimeter around the edges of the roof. Smoke ventilation options must exist between array installations and next to skylights or smoke and heat vents. Builders shall refer directly to the relevant sections of Title 24 (Part 2: Section 3111, Part 2.5 Section R331, and Part 9 Section 903.3) for detailed requirements.

In addition to the requirements in the fire code, the California Department of Forestry and Fire Protection − Office of the State Fire Marshal (CAL FIRE-OSFM), local fire departments (FD), and the solar photovoltaic industry previously developed the *Solar Photovoltaic Installation Guideline* to increase public safety for all structures equipped with solar photovoltaic systems. This guideline provides the solar photovoltaic industry with information that will aid in the designing, building, and installation of solar photovoltaic systems in a manner that should meet the objectives of both the solar photovoltaic industry and the requirements set forth in the California Fire Code. The guidelines include illustrations with examples of compliant solar photovoltaic system installations on nonresidential buildings.

The entire *Solar Photovoltaic Installation Guideline* can be accessed at http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf

9.8 Compliance and Enforcement

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and procedures for documenting compliance with the solar-ready requirements of the Energy Standards. The following discussion pertains to the designer preparing construction and compliance documents, and to enforcement agency plan checkers who are examining those documents for compliance with the Energy Standards.

There are four documents associated with the nonresidential solar ready requirements. Each document is briefly described below.

- NRCC-SRA-01-E: Certificate of Compliance: Nonresidential Solar Ready Areas

  This document is required for every project where the solar-ready requirements apply: newly constructed hotel/motel buildings with 10 or fewer stories, high-rise multifamily buildings with 10 or fewer stories, all other newly constructed nonresidential buildings with 3 or fewer stories, and additions to the previously mentioned buildings that increases roof area by more than 2,000 SF.

- NRCC-SRA-02-E: Certificate of Compliance: Minimum Solar Zone Area Worksheet

  This document is required when buildings comply with the solar-ready requirement by including a solar zone. That is, an appropriately sized solar PV system is not installed, an appropriately sized solar water heating system is not installed, the roof is not designed for vehicle traffic or a heliport, or the building is not a high-rise multifamily building that complies with all the OCST and high-efficacy lighting requirements in Exception 4 to §110.10(b)1B.

- NRCI-SPV-01-E: Certificate of Installation – Solar Photovoltaic System

  This document is required when the building is exempt from the solar zone requirements because an appropriately sized solar PV system has been installed.

- NRCI-STH-01-E: Certificate of Installation – Solar Water Heating System

  This document is required when the building is exempt from the solar zone requirements because an appropriately sized solar water-heating system has been installed.

Table of Contents

10. Covered Processes

10.1 Introduction

This chapter of the Nonresidential Compliance Manual addresses covered processes for the *2016 Building Energy Efficiency Standards* (Energy Standards) (§120.6 and §140.9).

10.1.1 Organization and Content

This chapter is organized as follows:

- 10.1 - Introduction to Covered Processes
- 10.2 - Enclosed Parking Garages
- 10.3 - Commercial Kitchens
- 10.4 - Computer Rooms
- 10.5 - Commercial Refrigeration
- 10.6 - Refrigerated Warehouses
- 10.7 - Laboratory Exhaust
- 10.8 - Compressed Air Systems
- 10.9 - Process Boilers
- 10.10 - Elevator Lighting and Ventilation Controls
- 10.11 - Escalators and Moving Walkways Speed Controls

10.1.2 Compliance Forms Checklist

Compliance documentation includes the Certificates of Compliance, reports and other information that are submitted to the enforcement agency with an application for a building permit. Compliance documentation also includes documentation completed by the installing contractor, engineer/architect of record, or owner's agent to verify that certain systems and equipment have been correctly installed and commissioned.

To assist in submitting proper compliance documentation, a checklist is available (Process Compliance Forms & Worksheets - Page 1 of NRCC-PRC-01-E). This checklist helps the enforcing agency to look for specific compliance documentation that is required for covered processes by the 2016 Energy Standards.

Under the prescriptive compliance approach, the project designer is responsible for completing the Process Compliance Forms & Worksheets. The project designer is required to check all applicable boxes on the NRCC-PRC-01-E on page 1 and furnishes all associated forms relevant to the checked features. This checklist is required on plans for all submittals with covered processes. For the performance compliance approach this form will automatically be completed by the approved computer compliance program. The following are the compliance forms:

- NRCC-PRC-01-E Certificate of Compliance - Process Compliance Forms & Worksheets (required on plans for all submittals with covered processes)
- NRCC-PRC-02-E Certificate of Compliance - Garage Exhaust

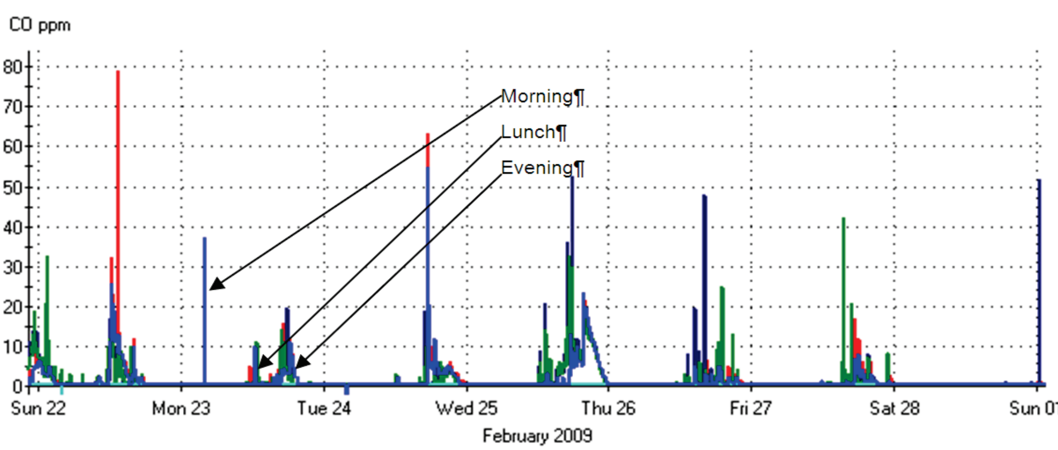
- NRCC-PRC-03-E Certificate of Compliance - Commercial Kitchen Requirements
- NRCC-PRC-04-E Certificate of Compliance - Computer Room Requirements
- NRCC-PRC-05-E Certificate of Compliance - Commercial Refrigeration
- NRCC-PRC-06-E Certificate of Compliance - Refrigerated Warehouse
- NRCC-PRC-07-E Certificate of Compliance - Refrigerated Warehouse ≥ 3,000 ft^2
- NRCC-PRC-08-E Certificate of Compliance - Refrigerated Warehouse ≥ 3,000 ft^2 Served by the Same Refrigeration System
- NRCC-PRC-09-E Certificate of Compliance - Laboratory Exhaust
- NRCC-PRC-10-E Certificate of Compliance - Compressed Air System
- NRCC-PRC-11-E Certificate of Compliance - Process Boilers Requirements
- NRCC-PRC-12-E Certificate of Compliance – Elevator Lighting and Ventilation Controls
- NRCC-PRC-13-E Certificate of Compliance - Escalators and Moving Walkways Speed Controls

10.2 Enclosed Parking Garages

10.2.1 Overview

Garages exhaust systems are sized to dilute the auto exhaust at peak conditions to an acceptable concentration for human health and safety. Energy management control system (EMCS) monitoring of garage carbon monoxide (CO) concentrations show that in a typical enclosed garage, there are three periods of concern: in the morning when cars enter the garage; during the lunch break when cars leave and reenter; and at the end of the day when cars leave. This mandatory measure requires modulating ventilation airflow in large enclosed parking garages based on pollutant concentrations. By modulating airflow based on need rather than running constant volume, the system will save energy and maintain a safe environment.

Figure 10-1: Garage CO Trends



10.2.2 Mandatory Measures

For garage exhaust systems with a total design exhaust rate ≥10,000 cubic feet per minute (cfm), §120.6(c) requires automatic controls to modulate airflow to ≤50% of design based on measurements of the contaminant concentrations. This includes:

- Minimum fan power reduction of the exhaust fan energy to ≤ 30% of design wattage at 50% of design flow. A two speed or variable speed motor can be used to meet this requirement.
- CO concentration shall be measured with at least one sensor per 5,000 ft^2 with each sensor located where the highest concentrations of CO are expected.
- CO concentration of 25 ppm or less as control set point at all times.
- A minimum ventilation of 0.15 cfm/ft^2 when the garage is "occupied".
- The system must maintain the garage at a neutral or negative pressure with respect to adjacent occupiable areas when the garage is scheduled to be occupied.
- CO sensors shall be certified to the minimum performance requirements listed under §120.6(c) of the Energy Standards.
- Acceptance testing of the ventilation system per NA7.12.

10.2.2.1 **Minimum Fan Power Reduction**

§120.6(c)2

Where required, the fan control must be designed to provide ≤30% of the design fan wattage at 50% of the fan flow. This can be achieved by either a two speed motor or a variable speed drive.

10.2.2.2 **CO Sensor Number and Location**

§120.6(c)3

CO sensors (or sampling points) must be located so that each unique sensor serves an area no more than 5,000 ft^2. Furthermore, the standard requires a minimum of two sensors per "*proximity zone*." A *proximity zone* is defined as areas that are separated by obstructions including floors or walls.

The typical design for garage exhaust is to have the exhaust pickups located on the other side of the parking areas from the source of makeup air. The ventilation air sweeps across the parking areas and towards the exhaust drops. Good practice dictates that you would locate sensors close to the exhaust registers or in dead zones where air is not between the supply and exhaust. Floors and rooms separated by walls should be treated as separate proximity zones.

10.2.2.3 **CO Sensor Minimum Requirements**

§120.6(c)7

To comply, each sensor must meet all of the following requirements:

- Certified by the manufacturer to: be accurate to +/- 5%; have 5% or less drift per year; and require calibration no more than once per year.
- Be factory calibrated.

- The control system must monitor for sensor failure. If sensor failure is detected the control system must reset to design ventilation rates and transmit an alarm to the facility operators.

10.2.3 Prescriptive Measures

There are no prescriptive measures for enclosed garage exhaust.

10.2.4 Additions and Alterations

There are no separate requirements for additions and alterations.

10.3 Commercial Kitchens

10.3.1 Overview

There are four energy saving measures associated with commercial kitchen ventilation. These four prescriptive measures address:

- Direct Replacement of Exhaust Air Limitations.
- Type I Exhaust Hood Airflow Limitations.
- Makeup and Transfer Air Requirements.
- Commercial Kitchen System Efficiency Options.

10.3.2 Mandatory Measures

There are no mandatory measures specific to commercial kitchens. Installed appliances and equipment must meet the mandatory requirements of §110.1 and §110.2, respectively.

10.3.3 Prescriptive Measures

10.3.3.1 **Kitchen Exhaust Systems**

§140.9(b)1

This section addresses kitchen exhaust systems. There are two requirements for kitchen exhaust:

- A limitation on use of short-circuit hoods §140.9(b)1A.
- Maximum exhaust ratings for Type I kitchen hoods §140.9(b)1B.

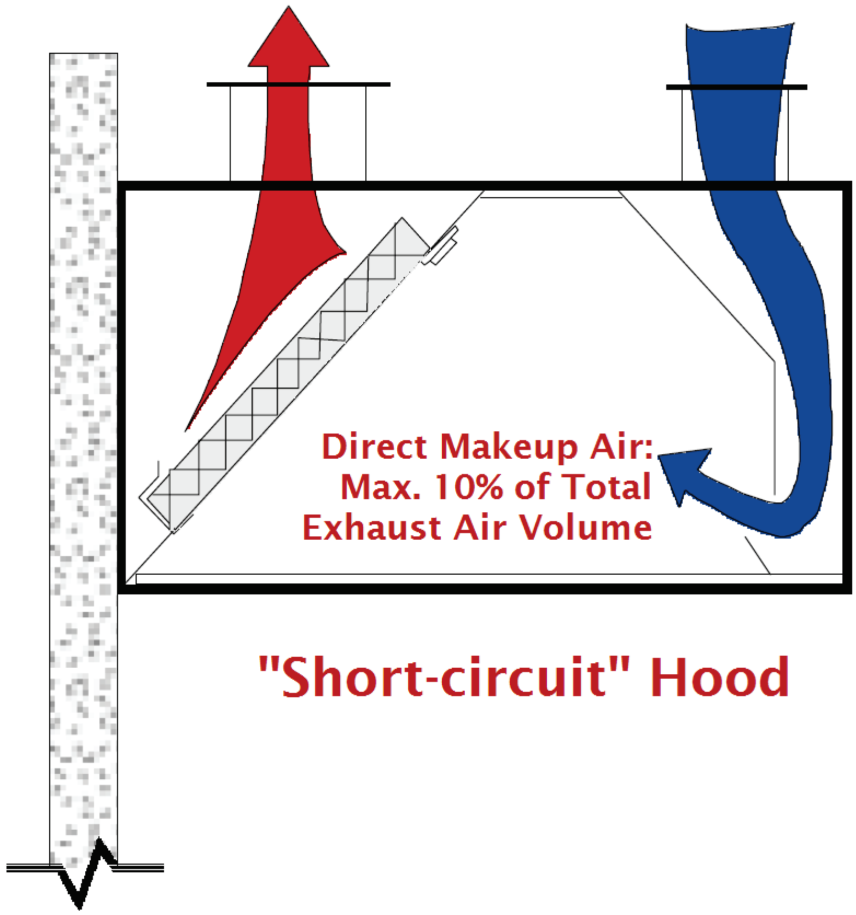
A. Limitation of Short-Circuit Hoods

§140.9(b)1A

Short-circuit hoods are limited to ≤10% replacement air as a percentage of hood exhaust airflow rate. The reasons for this include the following:

Studies by Pacific Gas & Electric (PG&E), American Gas Association (AGA) and the Energy Commission have shown that in short-circuit hoods, direct supply greater than 10% of hood exhaust significantly reduces capture and containment. This reduces the extraction of cooking heat and smoke from the kitchen, forcing facilities to increase the hood exhaust rate. This results in higher consumption of energy and conditioned makeup air.

Figure 10-2: Short-Circuit Hood



B. Maximum Exhaust Ratings for Type I Kitchen Hoods

§140.9(b)1B

The Energy Standards also limit the amount of exhaust for Type I kitchen hoods based on Table 140.9-A (Table 10-1 below), when the total exhaust airflow for Type I and II hoods are greater than 5,000 cfm. Similar to the description regarding short-circuit hoods, excessive exhaust rates for Type I kitchen hoods increases energy consumption and increases energy use for conditioning of the makeup air.

There are two exceptions for this requirement:

1. Exception 1 to §140.9(b)1B: where ≥75% of the total Type I and II exhaust makeup air is transfer air that would otherwise have been exhausted. This exception could be used when you have a large dining area adjacent to the kitchen, which would be exhausting air for ventilation purposes even if the hoods were not running. The exception is satisfied if: the air that would otherwise have been exhausted from the dining area (to meet ventilation requirements); is greater than 75 percent of the hood exhaust rate; and is transferred to the kitchen for use as hood makeup air.
2. Exception 2 to §140.9(b)1B: for existing hoods that are not being replaced as part of an addition or alteration.

The values in Table 140.9-A are based on the type of hood (left column) and the rating of the equipment that it serves (columns 2 through 5). The values in this table are typically less than the minimum airflow rates for unlisted hoods. These values are supported by ASHRAE research for use with listed hoods (RP-12002). To comply with this requirement, the facility will likely have to use listed hoods. The threshold of 5,000 cfm of total exhaust was included in the Energy Standards to exempt small restaurants.

The definitions for the types of hoods and the duty of cooking equipment are provided in ASHRAE Standard 154-2011.

Table 10-1: Maximum Net Exhaust Flow Rate, cfm per Linear Foot of Hood Length

Type of Hood	Light Duty Equipment	Medium Duty Equipment	Heavy Duty Equipment	Extra Heavy Duty Equipment
Wall-mounted Canopy	140	210	280	385
Single Island	280	350	420	490
Double Island	175	210	280	385
Eyebrow	175	175	Not Allowed	Not Allowed
Backshelf/Pass-over	210	210	280	Not Allowed

Energy Standards Table 140.9-A

10.3.3.2 Kitchen Ventilation

§140.9(b)2

This section covers two requirements:

- Limitations to the amount of mechanically heated or cooled airflow for kitchen hood makeup air §140.9(b)2A.
- Additional efficiency measures for large kitchens §140.9(b)2B.

For these requirements it is important to understand the definition of mechanical cooling and mechanical heating, which the Energy Standards define as:

- ***Mechanical cooling*** is lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space. In nonresidential, high-rise residential, and hotel/motel buildings, cooling of a space by direct or indirect evaporation of water alone is not considered mechanical cooling.
- ***Mechanical heating*** is raising the temperature within a space using electric resistance heaters, fossil fuel burners, heat pumps, or other systems that require energy from depletable sources to directly condition the space.

It is important to note that direct and indirect evaporation of water alone is not considered mechanical cooling. Therefore, air cooled by the evaporation of water can be used as kitchen hood makeup air with no restrictions.

A. Limitations to the Amount of Mechanically Heated or Cooled Airflow for Kitchens

§140.9(b)2A

This section limits the amount of mechanically cooled or heated airflow to any space with a kitchen hood. The amount of mechanically cooled or heated airflow must not exceed either:

- The supply flow required to meet the space heating or cooling load.
- The hood exhaust minus the available transfer air from adjacent spaces.

The supply flow required to meet the space heating or cooling loads can be documented by providing the load calculations.

To calculate the available transfer air:

1. Calculate the minimum outside air (OA) needed for the spaces that are adjacent to the kitchen.
2. From the amount calculated in 1, subtract the amount of air used by exhaust fans in the adjacent spaces. These include toilet exhaust and any hood exhaust in adjacent spaces.
3. From the amount calculated in 2, subtract the amount of air needed for space pressurization. The remaining air is available for transfer to the hoods.

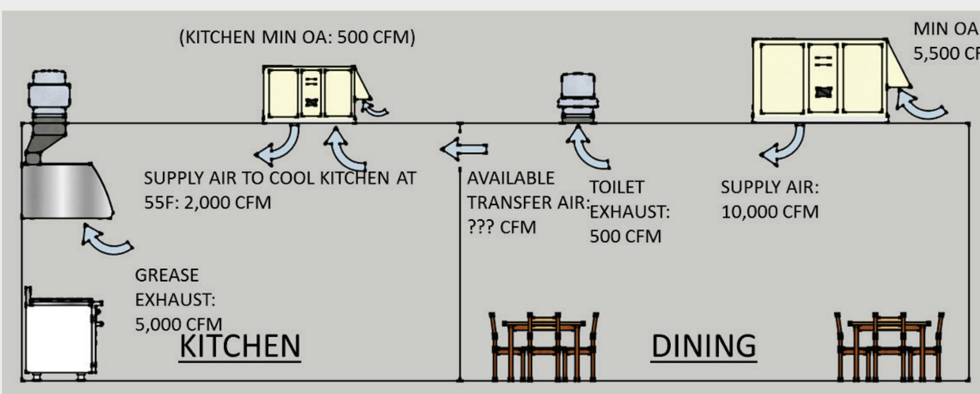
An exception is provided for existing kitchen makeup air units (MAU) that are not being replaced as part of an addition or alternation.

While the requirement to use available transfer air only refers to "adjacent spaces", available transfer air can come from any space in the same building as the kitchen. A kitchen on the ground floor of a large office building, for example, can draw transfer air from the return plenum and the return shaft. The entire minimum OA needed for the building, minus the other exhaust and pressurization needs, is available transfer air. If the return air path connecting the kitchen to the rest of the building is constricted, resulting in high transfer air velocities, then it may be necessary to install a transfer fan to assist the transfer air in making its way to the kitchen. The energy use of a transfer fan is small compared to the extra mechanical heating and cooling energy of an equivalent amount of OA.

Example 10-1

Question

What is the available transfer air for the kitchen make up in the scenario shown in the following figure?



Answer

5,000 cfm calculated as follows.

The OA supplied to the dining room is 5,500 cfm. From this we subtract 500 cfm for the toilet exhaust and 0 cfm for building pressurization.

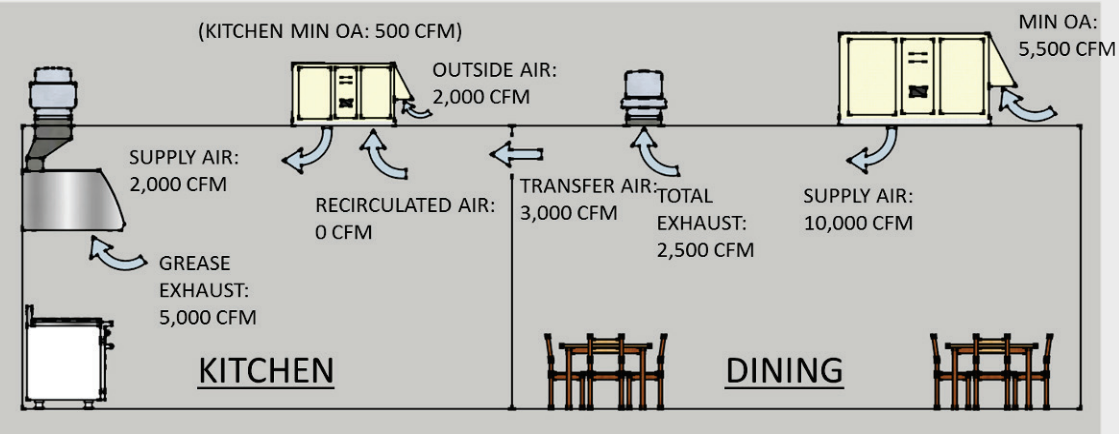
5,500 cfm – 500 cfm – 0 cfm = 5,000 cfm

The remaining 5,000 cfm of air is available transfer air.

Example 10-2

Question

Assuming that this kitchen needs 2,000 cfm of supply air to cool the kitchen with a design supply air temperature of 55°F, would the following design airflow meet the requirements of §140.9(b)2A?



Answer

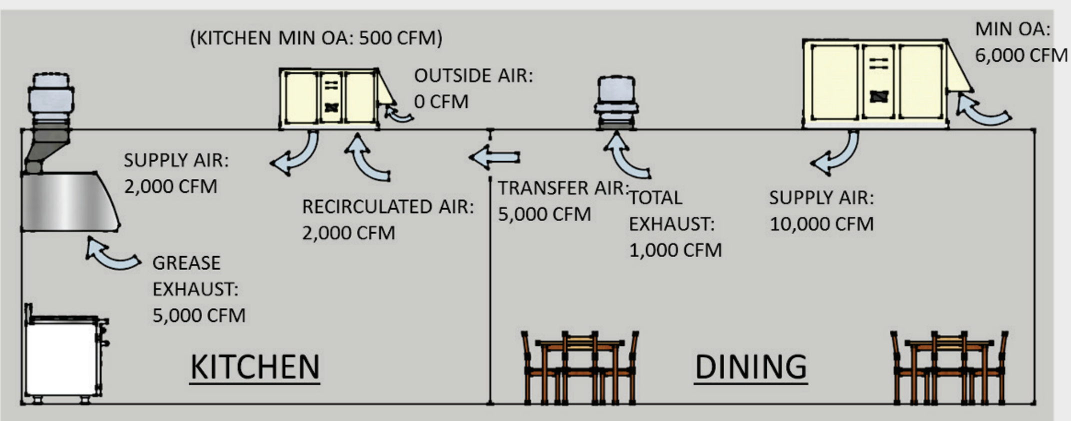
Yes. This example meets the first provision of §140.9(b)2A. The supply flow required to meet the cooling load is 2,000 cfm. Thus up to 2,000 cfm of mechanically conditioned make up air can be provided to the kitchen. Note that the supply from the MAU, 2,000 cfm, is not as large as the hood exhaust, 5,000 cfm. This means that the remainder of the makeup air, 3,000 cfm, must be transferred from the dining room space.

Although this is allowed under §140.9(b)2Ai, this is not the most efficient way to condition this kitchen as demonstrated in the next example.

Example 10-3

Question

Continuing with the same layout as the previous example, would the following design airflow meet the requirements of §140.9(b)2A?



Answer

Yes. In this example, 100% of the makeup air, 5,000 cfm, is provided by transfer air from the adjacent dining room. Note that the OA on the unit serving the dining room has been increased to 6,000 cfm to serve the ventilation for both the dining room and kitchen. Since the dining room has no sources of undesirable contaminants we can ventilate the kitchen with the transfer air.

Comparing this image to the previous example you will see that this design is more efficient for the following reasons:

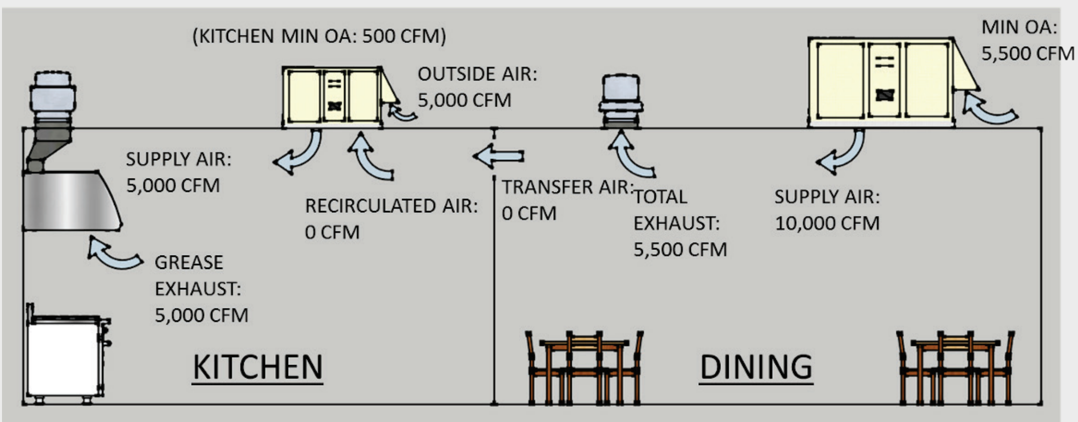
1. The total outside airflow to be conditioned has been reduced from 7,500 cfm in the previous example (2,000 cfm at the MAU and 5,500 cfm at the dining room unit) to 6,000 cfm; and
2. The dining room exhaust fan has dropped from 2,500 cfm to 1,000 cfm reducing both fan energy and first cost of the fan.

Note that an even more efficient design would be if the kitchen MAU had a modulating OA damper that allowed it to provide up to 5,000 cfm of outside air directly to the kitchen when OA temperature <kitchen space temperature. When OA temperature >kitchen space temperature then the OA damper on the MAU is shut and replacement/ventilation air is transferred from the dining area. This design requires a variable speed dining room exhaust fan controlled to maintain slight positive pressure in the dining area. This design is the baseline design modeled in the Alternative Calculation Methods (ACM) Reference Manual for performance compliance. The baseline model assumes that transfer air is available from the entire building, not just the adjacent spaces.

Example 10-4

Question

Continuing with the same layout as the previous examples, would the following design airflow meet the requirements of §140.9(b)2A?



Answer

Not if the kitchen unit is mechanically heated or cooled. Per §140.9(b)2A the maximum amount of air that can be mechanically heated or cooled must be less than either:

1. Per §140.9(b)2Ai: 2,000 cfm, the supply needed to cool the kitchen (from Example 10-2)
2. Per §140.9(b)2Aii: 0 cfm, the amount of hood exhaust (5,000 cfm) minus the available transfer air (also 5,000 cfm from Example 10-2).

B. Additional Efficiency Measures for Large Kitchens

§140.9(b)2B

For kitchens or dining facilities that have more than 5,000 cfm of Type I or II hood exhaust, the mechanical system must meet one of the following requirements:

1. At least 50% of all replacement air is transfer air that would have been exhausted.
2. Demand ventilation control on at least 75% of the exhaust air.
3. Listed energy recovery devices with a sensible heat recovery effectiveness ≥40% on ≥50% of the total exhaust flow.

4. ≥75% of the makeup air volume that is:
   a. Unheated or heated to no more than 60°F.
   b. Uncooled or cooled without the use of mechanical cooling.

Transfer Air: There is an exception for existing hoods not being replaced as part of an addition or alteration.

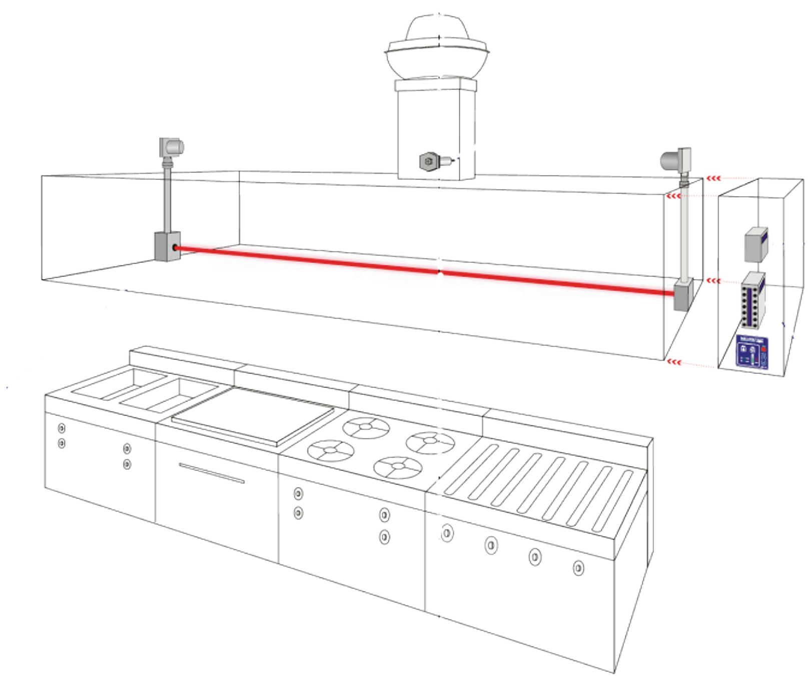
The concept of transfer air was addressed in the discussion of §140.9(b)2A above.

Demand Ventilation Control: Per §140.9(b)2Bii, demand ventilation controls must have all of the following characteristics:

- Include controls necessary to modulate airflow in response to appliance operation and to maintain full capture and containment of smoke, effluent and combustion products during cooking and idle.
- Include failsafe controls that result in full flow upon cooking sensor failure.
- Include an adjustable timed override to allow occupants the ability to temporarily override the system to full flow.
- Be capable of reducing exhaust and replacement air system airflow rates to the larger of:
  - 50% of the total design exhaust and replacement air system airflow rates.
  - The ventilation rate required per §120.1.

There are several off the shelf technologies that use smoke detectors that can comply with all of these requirements.

Figure 10-3: Demand Control Ventilation Using a Beam Smoke Detector



Energy Recovery: Energy recovery is provided using air to air heat exchangers between the unit providing makeup air and the hood exhaust. This option is most effective for extreme climates (either hot or cold). It is not commonly used in the mild climates of California.

Tempered Air with Evaporative Cooling: The final option is to control the heating (if there is heating) to a space by setting the temperature setpoint to 60°F and to use evaporative (non-compressor) cooling or no cooling at all for most of the makeup air.

10.3.3.3 Kitchen Exhaust Acceptance

§140.9(b)3

Acceptance tests for these measures are detailed in NA7.11. See Chapter 13 of this manual.

10.3.4 Additions and Alterations

The application of these measures to additions and alterations was presented in the text from the previous section.

10.4 Computer Rooms

10.4.1 Overview

§140.9(a) provides minimum requirements for conditioning of *computer rooms*. A *computer room* is defined in §100.1 Definitions as " a room whose primary function is to house electronic equipment and that has a design equipment power density exceeding 20 watts/ft^2 of conditioned floor area." All of the requirements in §140.9(a) are prescriptive.

10.4.2 Mandatory Measures

There are no mandatory measures specific to computer rooms. The equipment efficiencies in §110.1 and §110.2 apply.

10.4.3 Prescriptive Measures

The following is a summary of the measures in this section:

- Air or water side economizer - §140.9(a)1
- Restriction on reheat or recool - §140.9(a)2
- Limitations on the type of humidification - §140.9(a)3
- Fan power limitations - §140.9(a)4
- Variable speed fan control - §140.9(a)5, and
- Containment - §140.9(a)6

Each of these requirements is elaborated on in the following sections.

10.4.3.1 Economizers

§140.9(a)1

This section requires integrated air or water economizer. If an air economizer is used to meet this requirement, it must be designed to provide 100% of the expected system cooling load at outside conditions of 55°F Tdb with a coincident 50°F Twb. This is different from the non-computer room economizer regulations (§140.4(e)), which require that an air economizer must supply 100 percent of the supply-air as outside air. A computer room air economizer does not have to supply any outside air if it has an air-to-air heat exchanger that can meet the expected load at the conditions specified and can be shown (through modeling) to consume no more energy that the standard air economizer.

If a water economizer is used to meet the is requirement it must be capable of providing 100% of the expected system cooling load at outside conditions of 40°F Tdb with a coincident 35°F Twb.

See chapter 4 for a description of integrated air- and water-economizers and implementation details.

There are several exceptions to this requirement:

1. **Exception 1 to §140.9(a)1**: Individual *computer rooms* with cooling capacity of <5 tons in a building that does not have any economizers. This exception is different from the 54,000 btu-h (4.5 ton) exception in 140.4(e) for non-computer rooms in two important ways. First, the computer room exception refers to the cooling capacity of all systems serving the computer room, whereas the non-computer room regulation refers to each cooling system serving the building. Second, the computer room exception only applies if none of the other cooling systems in the building includes an economizer. Even a 1 ton computer room would have to be served by an existing cooling system with an economizer (see exception 4 below). The analysis for this requirement was performed using a 5 ton AC unit with an air/air heat exchanger. Even with the added cost and efficiency loss of a heat exchanger the energy savings in all of the California climates justified this requirement.
2. **Exception 2 to §140.9(a)1**: New cooling systems serving an existing c*omputer room* in an existing building up to a total of 50 tons of new cooling equipment per building. This exception permits addition of new IT equipment to an existing facility that was originally built without any economizers.

   This exception recognizes that an existing space with capacity for future expansion may not have been sited or configured to accommodate access to outside air.

   Above 50 tons of capacity (~175kW of IT equipment load) you would be forced to either provide economizer cooling or offset the energy loss by going the performance approach. Ways to meet this requirement include:

   - Provide the new capacity using a new cooling system that has a complying air or water economizer, or
   - If the facility has a chilled water plant install an integrated water-side economizer with a minimum capacity equal to the new *computer room* cooling load. Water-side economizers can be added to both air and water cooled chilled water plants.
3. **Exception 3 to §140.9(a)1**: New cooling systems serving a new c*omputer room* up to a total of 20 tons of new cooling load in an existing building.

   This is similar to the previous exception but now you have the option to plan the new space in a location where you can employ a system with an integrated economizer.
4. **Exception 4 to §140.9(a)1**: Applies to *computer rooms* in a larger building with a central air handling system with a complying air-side economizer that can fully condition the c*omputer rooms* on weekends and evenings when the other building loads are off. This exception allows the *computer rooms* to be served by fan-coils or split system DX units as long as the following conditions are met:

   - The economizer system on the central air handling unit is sized sufficiently that all of the *computer rooms* are less than 50% of its total airflow capacity.

- The central air handling unit is configured to serve only the *computer rooms* if all of the other loads are unoccupied. And,
- The supplemental cooling systems for the *computer rooms* are locked out when the outside air drybulb temperature is below 60°F and the non-*computer room* zones are less than 50% of the design airflow.

Example 10-5

Question

A new data center is built with a total c*omputer room* load of 1,500 tons of capacity. If the *computer rooms* are all served using recirculating chilled water *computer room* air-handling units (CRAHs) in in-row air handling units (IRAHs) would this data center meet the requirements of §140.9(a)1 if the chilled water plant had a water side economizer that complied with the requirements of §140.4(e)?

Answer

Yes, if the economizer can meet 100 percent of the 1,500 ton load at 40°F dry-bulb and 35°F wet-bulb. The design conditions in §140.9(a) would require a different heat exchanger and cooling towers than the conditions in §140.4(e) for non-process spaces for a given expected load. Note that the load on the cooling towers, while in economizer-only mode, is lower that the design load even if the computer room load is constant because the towers do not have to reject the heat from the chillers. Note also that there are no redundancy requirements in the energy code. Many data centers have more cooling towers than needed to meet the design load so that the design load can be met even if one or more towers is not available. If the system is capable of running all cooling towers in economizer-only mode than all towers can be included in the calculation for determining compliance with this requirement.

Example 10-6

Question

A new data center is built with chilled water CRAH units sized to provide 100% of the cooling for the IT equipment. The building also has louvered walls that can open to bring in outside air and fans on the roof that can exhaust air. Does this design meet the requirements of §140.9(a)1?

Answer

Yes provided that all of the following are true:

- The economizer system moves sufficient air so that it can fully satisfy the design IT equipment loads with the CRAH units turned off and the outside air dry-bulb temperature at 55°F. And,
- The control system provides integrated operation so that the chilled water coils in the CRAH units are staged down when cool outside air is brought into the data center. And,
- The economizer system is provided with a high limit switch that complies with §140.4(e). Although fixed dry-bulb switches are allowed in §140.4(e) they are not recommend in this application as the setpoints were based on office occupancies. A differential dry-bulb switch would provide much larger energy savings.

Example 10-7

Question

A new office building has a house air system with an air-side economizer that complies with §140.4(3). This building has two IDF rooms with split system DX units one is 4 tons of capacity and the other is 7-1/2 tons of capacity. Do the IDF rooms meet the requirements of the Energy Standards?

Answer

Not necessarily. Both IDF rooms are required to have economizers. The 4 ton IDF room does not meet Exception 1 to §140.9(a)1 because it is a building with an economizer. Per Exception 4 to §140.9(a)1 the IDF rooms can also be served by split system DX units without economizers if if they are also served by VAV boxes from the VAV reheat system. The DX units must be off when the VAV reheat system has enough spare capacity to meet the IDF loads. The VAV reheat system must be at least twice the capacity of all the IDF rooms. When the office spaces are expected to be unoccupied (e.g., at night) their VAV boxes must be shut so that the VAV system can serve only the IDF rooms.

Example 10-8

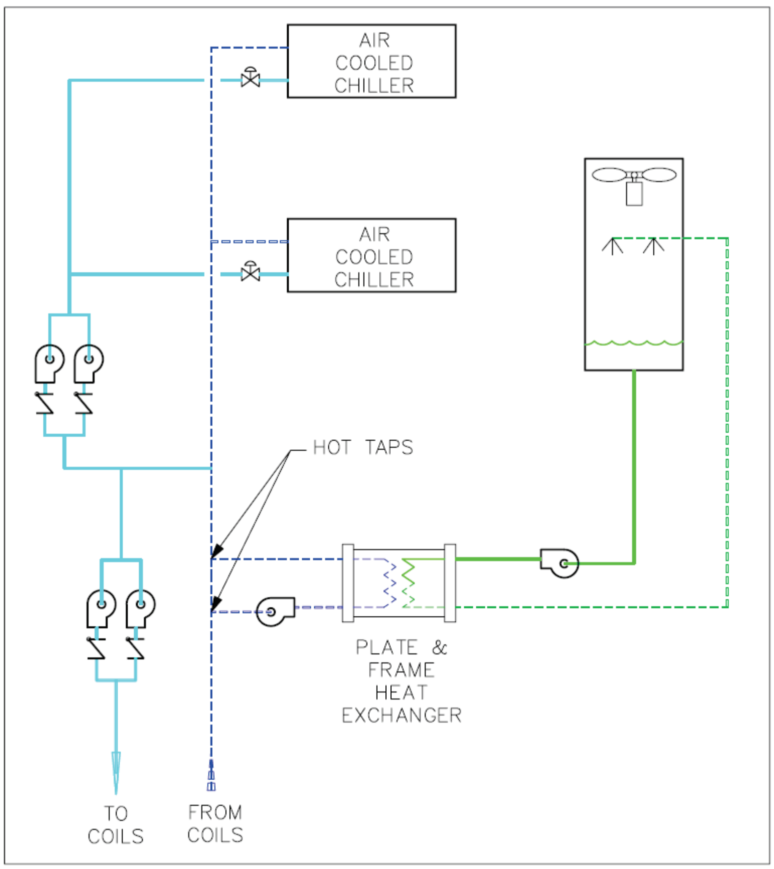
Question

A new data center employs rear door heat exchangers that are cooled entire with water that comes from a closed circuit fluid cooler. Does this design meet the economizer requirements of §140.9(a)1?

Answer

Yes. The standard definitions for e*conomizer* (both air and water) both have the phrase "to reduce or eliminate the need for m*echanical cooling*." In turn, the definition of *mechanical cooling* is "lowering the temperature within a space using refrigerant compressors or absorbers, desiccant dehumidifiers, or other systems that require energy from depletable sources to directly condition the space." Since this system does not use compressors, it complies.

Figure 10-4: Example of water-side economizer retrofit on a chilled water plant with air-cooled chillers



10.4.3.2 **Reheat/Recool**

§140.9(a)2

§140.9(a)2 prohibits reheating, recooling or simultaneous heating or cooling in c*omputer rooms*. In addition the definition of cooling includes both *mechanical cooling* and e*conomizers.* This provision is to prohibit use of CRAC and CRAH units with humidity controls that include reheat coils.

10.4.3.3 **Humidification**

§140.9(a)3

§140.9(a)3 prohibits the use of non-adiabatic humidification for c*omputer rooms*. The requirement of humidity control in *computer rooms* is controversial. On the low humidity side humidification was provided to reduce the risk of electrostatic discharge. On the high humidity side the concern has been CAF formation on the circuit boards. For both of these issues there is insufficient evidence that the risks either adequately address through the use of humidity controls. The telecommunications industry Standard for central office facilities has no restrictions on either the low or high humidity limits. Furthermore, the Electrostatic Discharge Association (ESDA) removed humidification as a primary control over electrostatic discharge in electronic manufacturing facilities (ANSI/ESDA Standard 20.20) as it wasn't effective and didn't supplant the need for personal grounding. The Energy Standards allows for humidification but prohibits the use of non-adiabatic humidifiers including the steam humidifiers and electric humidifiers that rely on boiling water as both of these add cooling load with the humidity. The technologies that meet the adiabatic requirement are direct evaporative cooling and ultrasonic humidifiers.

10.4.3.4 **Fan Power and Control**

§140.9(a)4 and 5

In §140.9(a)4, fan power for equipment cooling computer rooms is limited to 27W/kBtuh of net sensible cooling capacity. Net sensible cooling capacity is the sensible cooling capacity of the coil minus the fan heat. Systems that are designed for a higher airside ΔT (e.g., 25°F) will have an easier time meeting this requirement than systems designed for lower ΔT (e.g., 15°F)

Fan controls (§140.9(a)5) requires that fans serving *computer rooms* must have either variable speed control or two speed motors that provide for a reduction in fan motor power to ≤50% of power at design airflow when the airflow is at 67% of design airflow. This applies to chilled water units of all sizes and DX units with a rated cooling capacity of ≥ 5 tons.

10.4.3.5 **Containment**

§140.9(a)6

Computer rooms with a design IT equipment load exceeding 175 kW per room are required to have containment to separate the computer equipment inlets and outlets. The requirement can be met using hot-aisle containment, cold aisle containment or in-rack cooling. Exceptions are provided for:

- Expansions of existing *computer rooms* that don't already have containment.
- Computer racks with a design load of < 1 kW/rack (e.g. network racks).
- Equivalent energy performance demonstrated to the AHJ through use of CFD or other analysis tools.

Figure 10-5: Example of aisle containment using chimney racks

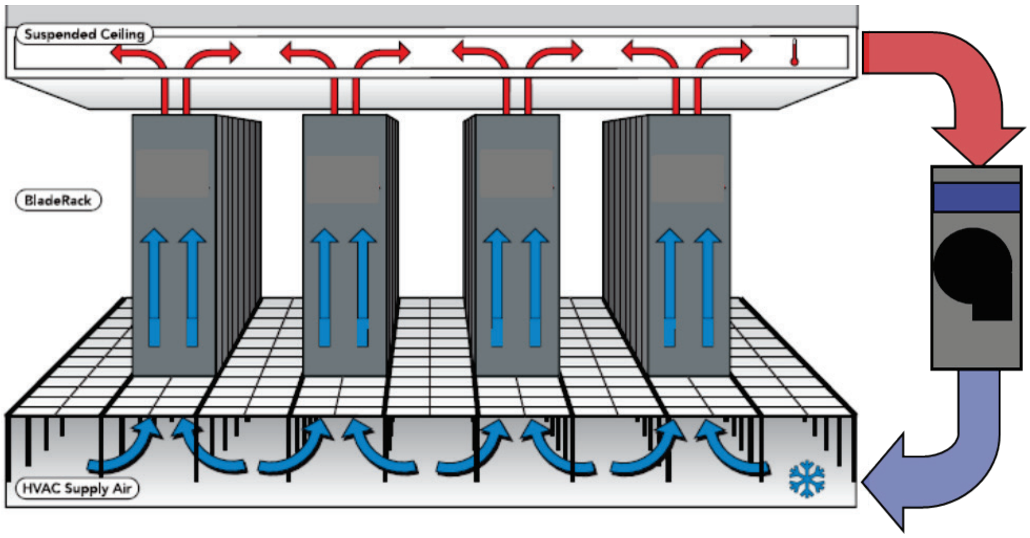


Figure 10-6: Example of aisle containment using hard partitions and doors

10.4.4 Additions and Alterations

The application to additions and alternations are covered under each measure.

10.5 Commercial Refrigeration

10.5.1 Overview

This section addresses §120.6(b) of the Energy Standards, which covers mandatory requirements for commercial refrigeration systems in retail food stores. This section explains the mandatory requirements for condensers, compressor systems, refrigerated display cases, and refrigeration heat recovery. All buildings under the Energy Standards must also comply with the General Provisions of the Energy Standards (§100.0 – §100.2, §110.0 – §110.10, §120.0 – §120.9, §130.0 – §130.5), and additions and alterations requirements (§141.1).

10.5.1.1 Mandatory Measures and Compliance Approaches

The energy efficiency requirements for commercial refrigeration are all mandatory. There are no prescriptive requirements or performance compliance paths for commercial refrigeration. Since the provisions are all mandatory, there are no tradeoffs allowed between the various requirements. The application must demonstrate compliance with each of the mandatory measures. Exceptions to each mandatory requirement where provided are described in each of the mandatory measure sections below.

10.5.1.2 What's New in the 2016 Energy Standards

In the 2016 Energy Standards, the exception to §120.6(b)3 is no longer available. This affects retail food stores with 8,000 square feet or more of conditioned area that use either: refrigerated display cases, or walk-in coolers or freezers connected to remote compressor units or condensing units, which are normally open for business for less than 140 hours per week. These stores must now comply with §120.6(b)3, without exception.

10.5.1.3 Scope and Application

§120.6(b)

§120.6(b) of the Energy Standards applies to retail food stores that have 8,000 square feet or more of conditioned area, and utilize either refrigerated display cases or walk-in coolers or freezers, which are connected to remote compressor units or condensing units. The Energy Standards have minimum requirements for the condensers, compressor systems, refrigerated display cases, and refrigeration heat recovery systems associated with the refrigeration systems in these facilities.

The Energy Standards do not have minimum efficiency requirements for walk-ins, as these are deemed appliances and are covered by the California Appliance Efficiency Regulations (Title 20) and Federal Energy Independence and Security Act of 2007. Walk-ins are defined as refrigerated spaces with less than 3,000 square feet of floor area that are designed to operate below 55°F (13°C). Additionally, the Energy Standards do not have minimum equipment efficiency requirements for refrigerated display cases, as the minimum efficiency for these units is established by Federal law in the Commercial Refrigeration Equipment Final Rule but there are requirements for display cases that do result in reduced energy consumption.

Example 10-9

Question

The only refrigeration equipment in a retail food store with 10,000 square feet of conditioned area is self-contained refrigerated display cases. Does this store need to comply with the requirements for Commercial Refrigeration?

Answer

No. Since the refrigerated display cases are not connected to remote compressor units or condensing units, the store does not need to comply with the Energy Standards.

Example 10-10

Question

A new retail store with 25,000 square feet conditioned area has two self-contained display cases. The store also has several display case line-ups and walk-in boxes connected to remote compressors systems. Do all the refrigeration systems need to comply with the requirements for Commercial Refrigeration?

Answer

There are no provisions in the Energy Standards for the two self-contained display cases. The refrigeration systems serving the other fixtures must comply with the Energy Standards.

10.5.2 Condensers Mandatory Requirements

§120.6(b)1

This section addresses the mandatory requirements for condensers serving commercial refrigeration systems. These requirements only apply to stand-alone refrigeration condensers and do not apply to condensers that are part of a unitary condensing unit.

If the work includes a new condenser replacing an existing condenser, the condenser requirements do not apply if all of the following conditions apply:

1. The Total Heat of Rejection of the compressor system attached to the condenser or condenser system does not increase, and
2. Less than 25% of the attached refrigeration system compressors (based on compressor capacity at design conditions) are new, and
3. Less than 25% of the display cases (based on display case design load at applied conditions) that the condenser serves, are new. Since the compressor system loads commonly include walk-ins (both for storage and point-of-sale boxes with doors), the 25% “display case" should be calculated with walk-ins included.

Example 10-11

Question

A supermarket remodel includes a refrigeration system modification where some of the compressors will be replaced, some of the refrigerated display cases will be replaced, and the existing condenser will be replaced. The project does not include any new load and the design engineer has determined that the total system heat of rejection will not increase. The replacement compressors comprise 20% of the suction group capacity at design conditions, and the replacement display cases comprise 20% of the portion of the design load that comes from display cases. There are no changes in walk-ins. Does the condenser have to comply with the provisions of the Energy Standards?

Answer

No. This project meets all three criteria of the exception to the mandatory requirements for condensers:

1. The new condenser is replacing an existing condenser

2. The total heat of rejection of the subject refrigeration system does not increase

3a. The replacement compressors comprise less than 25% of the suction group design capacity at design conditions

3b. The replacement display cases comprise less than 25% of the portion of the design load that comes from display cases.

10.5.2.1 **Condenser Fan Control**

§120.6(b)1A,B,& C

Condenser fans for new air-cooled or evaporative condensers, or fans on air- or water-cooled fluid coolers or cooling towers used to reject heat on new refrigeration systems, must be continuously variable speed. Variable frequency drives are commonly used to provide continuously variable speed control of condenser fans and controllers designed to vary the speed of electronically commutated motors are increasingly being used for the same purpose. All fans serving a common high side, or indirect condenser water loop, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single condenser or set of condensers serving a common high-side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level minimum level, usually no higher than 10-20%, the fans may be staged off to further reduce condenser capacity. As load increases, fans should be turned back on prior to significantly increasing fan speed, recognizing a control band is necessary to avoid without excessive fan cycling. Control of air-cooled condensers may also keep fans running and use a holdback valve on the condenser outlet to maintain the minimum condensing temperature once all fans have reached minimum speed; with the holdback valve set below the fan control minimum saturated condensing temperature setpoint.

To minimize overall system energy consumption, the condensing temperature control setpoint must be continuously reset in response to ambient temperatures, rather than using a fixed setpoint value. This strategy is also termed ambient-following control, ambient-reset, wetbulb following and drybulb following—all referring to control logic which changes the condensing temperature control setpoint in response to ambient conditions at the condenser. The control system calculates a control setpoint saturated condensing temperature that is higher than the ambient temperature by a predetermined temperature difference (i.e. the condenser control TD). Fan speed is then modulated so that the measured SCT (saturated condensing temperature) matches the calculated SCT control setpoint. The SCT control setpoint for evaporative condensers or water-cooled condensers (via cooling towers or fluid coolers) must be reset according to ambient wet bulb temperature, and the SCT control setpoint for air-cooled condensers must be reset according to ambient dry bulb temperature.

The condenser control TD is not specified in the Standard. The nominal control value is often equal to the condenser design TD; however the value for a particular system is left up to the system designer. Since the intent is to utilize as much condenser capacity as possible without excessive fan power, common practice is to optimize the control TD over a period of time such that the fan speed is in a range of approximately 60-80% during normal operation (i.e. when not at minimum SCT and not in heat recovery).

The minimum saturated condensing temperature setpoint must be 70°F (21°C) or less. For systems utilizing halocarbon refrigerants with glide, the SCT setpoint shall correlate with a midpoint temperature (between the refrigerant bubble-point and dew point temperatures) of 70°F (21°C) or less. As a practical matter, a maximum SCT setpoint is also commonly employed to set an upper bound on the control setpoint in the event of a sensor failure and to force full condenser operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

Split air-cooled condensers are sometimes used for separate refrigeration systems, with two circuits and two rows of condenser fans. Each condenser half would be controlled as a separate condenser. If a condenser has multiple circuits served by a common fan or set of fans, the control strategy may utilize the average condensing temperature or the highest condensing temperature of the individual circuits as the control variable for controlling fan speed.

Alternative control strategies are permitted to the condensing temperature reset control required in §120.6(b)1C. The alternative control strategy must be demonstrated to provide equal or better performance, as approved by the Executive Director.

Hybrid condensers, manufactured with integral capability to operate with either air-cooled or evaporative-cooled operation, are not covered. Air-cooled condensers with separately installed evaporative precoolers added to the condenser are not considered hybrid condensers for the purpose of this Standard. Air cooled condensers with an added evaporative precooling must meet the requirements for air cooled equipment, including specific efficiency and ambient-following control.

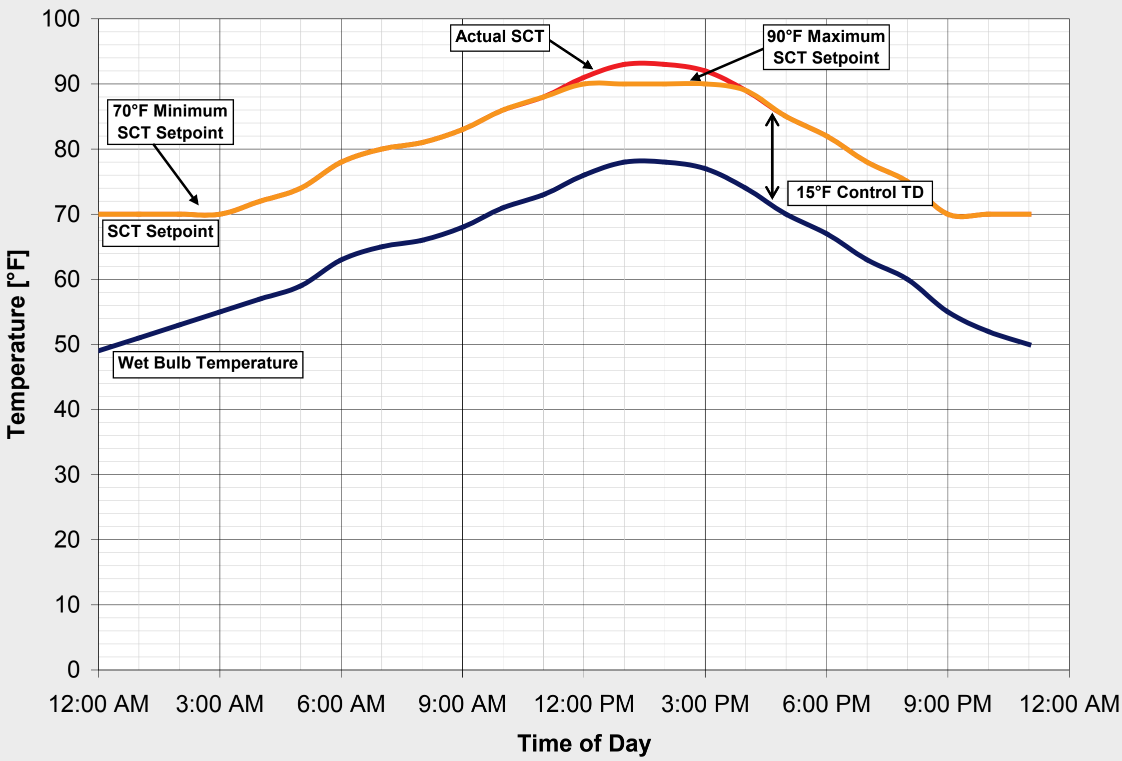
Example 10-12

Question

A new supermarket with an evaporative condenser is being commissioned. The control system designer has utilized a wet bulb-following control strategy to reset the system saturated condensing temperature (SCT) setpoint. The refrigeration engineer has calculated that adding a TD of 15°F (8.3°C) above the ambient wet bulb temperature should provide a saturated condensing temperature setpoint that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT setpoint trends look like over an example day?

Answer

The following figure illustrates what the actual saturated condensing temperature and SCT setpoints could be over an example day using the wet bulb-following control strategy with a 15°F (8.3°C) TD and also observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT setpoint is continuously reset to 15°F (8.3°C) above the ambient wet bulb temperature until the minimum SCT setpoint of 70°F is reached. The figure also shows a maximum SCT setpoint (in this example, 90°F (32.2°C) which may be utilized to limit the maximum control setpoint, regardless of the ambient temperature value or TD
parameter.



10.5.2.2 Condenser Specific Efficiency

All newly installed evaporative condensers and air-cooled condensers with capacities greater than 150,000 Btuh (at the specific efficiency rating conditions) shall meet the minimum specific efficiency requirements shown in Table 10-2.

Table 10-2: Fan-powered Condensers – Minimum Specific Efficiency Requirements

Condenser Type	Minimum Specific Efficiency	Rating Condition
Evaporative-Cooled	160 Btuh/Watt	100°F Saturated Condensing Temperature (SCT), 70°F Entering Wetbulb Temperature
Air-Cooled	65 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Entering Drybulb Temperature

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection (THR) Capacity / Input Power

The total heat rejection capacity is defined at the rating conditions of 100°F Saturated Condensing Temperature (SCT) and 70°F outdoor wetbulb temperature for evaporative condensers, and 105°F SCT and 95°F outdoor drybulb temperature for air-cooled condensers. Input power is the electric input power draw of the condenser fan motors (at full speed), plus the electric input power of the spray pumps for evaporative condensers. The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices such as sump heaters shall not be included in the specific efficiency calculation.

The data published in the condenser manufacturer's published rating for capacity and power shall be used to calculate specific efficiency. For evaporative condensers, manufacturers typically provide nominal condenser capacity, and tables of correction factors that are used to convert the nominal condenser capacity to the capacity at various applied condensing temperatures and wetbulb temperatures. Usually the manufacturer publishes two sets of correction factors: one is a set of "heat rejection" capacity factors, while the others are "evaporator ton" capacity factors. Only the "heat rejection" capacity factors shall be used to calculate the condenser capacity at the efficiency rating conditions for the purpose of determining compliance with this section.

For air-cooled condensers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and drybulb temperature. Manufacturers typically assume that air-cooled condenser capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The condenser capacity for air-cooled condensers at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of condenser, the actual manufacturer's rated motor power may vary from motor nameplate in different ways. Air cooled condensers with direct-drive OEM motors may use far greater input power than the nominal motor horsepower would indicate. On the other hand, evaporative condenser fans may have a degree of safety factor to allow for higher motor load in cold weather conditions (vs. the 100°F SCT/70°F WBT specific efficiency rating conditions). Thus, actual motor input power from the manufacturer must be used for direct-drive air-cooled condensers. For evaporative condensers and fluid coolers, the full load motor power, using the minimum allowable motor efficiencies published in the Nonresidential Appendix NA-3: Fan Motor Efficiencies is generally conservative but manufacturer's applied power should be used whenever possible to more accurately determine specific efficiency.

There are three exceptions to the condenser specific efficiency requirements.

1. If the store is located in Climate Zone 1 (the cool coastal region in northern California).
2. If an existing condenser is reused for an addition of alteration.
3. If the condenser capacity is less than 150 MBH at the specific efficiency rating conditions.

Example 10-13

Question

An air-cooled condenser is being designed for a new supermarket. The refrigerant is R-507. The condenser manufacturer's catalogue states that the subject condenser has a capacity of 500 MBH at 10°F TD between entering air and saturated condensing temperatures with R-507 refrigerant. Elsewhere in the catalog, it states that the condenser has ten ½ hp fan motors that draw 450 Watts each. Does this condenser meet the minimum efficiency requirements?

Answer

First, the condenser capacity must be calculated at the specific efficiency rating condition. From Table 10-6, we see that the rating conditions for an air-cooled condenser are 95°F entering drybulb temperature and 105°F SCT. The catalog capacity is at a 10°F temperature difference, which is deemed suitable for calculating the specific efficiency (105°F SCT - 95°F entering Drybulb = 10°F TD). Input power is equal to the number of motors multiplied by the input power per motor:

10 fan motors x $\frac{\textit{450 Watts}}{\textit{fan motor}}$ *= 4,500 Watts*

The specific efficiency of the condenser is therefore:

500MBH x $\frac{\textit{1,000 Btu/hr / 4,500Watts}}{\textit{4,500 Watts}}$ *= 111Btu/hr/ Watts*

This condenser has a specific efficiency of 111 Btuh per Watt, which is higher than the 65 Btuh per Watt minimum requirement. This condenser meets the minimum specific efficiency requirements.

Example 10-14

Question

An evaporative condenser is being designed for a new supermarket. The manufacturer's catalog provides a capacity of 2,000 MBH at standard conditions of 105°F SCT and 78°F wetbulb temperature. The condenser manufacturer's catalog provides the following heat rejection capacity factors:

Non-standard Conditions Heat Rejection Capacity			
Saturated Condensing Temperature (°F)	Wet Bulb Temperature (°F)		
	70	75	78
95	1.20	1.35	1.65
100	0.95	1.10	1.25
105	0.80	0.90	1.00

Elsewhere in the catalog, it states that the condenser model has one 10 HP fan motor and one 2 HP pump motor. Fan motor efficiencies and motor loading factors are not provided by the manufacturer. Does this condenser meet the minimum efficiency requirements?

Answer

First, the condenser capacity must be calculated at the specific efficiency rating condition. From Table 10-6, we see that the rating conditions for an evaporative condenser are 100°F SCT, 70°F WBT and a minimum specific efficiency requirement is 160 Btuh/Watt. From the Heat Rejection Capacity Factors table, we see that the correction factor at 100°F SCT and 70°F WBT is 0.95. The capacity of this model at the specific efficiency rating conditions is:

2,000 MBH / 0.95 = 2,105 MBH

To calculate input power, we will assume 100% fan and pump motor loading and minimum motor efficiencies since the manufacturer has not yet published actual motor specific efficiency at the specific efficiency rating conditions. We look up the minimum motor efficiency from Nonresidential Appendix NA-3: Fan Motor Efficiencies. For a 10 HP 6-pole open fan motor, the minimum efficiency is 91.7%. For a 2 HP 6-pole open pump motor, the minimum efficiency is 88.5%. The fan motor input power is calculated to be:

$$1\ \text{Motor} \times \frac{10\ \text{HP}}{\text{Motor}} \times 746\ \frac{\text{Watts}}{\text{HP}} \times \frac{100\%\ \text{assumed loading}}{91.7\%\ \text{efficiency}} = 8{,}135\ \text{Watts}$$

The pump motor input power is calculated to be:

$$1\ \text{Motor} \times \frac{2\ \text{HP}}{\text{Motor}} \times 746\ \frac{\text{Watts}}{\text{HP}} \times \frac{100\%\ \text{assumed loading}}{88.5\%\ \text{efficiency}} = 1{,}686\ \text{Watts}$$

The combined input power is therefore:

8,135 Watts + 1,686 Watts = 9,821 Watts

Note: Actual motor power should be used when available (see note in text).

Finally, the efficiency of the condenser is:

$$\left(2{,}105\ \text{MBH} \times \frac{1{,}000\ \text{Btuh}}{\text{MBH}}\right) / 9{,}821\ \text{Watts} = 214\ \text{Btuh/Watt}$$

214 Btuh per Watt is higher than the 160 Btuh per Watt requirement; this condenser meets the minimum efficiency requirements.

Air-cooled condensers shall have a fin density no greater than 10 fins per inch. Condensers with higher fin densities have a higher risk of fouling with airborne debris. This requirement does not apply for air-cooled condensers that utilize a micro-channel heat exchange surface, since this type of surface is not as susceptible to permanent fouling in the same manner as traditional tube-and-fin condensers with tight fin spacing.

The fin spacing requirement does not apply to condensers that are reused for an addition or alteration.

10.5.3 Compressor System Mandatory Requirements

§120.6(b)2

This section addresses mandatory requirements for remote compressor systems and condensing units used for refrigeration. In addition to the requirements described below, all the compressors and all associated components must be designed to operate at a minimum condensing temperature of 70°F (21°C) or less.

10.5.3.1 **Floating Suction Pressure Controls**

§120.6(b)2A

Compressors and multiple-compressor suction groups must have floating suction pressure control to reset the saturated suction pressure control setpoint based on the temperature requirements of the attached refrigeration display cases or walk-ins.

Exceptions to the floating suction pressure requirements are:

1. Single compressor systems that do not have continuously variable capacity capability.
2. Suction groups that have a design saturated suction temperature of 30°F or higher.
3. Suction groups that comprise the high side of a two-stage or cascade system.
4. Suction groups that primarily serve chillers for secondary cooling fluids.
5. Existing compressor systems that are reused for an addition or alteration.

The examples of a two-stage system and a cascade system are shown in Figure 10-7 and Figure 10-8, respectively. Figure 10-9 shows a secondary fluid system.

Figure 10-7: Two-stage System using a Two-Stage Compressor

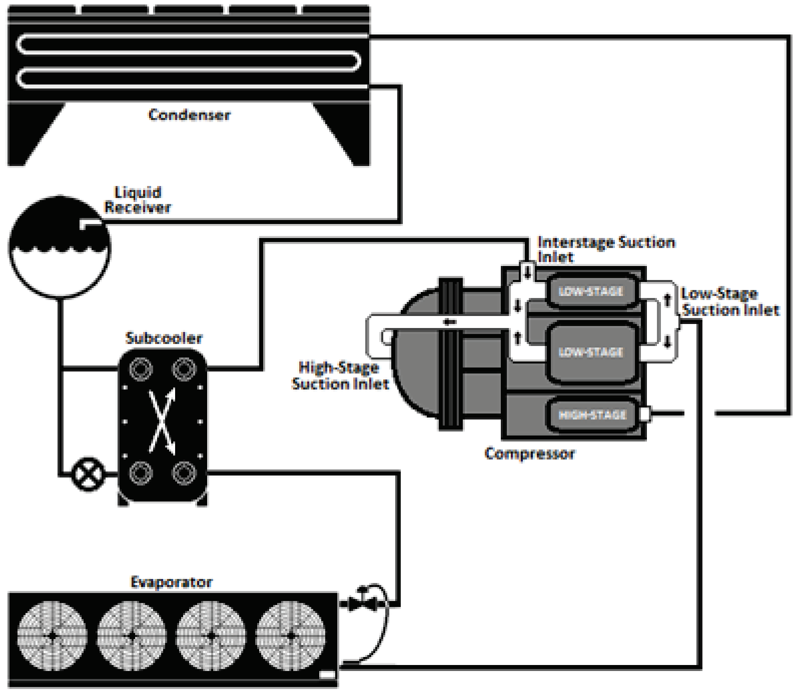


Figure 10-8: Cascade System

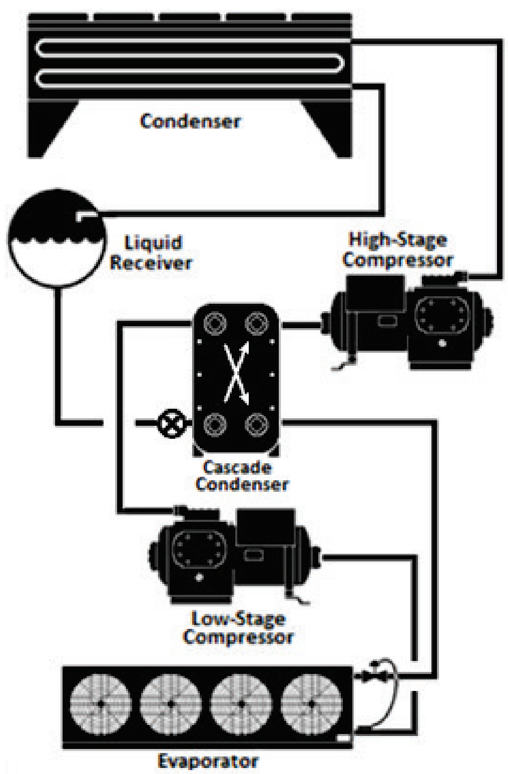
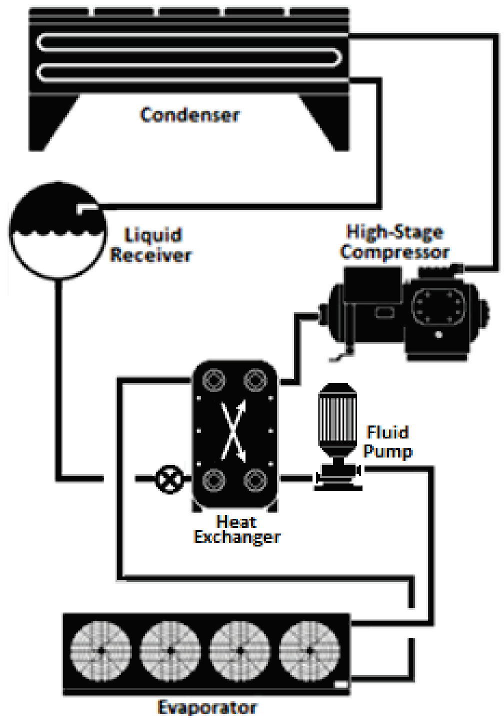


Figure 10-9: Secondary Fluid System



Example 10-15

Question

A retail food store has four suction groups, A, B1, B2 and C, with design saturated suction temperatures (SST) of -22°F, -13°F, 28°F and 35°F, respectively. System A is a condensing unit. The compressor in the condensing unit is equipped with two unloaders. Suction group B1 consists of a single compressor with no variable capacity capability. Suction group B2 has four compressors with no variable capacity capability and suction group C has three compressors with no variable capacity capability. Which of these suction groups are required to have floating suction pressure control?

Answer

Suction Groups A and B2 are required to have floating suction pressure control. The rationale is explained below.

Suction group A: Although the suction group has only one compressor, the compressor has variable capacity capability in the form of unloaders. Therefore, the suction group is required to have floating suction pressure control.

Suction group B1: The suction group has only one compressor with no variable capacity capability. Therefore, the suction group is not required to have floating suction pressure control.

Suction group B2: Although the suction group has compressors with no variable capacity capability, the suction group has multiple compressors which can be sequenced to provide variable capacity capability. Therefore, the suction group is required to have floating suction pressure control.

Suction group C: The design SST of the suction group is higher than 30°F. Therefore, the suction group is not required to have floating suction pressure control.

Example 10-16

Question

A retail food store has two suction groups, a low temperature suction group A (-22°F design SST) and medium temperature suction group B (18°F design SST). Suction group A consists of three compressors. Suction group B has four compressors that serve a glycol chiller working at 23°F. Which of these suction groups are required to have floating suction pressure control?

Answer

Suction group A: The suction group has multiple compressors. Therefore, the suction group is required to have floating suction pressure control.

Suction group B: Although the suction group has multiple compressors, it serves a chiller for secondary cooling fluid (glycol). Therefore, the suction group is not required to have floating suction pressure control.

Example 10-17

Question

A retail food store is undergoing an expansion and has two refrigeration systems: an existing system and a new CO_2 cascade system. The existing system consists of four compressors and a design SST of 18°F. The cascade refrigeration system consists of four low temperature compressors operating at -20°F SST and three medium temperature compressors operating at 26°F SST. Which of these systems are required to have floating suction pressure control?

Answer

Existing system: Although the system has multiple compressors, the compressor system is being reused, and the existing rack controller and sensors may not support floating suction pressure control. Therefore, the system is not required to have floating suction pressure control.

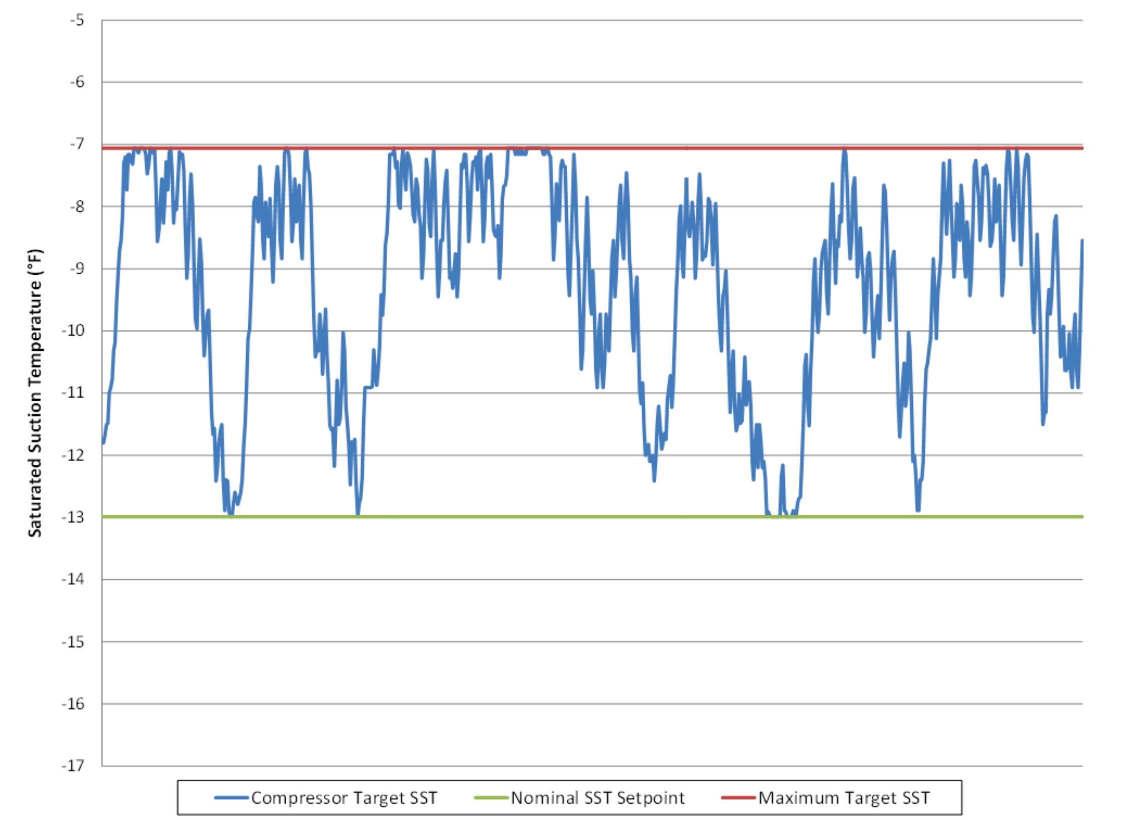
Cascade system: Only low temperature suction group of the system is required to have floating suction pressure control.

Evaporator coils are sized to maintain a design fixture temperature under design load conditions. Design loads are high enough to cover the highest expected load throughout the year, and inherently include safety factors. The actual load on evaporator coils varies throughout the day, month and year, and an evaporator coil operating at the design saturated evaporating temperature (SET) has excess capacity at most times. The SET can be safely raised during these times, reducing evaporator capacity and reducing the required “lift” of the suction group, saving energy at the compressor while maintaining proper fixture (and product) temperature.

In a floating suction pressure control strategy, the suction group target saturated suction pressure (SST) setpoint is allowed to vary depending on the actual requirements of the attached loads, rather than fixing the SST setpoint low enough to satisfy the highest expected yearly load. The target setpoint is adjusted so that it is just low enough to satisfy lowest current SET requirement of any attached refrigeration load while still maintaining target fixture temperatures, but not any higher. The controls are typically bound by low and high setpoints limits. The maximum float value should be established by the system designer, but a minimum value equal to the design SST (that is no negative float) and a positive float range of 4-6°F of saturation pressure equivalent have been used successfully.

Figure 10-10 shows hourly values for floating suction pressure control over a one week period, expressed in equivalent saturation temperature. The suction pressure control setpoint is adjusted to meet the temperature setpoint at the most demanding fixture or walk-in. The difference in SST between the floating suction pressure control and fixed suction pressure control translates into reduced compressor work and thus energy savings for the floating suction control.

Figure 10-10: Example of Floating Suction Pressure Control



A. Floating Suction Pressure Control with Mechanical Evaporator Pressure Regulators

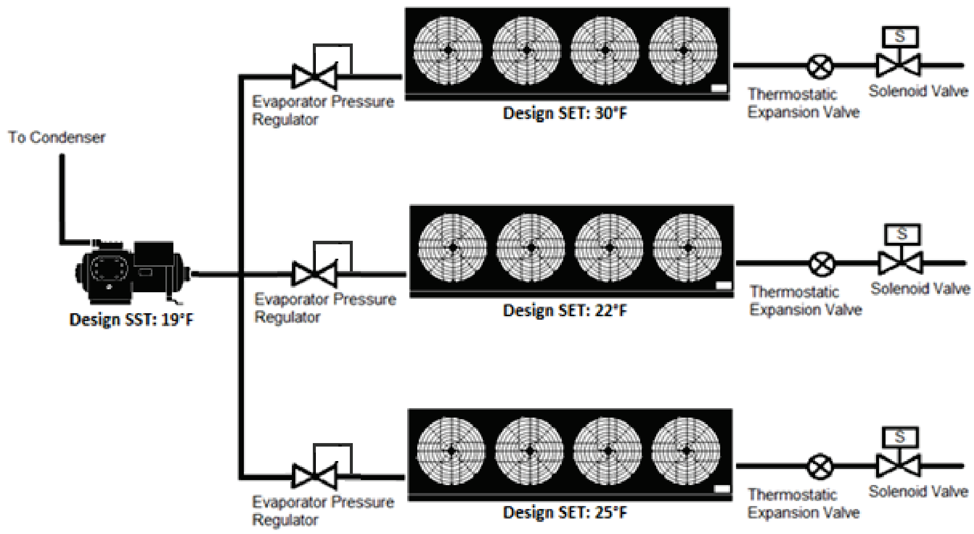
Mechanical evaporator pressure regulators (EPR valves) are often used on multiplex systems to maintain temperature by regulating the SET at each multiple evaporator connected to the common suction group, and often to also function as a suction-stop valve during defrost. EPR valves throttle to maintain the pressure at the valve inlet and thus indirectly control the temperature at the case or walk-in. The valves are manually adjusted to the pressure necessary to provide the desired fixture or walk-in air temperature. The load (circuit) with the lowest EPR pressure governs the required compressor suction pressure setpoint.

Floating suction pressure on a system with EPR valves requires special attention to valve settings on the circuit(s) used for floating suction pressure control. EPR valves on these circuit(s) must be adjusted “out of range”, meaning the EPR pressure must be set lower than what would otherwise be used to maintain temperature. This keeps the EPR valve from interfering with the floating suction control logic. In some control systems, two circuits are used to govern floating suction control; commonly designated as primary and secondary float circuits. EPR valves may also be equipped with electrically controlled wide-open solenoid pilots for more fully automatic control if desired.

Similar logic is applied on systems using on/off liquid line solenoid valves (LLSV) for temperature control, with the control of the solenoid adjusted slightly out of range to avoid interference with floating suction pressure.

These procedures have been employed to float suction on supermarket control systems since the mid-80's, however careful attention is still required during design, start-up and commissioning to insure control is effectively coordinated.

Figure 10-11: Evaporators with Evaporative Pressure Regulator Valves



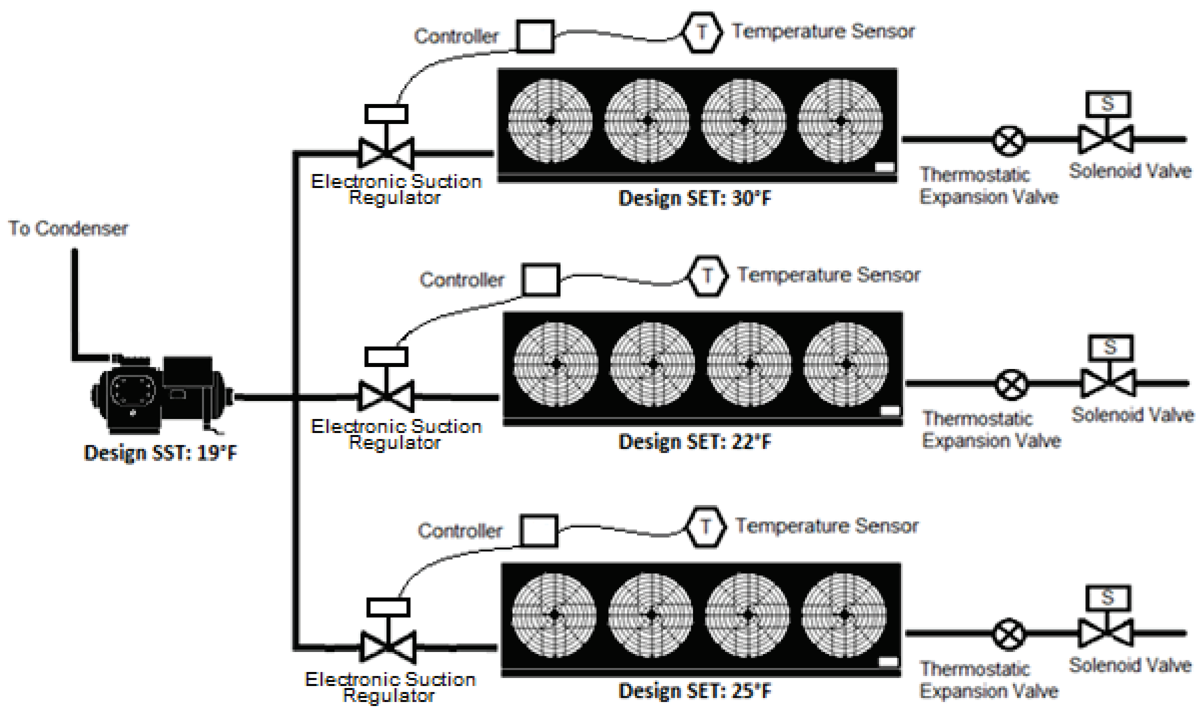
B. Floating Suction Pressure Control with Electronic Suction Regulators

An electronic suction regulator (ESR) valve is an electronically controlled valve used in the place of a mechanical evaporator pressure regulator valve. ESRs are known in industry as electronic suction regulator (ESR) or electronic evaporator pressure regulator (EEPR). It is important to note that ESR valves are not pressure regulators; instead they control the flow through the evaporator based on a setpoint air temperature at the case or walk-in. ESR valves are modulated to maintain precise temperature. This provides more accurate temperature compared to an EPR which controls temperature indirectly through pressure and is subject to pressure drop in piping and heat load (and thus TD) on the evaporator coil.

Floating suction pressure strategies with ESR valves vary depending on the controls manufacturer, but will generally allow for more flexibility than systems with EPR valves. In general, the control system monitors how much each ESR valve is opened. If an ESR is fully open, indicating that the evaporator connected to the ESR requires more capacity, the control system will respond by decrementing the SST setpoint. If all ESR valves are less than fully open, the control system increments the suction pressure up until an ESR valve fully opens. At this point, the control system starts floating down the suction pressure again. This allows suction pressure to be no lower than necessary for the most demanding fixture.

Figure 10-12 shows multiple evaporators controlled by ESR valves connected to a common suction group.

Figure 10-12: DX Evaporators with ESRs on a Multiplex System



10.5.3.2 Liquid Subcooling

§120.6(b)2B

Liquid subcooling must be provided for all low temperature compressor systems with a design cooling capacity of 100,000 Btuh or greater and with a design saturated suction temperature of -10°F or lower. The subcooled liquid temperature of 50°F or less must be maintained continuously at the exit of the subcooler. Subcooling load may be handled by compressor economizer ports, or by using a suction group operating at a saturated suction temperature of 18°F or higher. Figure 10-13 and Figure 10-14 show example subcooling configurations.

Exceptions to the liquid subcooling requirements are:

1. Low temperature cascade systems that condense into another refrigeration system rather than condensing to ambient temperature.
2. Existing compressor systems that are reused for an addition or alteration.

Figure 10-13: Liquid Subcooling Provided by Scroll Compressor Economizer Ports

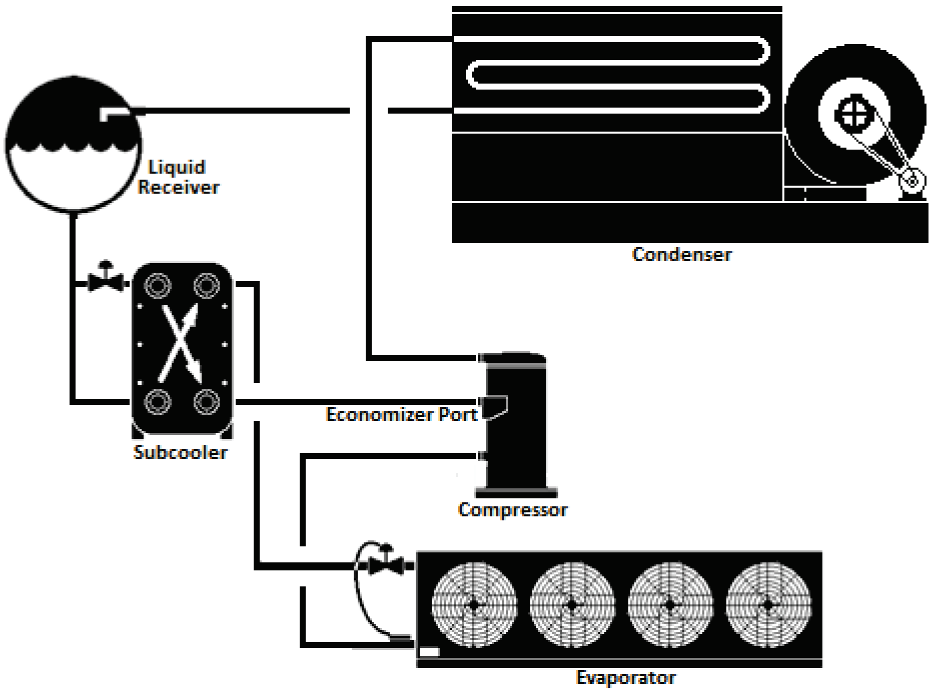
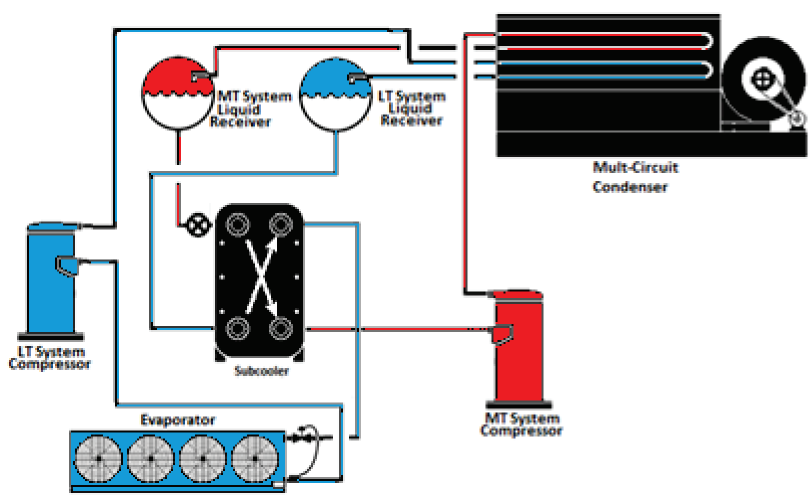


Figure 10-14: Liquid Subcooling Provided By a Separate Medium-Temperature System



10.5.4 Refrigerated Display Case Lighting Control Requirements

§120.6(b)3

All lighting in refrigerated display cases, and lights installed on glass doors of walk-in coolers and freezers shall be controlled by either automatic time switch controls and/or motion sensor control.

A. Automatic Time Switch Control

Automatic time switch controls shall turn off the lights during non-business hours.

Timed overrides for a display case line-up or walk-in case may be used to turn on the lights for stocking or non-standard business hours. The override must time-out and automatically turn the lights off again in one hour or less. The override control may be enabled manually (e.g. a push button input to the control system) or may be scheduled by the lighting control or energy management system.

B. Motion Sensor

Motion sensor control can be used to meet this requirement by either dimming or turning off the display case lights when space near the case is vacated. The lighting must dim so that the lighting power reduces to 50% or less. The maximum time delay for the motion sensor must be 30 minutes or less.

10.5.5 Refrigeration Heat Recovery

§120.6(b)4

This section addresses mandatory requirements for the use of heat recovery from refrigeration system(s) to HVAC system(s) for space heating and the charge limitations when implementing heat recovery, including an overview of configurations and design considerations for heat recovery systems. Heat rejected from a refrigeration system is the total of the cooling load taken from display cases and walk-ins in the store plus the electric energy used by the refrigeration compressors. Consequently, there is a natural relationship between the heat available and the heating needed; a store with greater refrigeration loads needs more heat to make up for the cases and walk-ins and also has more heat available.

The heat recovery requirements apply only to space heating.

There are many possible heat recovery design configurations due to the variety of refrigeration systems, HVAC systems and potential arrangement and locations of these systems. A number of examples are presented here but the Energy Standards do not require these configurations to be used. The heat recovery design must be consistent with the other requirements in the Energy Standards such as condenser floating head pressure.

At least 25 percent of the sum of the design Total Heat of Rejection (THR) of all refrigeration systems with individual design Total Heat of Rejection of 150,000 Btu/h or greater must be utilized for space heat recovery.

Exceptions to the above requirements for heat recovery are:

1. Stores located in Climate Zone 15, which is the area around Palm Springs, California. Weather and climate data are available in Joint Appendix JA2 – Reference Weather/Climate Data.
2. The above requirements for heat recovery do not apply to the HVAC and refrigeration systems that are reused for an addition or alteration.

The Energy Standards also limit the increase in hydrofluorocarbon (HFC) refrigerant charge associated with refrigeration heat recovery. The increase in HFC refrigerant charge associated with refrigeration heat recovery equipment and piping must not be greater than 0.35 lbs. per 1,000 Btuh of heat recovery heating capacity.

Example 10-18

Question

A store has three new distributed refrigeration systems, A, B and C, with design Total Heat of Rejection (THR) of 140,000 Btuh, 230,000 Btu/h and 410,000 Btuh, respectively. What is the minimum required amount of refrigeration heat recovery?

Answer

Refrigeration systems B and C have individual design THR of greater than 150,000 Btu/h, whereas refrigeration system A has design THR of less than 150,000 Btuh. Therefore, the store must have the minimum refrigeration heat recovery equal to 25% of the sum of THR of refrigeration systems B and C only. The minimum required heat recovery is therefore:

25% x (230,000 Btuh + 410,000 Btuh) = 160,000 Btuh

Example 10-19

Question

How should the Total Heat of Rejection be calculated for the purpose of this Section?

Answer

The THR value is equal to the total compressor capacity plus the compressor heat of compression.

Example 10-20

Question

A 35,000 ft2 food store is undergoing an expansion to add 20,000 square feet area. The store refrigeration designer plans to use two existing refrigeration systems with 600,000 Btu/h of design total heat rejection capacity and add a new refrigeration system with a design total heat rejection capacity of 320,000 Btu/h. The store mechanical engineer plans on replacing all the existing HVAC units. Is the store required to have refrigeration heat recovery for space heating?

Answer

Yes. The store must have the minimum required refrigeration heat recovery from the new refrigeration system. The new refrigeration system has a design THR of greater than 150,000 Btu/h threshold. The minimum amount of the refrigeration heat recovery is 25% of the new system THR. The existing refrigeration systems are not required to have the refrigeration heat recovery.

10.5.5.1 Refrigeration Heat Recovery Design Configurations

The designer of heat recovery systems must consider the arrangement of piping, valves, coils, and heat exchangers as applicable to comply with the Energy Standards. Numerous refrigeration heat recovery systems configurations are possible depending upon the refrigeration system type, HVAC system type and the store size. Some possible configurations are:

1. Direct heat recovery.
2. Indirect heat recovery.
3. Water loop heat pump system.

These configurations are described in more detail with the following sections.

A. Direct Heat Recovery

Figure 10-15 shows a series-connected direct condensing heat recovery configuration. In this configuration, the heat recovery coil is placed directly within the HVAC unit airstream (generally the unit serving the main sales area), and the discharge refrigerant vapor from the compressors is routed through the recovery coil and then to the outdoor refrigerant condenser when in heating mode. If two or more refrigeration systems are used for heat recovery, a multi-circuit heat recovery coil could be used.

This configuration is very suitable when the compressor racks are close to the air handling units used for heat recovery. If the distance is too far, an alternative design should be considered; the long piping runs may result in a refrigerant charge increase that exceeds the maximum defined in the Energy Standards, or there may be excessive pressure losses in the piping that could negatively affect compressor energy.

Figure 10-15: Series Direct Heat Recovery Configuration

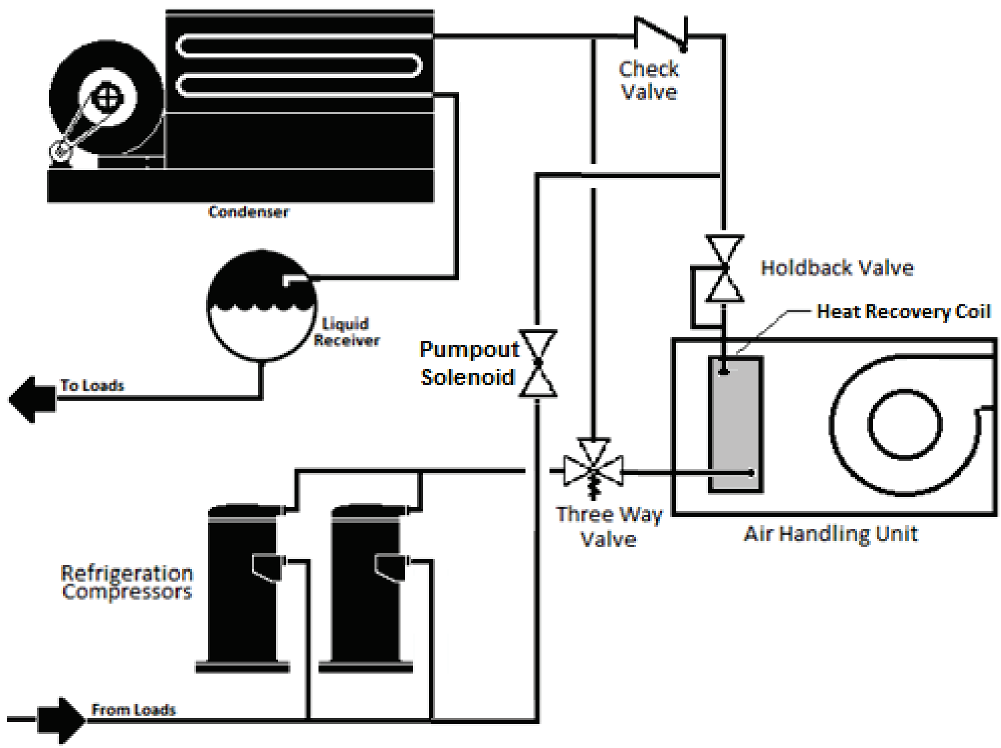
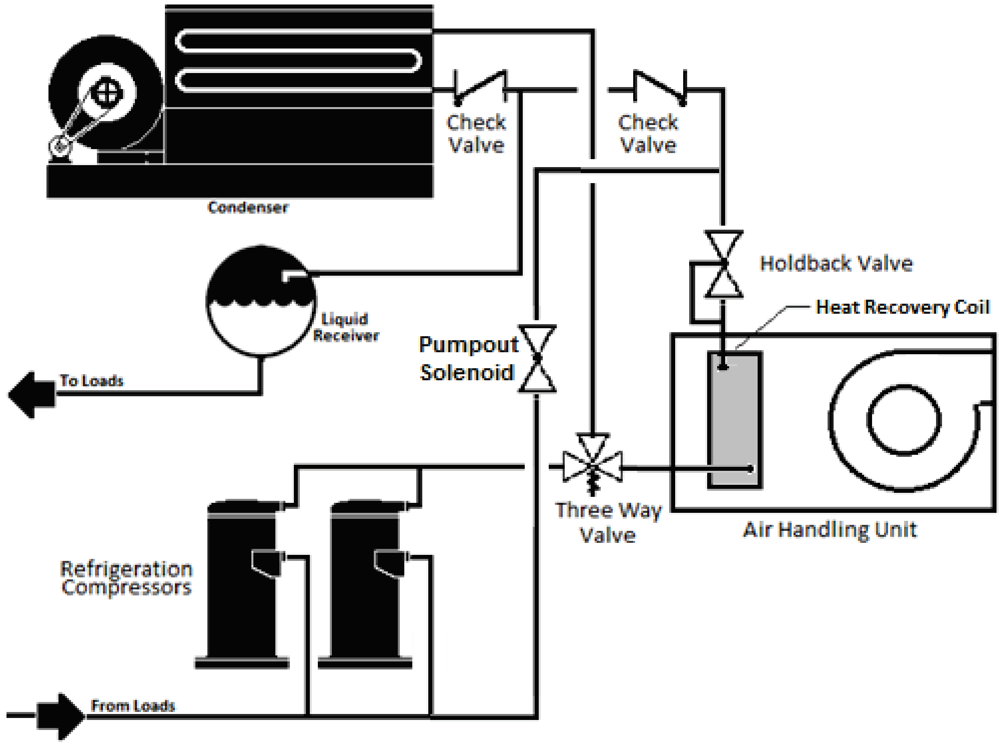


Figure 10-16 shows a parallel-connected direct-condensing configuration. In this configuration, the heat recovery coil handles the entire condensing load for the connected refrigeration system(s) when the air handling unit is in heating mode. Reduced refrigerant charge is the primary advantage of this configuration. Since the unused condenser (either the heat recovery condenser or the outdoor condenser) can be pumped out, there is no increase in refrigerant charge. A high degree of design expertise is required with this configuration in that the heat recovery condenser and associated HVAC system must take the entire heating load while operating at reasonable condensing temperatures—in any event, no higher than the system design SCT and in most instances with reasonable design no higher than 95°F-100°F condensing temperature in the heat recovery condenser. Ducting with under case or low return air design is essential in this type of system, in order to obtain cooler entering air and maintain reasonable condensing temperatures. Provision is required for practical factors such as dirty air filters.

Since the main condenser is not in use during heat recovery, the condenser floating head pressure requirements do not apply.

Figure 10-16: Parallel Direct Condensing Heat Recovery Configuration

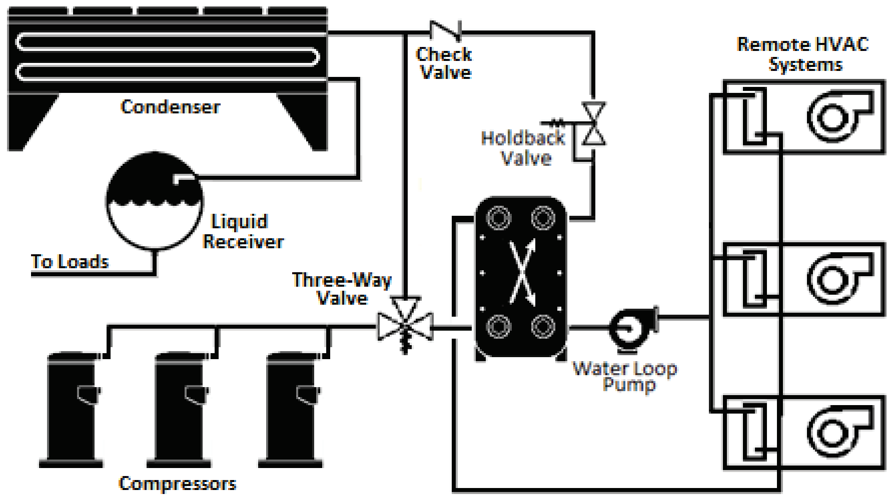


B. Indirect Heat Recovery

Figure 10-17 shows an indirect heat recovery configuration with a fluid loop. In this configuration, the recovered heat is transferred from the refrigerant to an intermediate fluid, normally water or water-glycol, which is circulated through a fluid-to-air heat exchanger located in the air handling unit airstream. Like the direct condensing configuration, discharge refrigerant gas from the compressors is routed through the refrigerant-to-fluid heat exchanger and then to the outdoor refrigerant condenser when in heating mode.

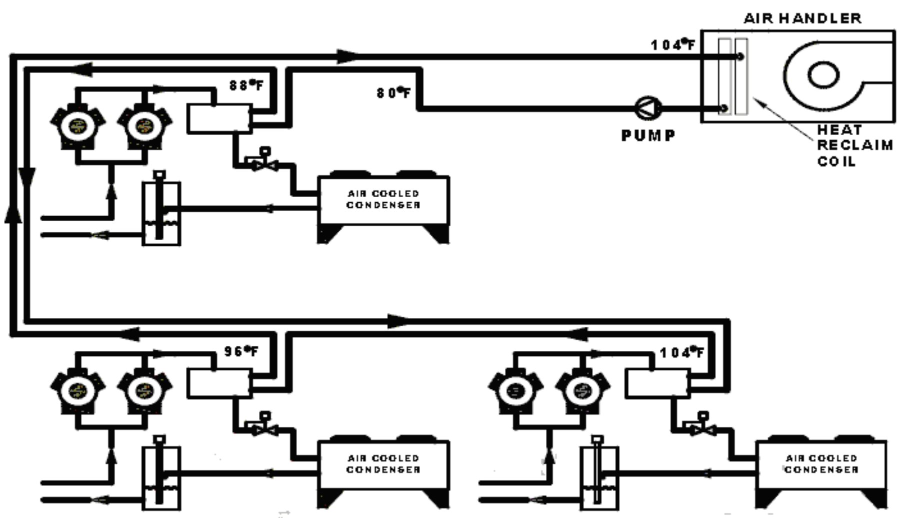
The refrigerant-to-fluid heat exchanger can be located close to the refrigeration system compressors, maximizing the available heat for recover while keeping the overall refrigerant charge increase low. This configuration is also suitable when multiple HVAC units are employed for the refrigeration heat recovery. Indirect systems must utilize a circulation pump to circulate the fluid between the HVAC unit and the recovery heat exchanger.

Figure 10-17: Indirect Heat Recovery with an Indirect Loop



Multiple refrigeration systems can also be connected in parallel or in series, using a common indirect fluid loop. Figure 10-18 shows three refrigeration systems connected in series by a common fluid loop. The temperatures shown are only examples.

Figure 10-18: Series-Piped Indirect Water Recovery



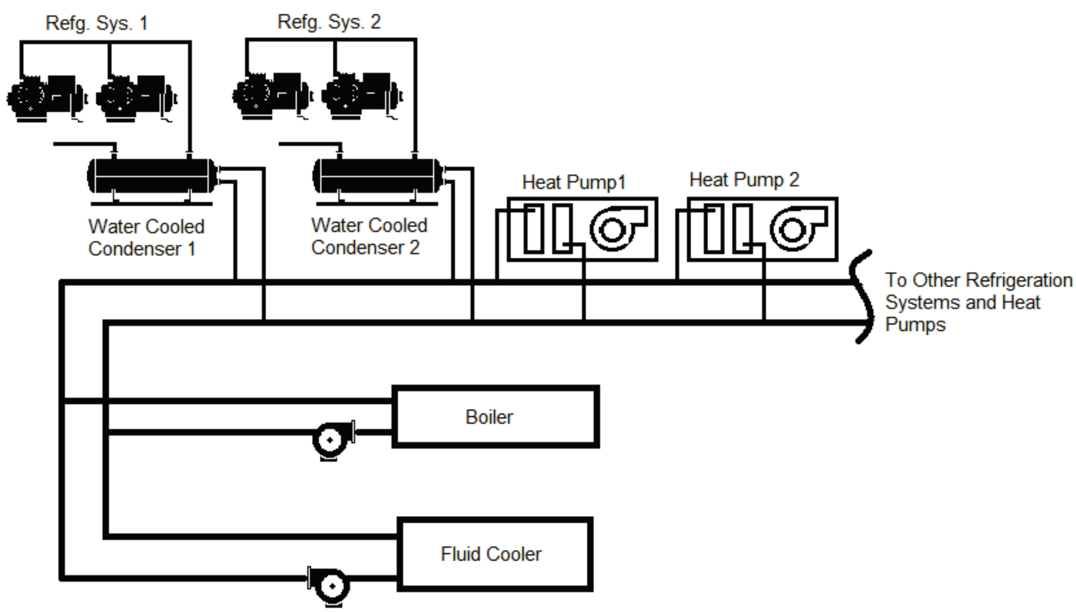
This configuration allows the refrigerant-to-water condenser temperature difference (TD) to be kept low at each refrigeration system (e.g. 8°-10°F is possible) while maintaining a sufficiently high water-side TD at the air handling unit (e.g. 20°-25°F depending on specifics) to allow an effective selection of the water-to-air heating coil vs. the available airflow. This method also minimizes both the required fluid flow and pump power.

C. Water Loop Heat Pump Heat Recovery

Water-source heat pumps (WLHP) can be used for in conjunction with water cooled refrigeration systems, connected to a common water loop as shown in Figure 10-19. Refrigeration systems heat pumps serving various zones of the store reject heat into a water loop, which in turn is rejected to ambient by an evaporative fluid cooler. When the heat pumps are in heating mode, they extract the heat rejected by the refrigeration systems from the water loop. Additional heat, if required, is provided by a boiler connected to the water loop. A significant advantage of this design is low refrigerant charge, since the refrigeration systems use a compact water-cooled condenser, typically with less charge than an air-cooled condenser and no heat recovery condenser is required. Compared with other methods, however, the electric penalty is somewhat higher to utilize the available heat.

The floating pressure requirements in the standard would apply to the fluid coolers, i.e. controls to allow refrigeration systems to float to 70°F SCT and use of wetbulb following control logic.

Figure 10-19: Water Loop Heat Pump Example

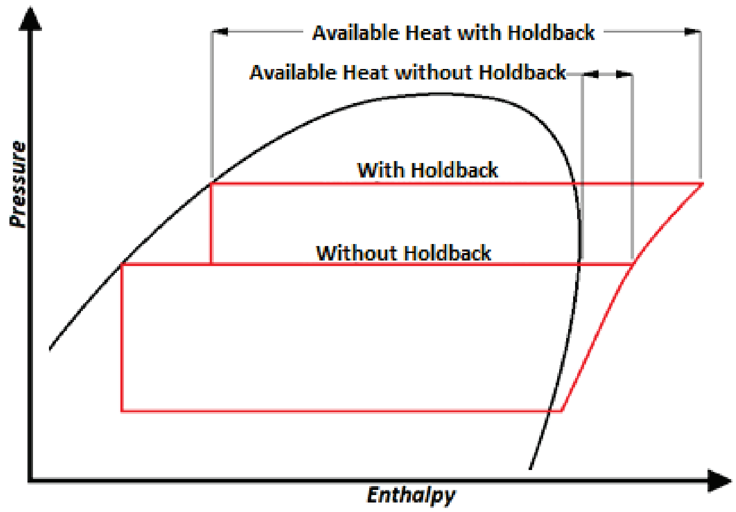


10.5.5.2 Control Considerations

A. Holdback Considerations

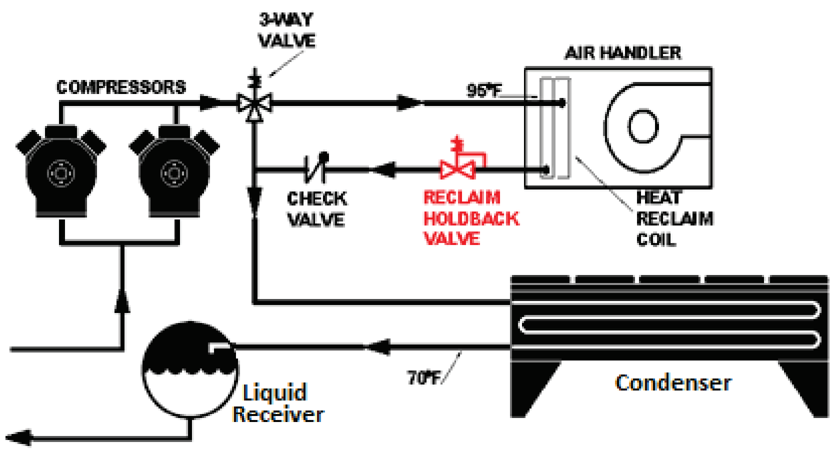
For direct and indirect systems, a holdback valve is required to control the refrigerant condensing temperature in the heat recovery coil (for direct systems) or the refrigerant-to-water condenser (for indirect systems) during heat recovery operation. Regulating the refrigerant pressure to achieve condensing recovers the latent heat from the refrigerant. Without condensing, only the sensible heat (i.e. superheat) is obtained, which is only a small fraction of the available heat. Figure 10-20 is a pressure-enthalpy diagram showing the difference in available recovery heat from a refrigeration system with and without a holdback valve.

Figure 10-20: Pressure-Enthalpy Diagram with and without a Holdback Valve



The holdback valve regulates pressure at its inlet, and is located at the exit of the recovery heat exchanger. Figure 10-21 shows a direct-condensing configuration with the proper location of the holdback valve.

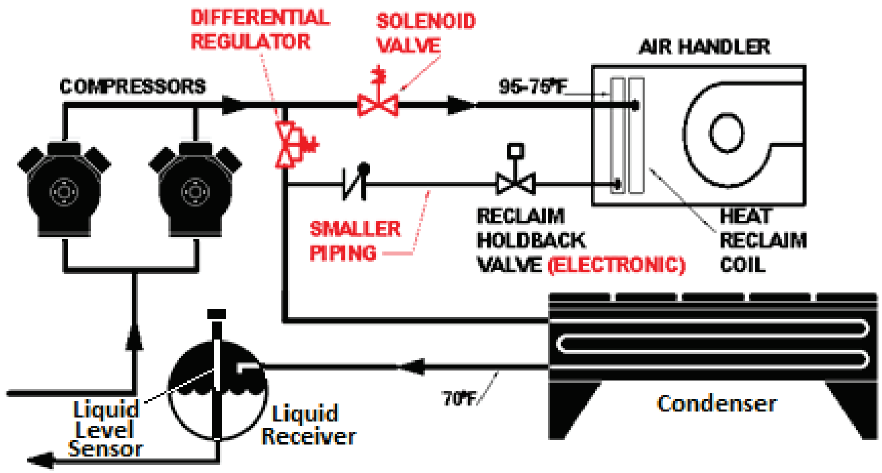
Figure 10-21: Direct-condensing configuration showing location of holdback valve



A more advanced design uses an electronic holdback valve controlled based on the temperature of the air entering the heat recovery coil. The electronic heat recovery holdback valve controls the valve inlet pressure and thus the heat recovery coil condensing temperature to maintain only the pressure necessary to achieve the required condensing TD (heat recovery SCT less entering air temperature) thereby minimizing compressor efficiency penalty. This is particularly useful when the volume outside air can significantly change the mixed air temperature entering the heat recovery coil. In colder climates, reducing the heat recovery holdback pressure can be important as a means to avoid over-condensing (i.e. subcooling). As shown in the pressure-enthalpy diagram above, there is additional flash gas handled by the condenser (even if the refrigerant fully condenses in the heat recovery coil) which is necessary to maintain piping and condenser velocity and thus minimize the charge in the outdoor condenser.

Other designs can replace the three-way valve with a differential pressure regulator and solenoid valve. Figure 10-22 shows a direct-condensing configuration with an electronic heat recovery holdback valve, solenoid valve, and differential pressure regulator.

Figure 10-22: Direct-condensing configuration showing differential regulator, solenoid valve, electronic holdback valve

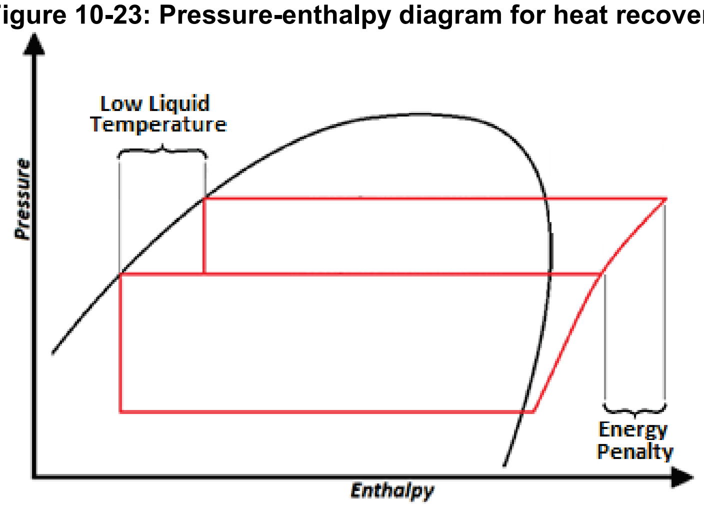


B. Heat Recovery and Floating Head Pressure

There is typically a tradeoff between heat recovery and refrigeration system efficiency, in that compressor discharge pressure must be increased to provide condensing for heat recovery. If implemented properly, the electric penalty at the refrigeration system compressors is small compared to the heating energy savings.

The Energy Standards require that the minimum condensing temperature at the refrigeration condenser shall be 70°F or less. That means that (in the typical case of series-connected heat recovery) the refrigeration “cycle” still benefits from lower refrigerant liquid temperature, even if the compressor power is somewhat increased during heat recovery. The pressure-enthalpy diagram shown in Figure 10- 23 shows the incremental energy penalty at the refrigeration compressors due to the higher discharge pressure required for heat recovery, as well as the lower liquid temperature (and thus improved refrigerant cooling capacity) by floating head pressure at the outdoor condenser.

Figure 10-23: Pressure-enthalpy diagram for heat recovery



10.5.5.3 Recovery Coil Design Considerations

A. Recovery Coil Sizing Example

Selecting an appropriately-sized heat recovery coil is essential to proper heat recovery system operation. The following example details the process of selecting a right-sized heat recovery coil.

Example 10-21

Question

A supermarket is being constructed that will utilize heat recovery. The refrigeration system selected for recovery has the following parameters:

Design Refrigeration Load: 455.8 MBH
System design SST: 24°F
Representative Compressor Capacity at Design Conditions: 54.2 MBH
Representative Compressor Power at Design Conditions: 5.59 kW

The HVAC system serving the supermarket sales area is a central air handling unit. Heat recovery will be accomplished with a direct-condensing recovery coil inside the air handling unit, downstream of both the return air duct and the outside air damper. The air handling unit has the following design parameters:

Design Air Volume: 25,000 cfm
Design Coil Face Area: 41.7 sq.ft.

To avoid excessive pressure drop across the recovery coil, the designer will select a coil with a fin density of 10 fins per inch. The heat recovery circuit will use a holdback valve set at 95°F SCT.

What is the procedure for selecting a heat recovery coil?

Answer

To size a heat recovery system, the designer should first establish a design recovery coil capacity by analyzing the refrigeration system from which heat will be recovered. Best practice dictates that the recovery system should be sized to recovery most of the available system total heat of rejection at typical operating conditions, not peak conditions. Since we are designing for average operating conditions, the designer assumes the average refrigeration load is 70% of the design load. Therefore, the average system THR for heating design is:

Average System THR = 70% x Design Refrigeration Load x THR Adjustment Factor

where:

$$\text{THR Adjustments Factor} = \frac{\text{Representative Compressor THR}}{\text{Representative Compressor Capacity}}$$

and:

Rep. Compressor THR = Rep. Compressor Capacity + Rep. Compressor Heat of Compression

Using values from the example:

$$\text{Representative Compressor THR} = 54.2\text{MBH} + \left(5.50 \text{ kW} \times 3.415 \frac{\text{MBH}}{\text{kW}}\right)$$

Representative Compressor THR = 73.3 MBH

Therefore,

$$\text{THR Adjustment Factor} = \frac{73.3 \text{ MBH}}{54.2 \text{ MBH}}$$

THR Adjustment Factor = 1.35

Using the values in this example and the calculated THR Adjustment Factor, the average system THR is:

Average system THR = 70% x 455.8 MBH x1.35

Average system THR = 430.1 MBH

It is important to note that the recovery system will not be capable of extracting 100% of the total heat of rejection since the condenser operates at a lower pressure and will reject additional heat, even if the heat recovery coil achieves full condensing. In addition, the heat recovery coil performance may often be limited by the available airflow across the coil and the consequent temperature rise vs. the heat being transferred. This performance is determined through evaluation of coil performance, considering entering air temperature, and condensing temperature, as well as the coil design (e.g. rows, fins, air velocity and other factors). Airside pressure drop can be minimized by using a larger face area, requiring lower face velocity and fewer rows.

For in this example, it was assumed that after evaluating coil performance, 85% of the average THR could be recovered with a reasonable coil velocity and coil depth.

Available Heat for Reclaim = 85% x Average System THR

Available Heat for Reclaim = 85% x 430.1 MBH

Available heat for Reclaim = 365.6 MBH

The available heat for recovery is the design capacity of the recovery coil we will select for our air handling unit.

Next, the designer needs to know the face velocity of the airstream in the air handling unit. The face velocity is:

$$F.V. = \frac{\text{Design cfm}}{\text{AHU Face Area}}$$

$$F.V. = \frac{25{,}000\ \text{cfm}}{41.7\ ft^2}$$

F.V. = 600 ft/min

Finally, the designer needs to know the temperature difference between the condensing temperature (inside the recovery coil) and the temperature of the air entering the recovery coil. Since the coil will be installed in an air handling unit downstream of the outside air damper, the designer assumes that the air entering the coil is a mix of return air from the store and outside air. The designer must determine an appropriate design temperature for the air entering the recovery coil (Entering Air Temperature or EAT) during average heating hours, which is this instance was determined to be 65°F. From the example, the heat recovery system will have a holdback valve setting of 95°F SCT. Therefore, the temperature difference is:

TD = SCT – EAT

TD = 95°F - 65°F

TD = 30°F

Using the face velocity, design coil capacity, and temperature difference between condensing temperature and entering air temperature, the designer then refers to the air handling unit catalog to select a recovery coil. Then the designer uses the following two tables:

Heat reclaim correction factor for temperature difference between air and refrigerant.

Temperature Difference (°F)	20	25	30	35	40	45	50	60
Correction Factor	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2

Hot Gas Reclaim Heating Capacities
MBH per SQ FT of coil face area

Rows	FPI	Face Velocity (ft/min)		
		500	550	600
2	8	10.9	11.38	11.85
	10	12.15	12.73	13.18
	12	13.13	13.77	14.35
3	8	14.56	15.25	15.9
	10	15.93	16.8	17.63
	12	17.08	18.03	18.95
4	8	17.43	18.47	19.47
	10	18.75	19.92	21.07
	12	19.98	21.25	22.5

The designer enters the first table with the calculated TD of 30°F, finding a correction factor of 0.6. We enter the second table with the value:

$$\text{MBH per SQ FT} = \frac{\text{(Design Coil Capacity)}}{\text{Coil Face Area}} / \text{Correction Factor}$$

$$\text{MBH per SQ FT} = \frac{\text{(4184 MBH)}}{41.7\ ft^2} / 0.6$$

MBH per SQ FT = 16.72

Per design requirements, the designer will select a 10 fin-per-inch coil. From the second table, the designer selects the 3-row, 10 fin-per-inch coil for this application.

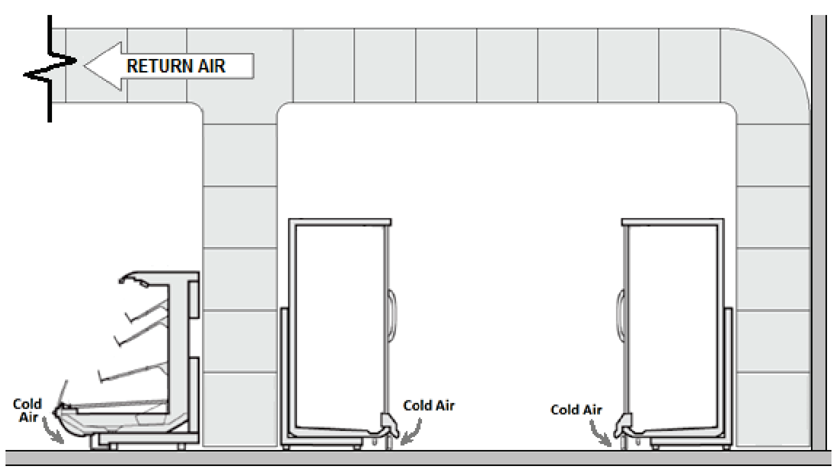
More commonly, computerized selection tools are used to select heat recovery coils, allowing vendors to provide multiple selections for comparison.

B. Air-side Integration Considerations

1. Return Air Location

In supermarkets, ducting return air from behind display cases or near the floor is beneficial in improving comfort by removing the stagnant cool air that naturally occurs due to product refrigeration cases. This approach also increases the effectiveness of refrigeration heat recovery by increasing the temperature difference between the return air temperature and the refrigerant condensing temperature in the heat recovery coil. Figure 10-24 shows the location of an HVAC return air duct positioned to scavenge cool air from the floor level near refrigerated display cases.

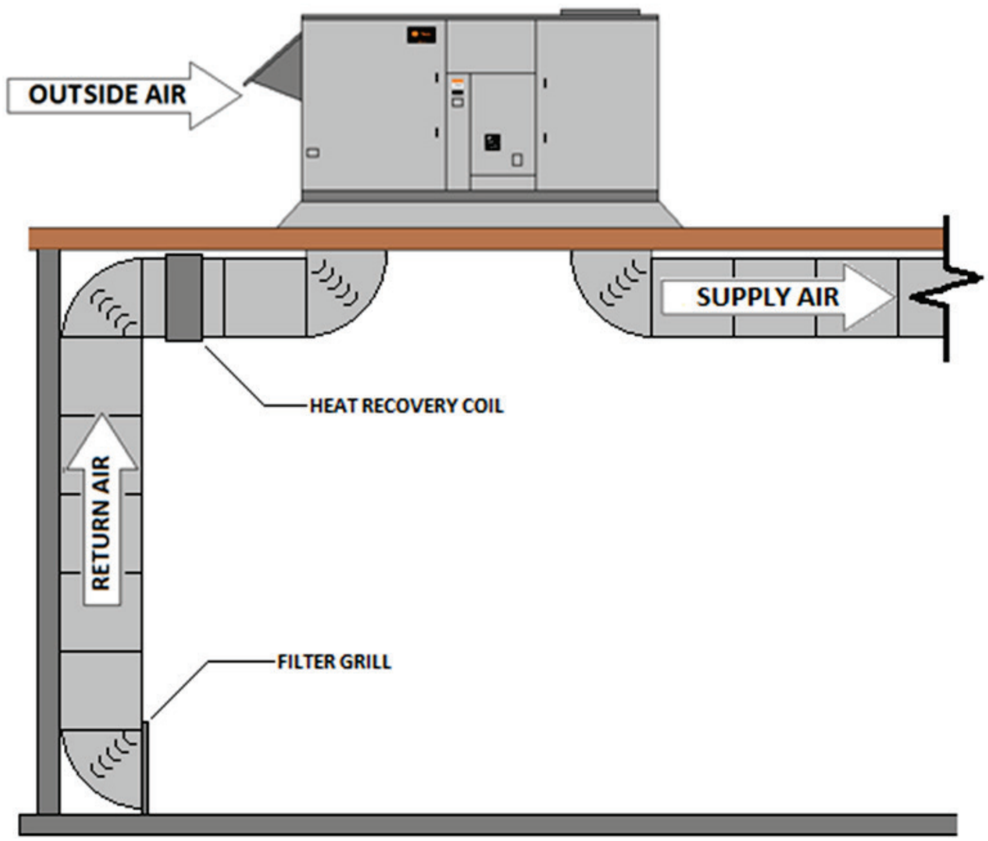
Figure 10-24: Low Return Air Example



2. Return Air Duct Configuration

Heat recovery can be incorporated into rooftop HVAC units (RTU) by installing the heat recovery coil inside the RTU cabinet or by installing in the return air duct upstream of the RTU, as shown in Figure 10-25. Location inside the RTU is preferable when outside air is a substantial part of the heating load, but location in the return air duct is reasonable and can provide greater flexibility in selecting the heat recovery coil (e.g. for low face velocity and pressure drop), particularly when coupled with low return air on units located in the refrigerated space, which predominantly provide heating. The fan design must allow for the additional ductwork and coil pressure drop.

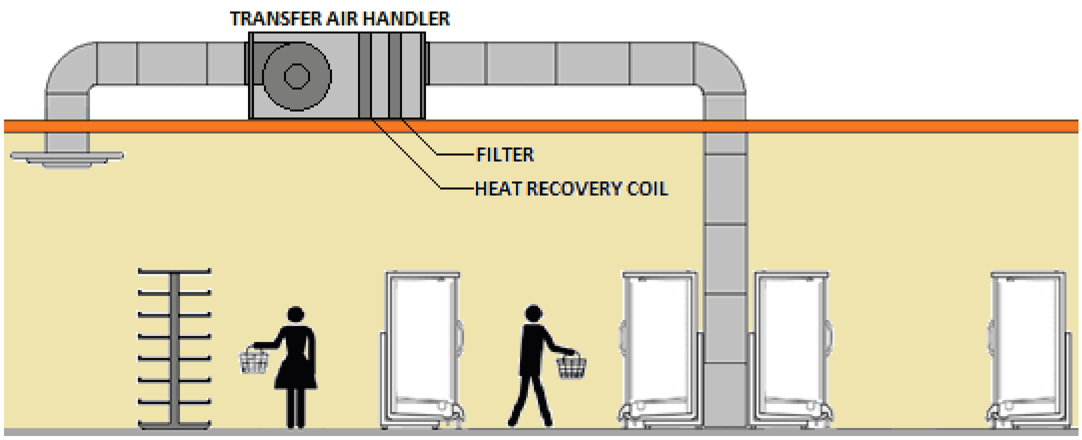
Figure 10-25: Heat Recovery Coil in Return Air Duct



3. Transfer Fan Configuration

A ducted transfer system is sometimes employed to remove cold air from aisles with refrigerated display cases (rather than blowing warm air into the refrigerated areas) and can be an easy and appropriate way to utilize heat recovery, particularly from smaller distributed systems. Figure 10-26 depicts a ducted transfer system.

Figure 10-26: Ducted Transfer System



4. Calculating Charge Increase

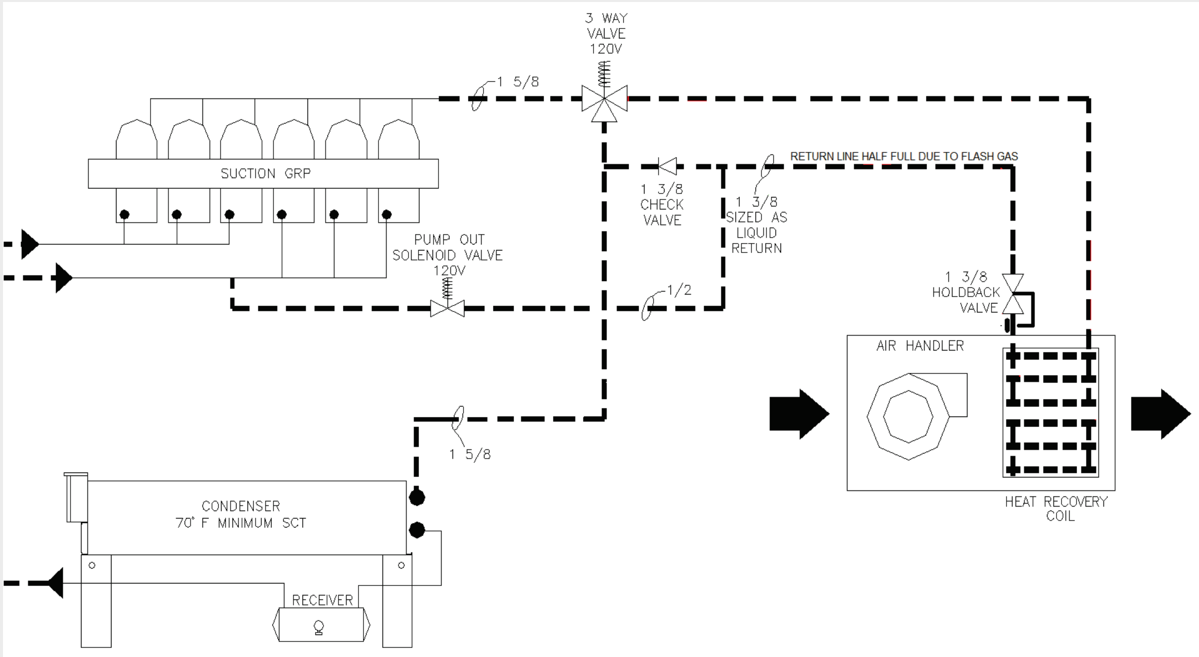
The Energy Standards require that the increase in HFC refrigerant charge from all equipment related to heat recovery for space heating shall be less than 0.35 lbs. for every 1,000 Btuh of heat recovery capacity at design conditions. Refrigerant charge may increase due to the addition of the recovery coil itself (either the refrigerant-to-air heat exchanger for direct configurations, or the refrigerant-to-water heat exchanger for indirect configurations), and the additional piping between the compressor group and the recovery coil. In addition, the refrigerant leaving the recovery coil and entering the refrigerant condenser will be mostly condensed, which increases the charge in the outdoor condenser compared with normal operation. Operating the outdoor condenser at lower pressure (i.e. the required floating heat pressure control) vs. the higher setting at the heat recovery coil holdback valve creates pressure drop, flashing of some liquid to vapor and an increase in velocity due to the much larger volume of a pound of vapor vs. a point of liquid refrigerant. Split condenser control, which is very common in cooler climates, can also be used to close-off and pump out half of the outdoor condenser.

It is the responsibility of the system designer to fully understand how the heat recovery system affects overall refrigerant charge.

Example 10-22

Question

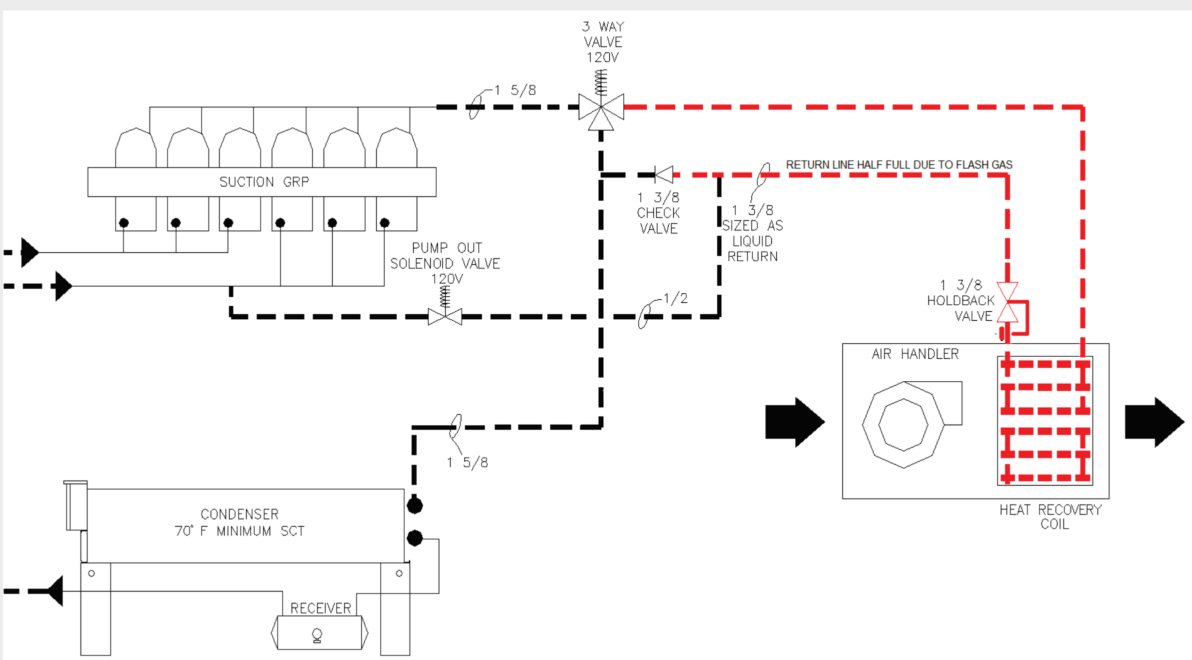
A heat recovery system is being designed for a new supermarket. The refrigerant is R-404A. The proposed design is shown below:



Which piping runs should be included in the calculation of refrigerant charge increase in the proposed design?

Answer

Only the additional piping required to route the refrigerant to the heat recovery coil needs to be considered in this calculation. The piping runs shown in red in the following figure should be included in the calculation of refrigerant charge increase from heat recovery.



Example 10-23

Question

What is the refrigerant charge size increase in the example described above?

Answer

The system designer prepares the following analysis to calculate the charge size in the refrigerant piping

	Saturation Temperature (°F)	Pipe OD (in)	Pipe ID (in)	Pipe Length (ft)	Line Volume (ft^3)	% Vapor, Liquid by Mass	% Vapor, Liquid by Volume	Refrigerant Charge (lbs)
Discharge Line to Reclaim Coil	95	1 5/8	1 1/2	100	1.2	100%, 0%	100%, 0%	6.7
Liquid/Vapor Return Line	80	1 3/8	1 1/4	100	0.9	9%, 91%	59%, 41%	25.5
							Total Charge:	32.2

The outdoor condenser has a capacity of 350 MBH at a TD of 10°F. Using manufacturers published data, the designer determines that the condenser normal operating charge (without heat recovery) is 26.9 lbs. To calculate the charge increase in the condenser due to heat reclaim, the designer estimates the condenser could be as much as 75% full of liquid, resulting in a condenser charge of 68.8 lbs. with heat recovery.

The heat recovery coil has a capacity of 320 MBH at a design TD of 20°F. The system designer uses manufacturer's documentation to determine that the heat recovery coil refrigerant charge is 14.1 lbs.

The total refrigerant charge with heat recovery is:

32.2 lbs (piping) + 68.8 lbs (system condenser) + 14.1 lbs (recovery coil) = 115.1 lbs

Therefore, the refrigerant charge increase with heat recovery is:

115.1 lbs – 26.9 lbs = 88.2 lbs

Example 10-24

Question

In the example above, does the recovery design comply with the requirement in the Energy Standards that the recovery design shall utilize at least 25% of the design Total Heat of Rejection (THR) of the refrigeration system?

Answer

The system designer determines that the total THR of all the refrigeration systems in the new supermarket is 800 MBH. From the previous example, the heat recovery capacity is 320 MBH.

$$100\ \% \times \frac{320\ MBH}{800\ MBH} = 40\%$$

Therefore, the design is in compliance with the Energy Standards.

Example 10-25

Question

In the example above, does the recovery design comply with the requirement in the Energy Standards that the recovery design shall not increase the refrigerant charge size by more than 0.35 lbs. of refrigerant per 1,000 Btuh of recovery capacity?

Answer

From the previous example, the recovery capacity is 320 MBH at design conditions, and the total refrigerant charge size increase is 88.2 lbs.

$$\frac{88.2\ lbs}{320\ MBH} = 0.28\ lbs/Btuh$$

Since the refrigerant charge increases by less than 0.35 lbs/MBH, this design is in compliance with the Energy Standards.

10.5.6 Additions and Alterations

§141.1(b)

Requirements related to commercial refrigeration additions and alterations to existing buildings are covered by the Energy Standards in §141.1(b). The specific requirements for additions and alterations for Commercial Refrigeration are included in §120.6(b).

10.5.7 Compliance Documentation

Compliance documentation includes the forms, reports and other information that are submitted to the enforcement agency with an application for a building permit (Certificate of Compliance). Compliance documentation also includes documentation completed by the installing contractor, engineer/architect of record, or owner's agent to verify that certain systems and equipment have been correctly installed and commissioned (Installation Certificate).

Form NRCC-PRC-05-E for Commercial Refrigeration - Certificate of Compliance

NRCC-PRC-05-E is the primary form for commercial refrigeration in retail food stores, which provides compliance information for the use of the enforcement agency's field inspectors. This form must be included on the plans. A copy of this form should also be submitted to the enforcement agency along with the rest of the compliance submittal at the time of building permit application. With enforcement agency approval, the applicant may use alternative formats of these forms (rather than the Energy Commission's forms), provided the information is the same and in similar format.

10.6 Refrigerated Warehouses

10.6.1 Overview

This section of the manual focuses on the Energy Standards provisions unique to refrigerated warehouses. The Energy Standards described in this chapter of the manual address refrigerated space insulation levels, underslab heating requirements in freezers, infiltration barriers, evaporator fan controls, condenser sizing and efficiency requirements, condenser fan controls, and screw compressor variable speed requirements.

All buildings regulated under Part 6 of the Energy Standards must also comply with the General Provisions of the Energy Standards (§100.0 – §100.2, §110.0 – §110.10, §120.0 – §120.9, §130.0 – §130.5), and additions and alterations requirements (§141.1). These topics are generally addressed in Chapter 3 of this manual.

10.6.1.1 Mandatory Measures and Compliance Approaches

The energy efficiency requirements for refrigerated warehouses are all mandatory. There are no prescriptive requirements or performance compliance paths for refrigerated warehouses. Since the provisions are all mandatory, there are no trade-offs allowed between the various requirements. The application must demonstrate compliance with each of the mandatory measures. Exceptions to each mandatory requirement, when applicable, are described in each of the mandatory measure sections below.

10.6.1.2 Scope and Application

§120.6(a)

§120.6(a) of the Energy Standards addresses the energy efficiency of refrigerated spaces within buildings, including coolers and freezers, as well as the refrigeration equipment that serves those spaces. Coolers are defined as refrigerated spaces designed to operate at or above 28°F (-2°C) and at or below 55°F (13°C). Freezers are defined as refrigerated spaces designed to operate below 28°F (-2°C). The subsections of §120.6(a) that cover refrigerated space requirements are 1, 2, 3, 6, and 7. The Energy Standards do not address walk-in coolers and freezers, as these are covered by the Appliance Efficiency Regulations (Title 20). A walk-in is defined as a refrigerated space that is less than 3,000 ft² in floor area. However, refrigeration systems (compressors and condensers that have a common refrigerant supply) that serve a sum total of 3,000 ft² or more are required to comply with the subsections of §120.6(a) that addresses those components specifically (subsections 4, 5, and 7). Also note that refrigeration systems and refrigerated display fixtures in grocery stores are covered in §120.6(b) and are described in Section 10.5 of this manual.

Additionally, areas within refrigerated warehouses designed solely for the purpose of quick chilling or quick freezing of products are exempt from the Energy Standards. Quick chilling and freezing spaces are defined as spaces with a design refrigeration evaporator load of greater than 240 Btu/hr-ft² of floor space, which is equivalent to 2 tons per 100 ft² of floor space. A space used for quick chilling or freezing and also used for refrigerated storage must still meet the requirements of §120.6(a).

The intent of the Energy Standards is to regulate storage space, not quick chilling or freezing space, or process equipment. Recognizing that there is often a variety of space types and equipment connected to a particular suction group in a refrigerated warehouse, it is not always possible to identify compressor plant equipment that serves the storage space only. It would be outside the intent of the Energy Standards to apply the compressor plant requirements to an industrial process that is not covered by the Energy Standards simply because a small storage space is also attached to the suction group. Similarly, it would be outside of the intent of the Energy Standards to exclude a compressor plant connected to a suction group serving a large storage space covered by the Energy Standards on the basis of a small process cooler or quick chill space also connected to the same suction group. For the purposes of compliance with the Energy Standards, the compressor plant requirements apply when 80 percent or more of the design refrigeration capacity connected to the suction group is from refrigerated storage space(s). A suction group refers to one or more compressors that are connected to one or more refrigeration loads, whose suction inlets share a common suction header or manifold.

A variety of space types and processes may be served by a compressor plant at different suction pressures. When all of these compressors share a common condensing loop, it is impossible to address only the equipment serving refrigerated storage spaces. For the purposes of compliance with the Energy Standards, the provisions addressing condensers, subsection 4, apply only to new condensers that are part of new refrigeration systems when the total design capacity of all refrigerated storage spaces served by compressors using a common condensing loop is greater than or equal to 80 percent of the total design capacity.

In addition to an all-new refrigerated facility, the Energy Standards cover expansions and modifications to an existing facility and an existing refrigeration plant. The Energy Standards do not require that all existing equipment must all comply when a refrigerated warehouse is expanded or modified using existing refrigeration equipment. Exceptions are stated in the individual equipment requirements and an explanation of applicability to Additions and Alterations is included in Section 10.4.

10.6.1.3 **Ventilation**

§120.1(a)1 of the Energy Standards, concerning ventilation requirements, includes an exception for “Refrigerated warehouses and other spaces or buildings that are not normally used for human occupancy and work”. The definition of refrigerated warehouses covers all refrigerated spaces at or below 55°F (13°C) which will in some instances include spaces with occupancy levels or durations, effect of stored product on space conditions, or other factors which may require ventilation for one or more reasons. Accordingly, while the Energy Standards do not require ventilation for refrigerated warehouses, it is acknowledged that ventilation may be needed in some instances and is left to the determination of the owner and project engineer.

Example 10-26

Question

A space that is part of a refrigerated facility is used solely to freeze meat products and not for storage. The design evaporator load is 310 Btu/hr-ft² at the applied conditions. Does the space have to comply with the space requirements (subsections 1, 2, 3, 6, and 7) of the Energy Standards?

Answer

No. The design evaporator capacity is more than 240 Btu/hr-ft² and the space is not used for long-term storage. This space meets the definition of a quick chilling space. Therefore, the space does not have to comply with the space requirements (subsections 1, 2, 3, 6, and 7) of the Energy Standards.

Example 10-27

Question

A refrigerated warehouse space is used to cool and store melons received from the field. After the product temperature is pulled down, the product is stored in the same space for a few days until being shipped or sent to packaging. The design evaporator capacity is 300 Btu/hr-ft^2 at the applied conditions. Does the space have to comply with the space requirements (subsections 1, 2, 3, 6, and 7) of the Energy Standards?

Answer

Yes. While the design evaporator capacity is greater than 240 Btu/hr-ft² and the space is used for product pull down for part of the time, the space is also used for holding product after it has been cooled. Accordingly, the space has to comply with the space requirements (subsections 1, 2, 3, 6, and 7) of the Energy Standards.

Comment: The Standard does not define a specific time limit that a quick chill (which for clarity includes quick “freeze”) space could operate as a holding space (i.e. at full speed and thus full fan power). The typical high fan power density in a quick chill space, particularly at full speed after the high cooling load has been removed, is very inefficient. Thus a reasonable expectation for a dedicated quick chill space is to allow no more time (at full speed) than is appropriate to remove the product in a normal business cycle of loading, cooling/freezing, and removing product once it has been reduced to temperature. If product is to be held any longer, variable speed is required to reduce fan power. Variable speed requirements are discussed in under mechanical system requirements (sub-section 10.6.3B) of this Chapter 10.

Example 10-28

Question

A new refrigeration system serves both storage and quick chilling space. The design refrigeration capacity of the storage space is 500 tons. The design capacity of the quick chilling space is 50 tons. Is the refrigeration system required to meet the requirements of the Energy Standards?

Answer

Yes. Since more than 80 percent of the design capacity of the system is serving storage space, the refrigeration system requirements apply.

Example 10-29

Question

A new refrigerated warehouse is being constructed, which will include a 1,500 ft² cooler space, and a 2,500 ft² freezer space. Both the cooler and freezer are served by a common refrigeration system. Is the refrigeration system required to comply with the Standard?

Answer

Since the cooler and freezer each have less than 3,000 ft² of floor area, they are not required to comply with the Standard. However, they are considered walk-ins and must comply with the requirements of the Appliance Efficiency Regulations (Title 20).

Since the suction group serves a sum total 4,000 ft² of refrigerated floor area, the compressors and condenser are required to comply with subsections 4, 5, and 7 of §120.6(a), which specifically address refrigeration system requirements.

10.6.2 Building Envelope Mandatory Requirements

§120.6(a) subsections 1, 2, and 6 of the Energy Standards address the mandatory requirements for refrigerated space insulation, underslab heating, and infiltration barriers.

10.6.2.1 Envelope Insulation

§120.6(a)1

A. Wall and Roof Insulation

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Material* (C.C.R., Title 24, Part 12, Chapters 12-13), which ensure that insulation sold or installed in the state performs according to stated R-values and meets minimum quality, health, and safety standards. These Standards state that all thermal performance tests shall be conducted on materials which have been conditioned at 73.4° ± 3.6°F and a relative humidity of 50 ± 5 percent for 24 hours immediately preceding the tests. The average testing temperature shall be 75° ± 2°F with at least a 40°F temperature difference. Builders may not install insulating materials unless the product has been certified by the Department of Consumer Affairs, Bureau of Home Furnishing and Thermal Insulation. Builders and enforcement agencies shall use the Department of Consumer Affairs Directory of Certified Insulation Material to verify the certification of the insulating material.

Refrigerated spaces with 3,000 ft² of floor area or more shall meet the minimum R-Value requirements shown in Table 10-3.

Table 10-3: Refrigerated Warehouse Insulation

SPACE	SURFACE	MINIMUM R-VALUE (°F·hr·ft²/Btu)
Freezers	Roof/Ceiling	R-40
	Wall	R-36
	Floor	R-35
	Floor with all heating from productive refrigeration capacity	R-20
Coolers	Roof/Ceiling	R-28
	Wall	R-28

The R-values shown in Table 10-3 apply to all surfaces enclosing a refrigerated space, including refrigerated spaces adjoining conditioned spaces, other refrigerated spaces, unconditioned spaces and the outdoors. If a partition is used between refrigerated spaces that are designed to always operate at the same temperature, the requirements do not apply. The R-values are the nominal insulation R-values and do not include other building materials or internal or external “film” resistances.

Example 10-30

Question

A refrigerated warehouse designed to store produce at 45°F (7°C) is constructed from tilt-up concrete walls and concrete roof sections. What is the minimum R-value of the wall and roof insulation?

Answer

Since the storage temperature is greater than 28°F (-2°C), the space is defined as a cooler. The minimum R-value of the wall and roof insulation according to Table 10-3 is R-28.

Example 10-31

Question

A refrigerated warehouse is constructed of a wall section consisting of 4 inches of concrete, 6 inches of medium density (2 lb/ft³) foam insulation and another 4 inches of concrete. The nominal R-value of the foam insulation is R-5.8 per inch. What is the R-value of this wall section for code compliance purposes?

Answer

The insulating value of the concrete walls is ignored. The R-value of this wall section for code compliance purposes is based on the 6 inches of foam insulation at R-5.8 per inch, or R-34.8.

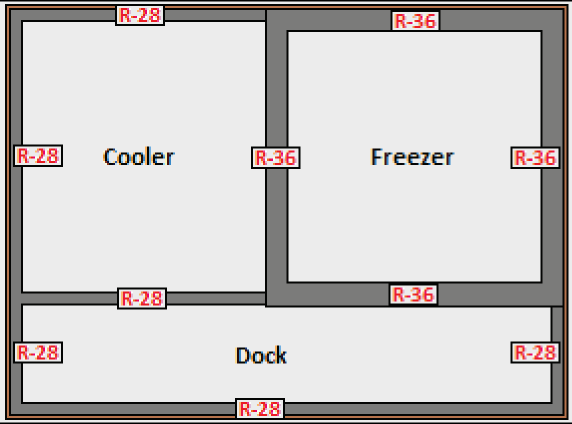
Example 10-32

Question

A 35°F cooler space is adjacent to a -10°F freezer space. What is the minimum required insulation R-value of the shared wall between the cooler and freezer spaces?

Answer

The minimum insulation R-value requirements should be interpreted to apply to all surfaces enclosing the refrigerated space at the subject temperature. Therefore, since the freezer space walls must be insulated to the minimum R-value requirements shown in Table 10-3, the R-value of the shared wall insulation must be at least R-36. The minimum insulation R-value requirement of the other three cooler walls is R-28. The figure below illustrates this example.



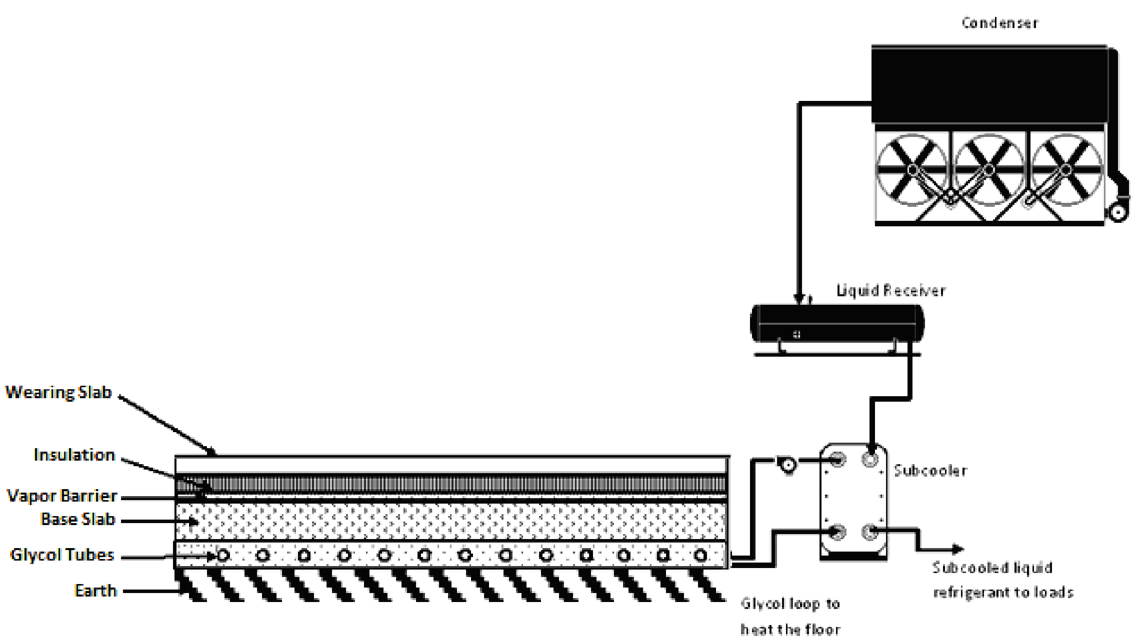
B. Freezer Floor Insulation

Freezer spaces with 3,000 ft² of floor area or more shall meet the minimum floor insulation R-value requirements shown in Table 10-3. The requirement is a minimum R-value of R-35, with an exception if the underslab heating system increases productive refrigeration capacity, in which case the minimum R-value is R-20.

The predominant insulating material used in freezer floors is extruded polystyrene, which is commonly available in 2”-thick increments, but can optionally be purchased in 1”-thick increments as well. Extruded polystyrene has an R-value of R-5 per inch at standardized rating conditions, and extruded polystyrene panels can be stacked, so the freezer floor can be constructed with R-value multiples of 5 (R-30, R-35, R-40).

A lower floor insulation R-value of R-20 is allowed if all of the underslab heat is provided by an underslab heating system that increases productive refrigeration capacity. An example of an underslab heating system utilizing heat from a refrigerant liquid subcooler is shown in Figure 10-27.

Figure 10-27: Underslab Heating System that Utilizes Refrigerant Subcooling



The lower R-value requirement when this type of underslab heating system is used is justified because the increased underslab heat gain to the space due to reduced insulation is offset by the heat extracted from the refrigerant liquid—which is a direct reduction in compressor load. The minimum requirement of R-20 does not mean that R-20 is the optimum or appropriate insulation choice in all installations. Rather, R-20 is a cost-effective trade-off when underfloor heating is obtained via productive refrigeration. Higher insulation levels combined with heating from productive refrigeration would further improve efficiency.

10.6.2.2 **Underslab Heating Controls**

§120.6(a)2

Underslab heating systems should be used under freezer spaces to prevent soil freezing and expansion. The underslab heating element might be electric resistance, forced air, or heated fluid; however, underslab heating systems utilizing electric resistance heating elements are not permitted unless they are thermostatically-controlled and disabled during the summer on-peak period. The summer on-peak period is defined by the supplying electric utility, but generally occurs from approximately 12 PM to 6 PM weekdays during the months of May through October. The control system used to control any electric resistance underslab heating elements must automatically turn the elements off during this on-peak period. The control system used to control electric resistance underslab heating elements must be shown on the building drawings, and the control sequence demonstrating compliance with this requirement must be documented on the drawings and in the control system specifications.

10.6.2.3 **Infiltration Barriers**

120.6(a)6

Passageways between freezers and higher-temperature spaces, and passageways between coolers and non-refrigerated spaces, shall have an infiltration barrier such as:

- Strip curtains.
- An automatically closing door.
- Air curtain.

Examples of each are shown in the figures below.

Figure 10-28: Strip Curtains

Figure 10-29: Bi-parting automatic door

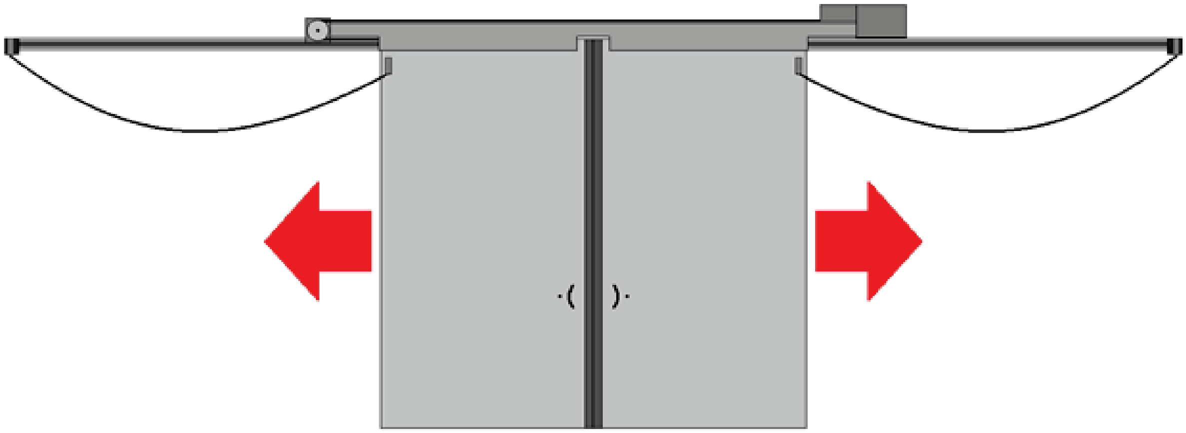


Figure 10-30: Hinged door with spring-action door closer and door "tight" closer

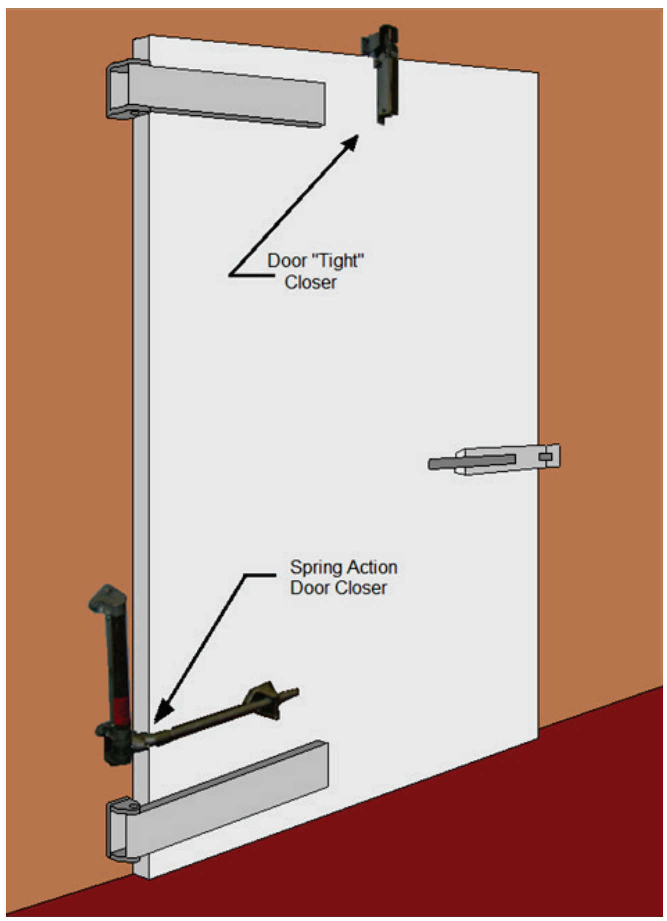
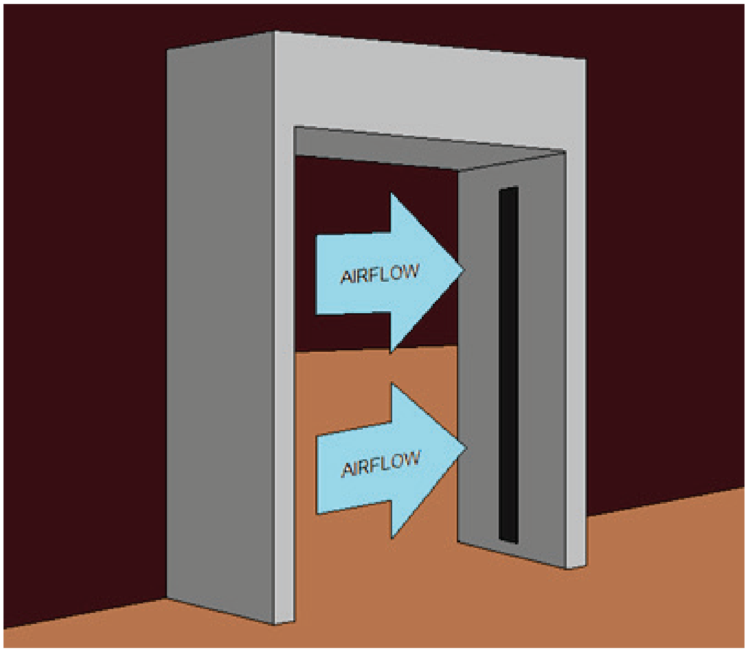


Figure 10-31: Air Curtain



The passageways may be for, but are not limited to, people, forklifts, pallet lifts, hand-trucks, or conveyor belts.

Strip curtains are commercial flexible plastic strips made for refrigerated openings with material type, weight and overlap design, designed for the size of the passageway opening and the temperatures of the subject spaces.

An automatically closing door is a door that fully closes under its own power. Examples include:

- Single acting or double acting hinge-mounted doors with a spring assembly or cam-type gravity hinges.
- Powered single-sliding, bi-parting or rollup doors which open based on a pull-cord, proximity or similar sensors, or by operator signal and close automatically through similar actions or after a period of time sufficient to allow passageway transit.

An air curtain is a commercial fan powered assembly intended to reduce air infiltration and designed by its manufacturer for use on refrigerated warehouse passageways, and for use on the opening size and the temperatures for which it is applied.

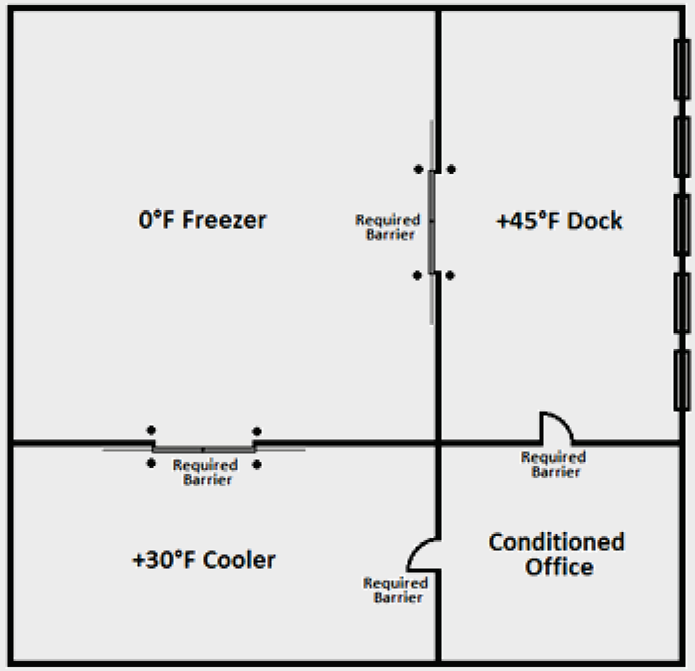
There are two exceptions to the requirements for infiltration barriers:

1. Openings with less than 16 square. feet of opening area, such as small passageways for conveyor belts
2. Loading dock doorways for trailers.

Example 10-33

Question

A refrigerated warehouse includes a freezer, cooler, a refrigerated dock, and a conditioned office, as shown in the following figure. Where are infiltration barriers required?



Answer

Infiltration barrier are required between all spaces including the hinge-mounted doors between the dock and the office. The dock doors do not require infiltration barriers.

Example 10-34

Question

A refrigerated warehouse is being constructed for a flower distribution company. Strip curtains cannot be used on the doors because the strips will damage the flowers when the pallet jack passes through. Is the warehouse still required to have infiltration barriers?

Answer

Yes, the warehouse is required to have infiltration barriers. If strip curtains cannot be used, the designer may choose another method, such as double-acting hinged doors, sliding or rollup doors with automatic door closers.

10.6.2.4 Acceptance Requirements

§120.6(a)7

The Energy Standards include acceptance test requirements for electric resistance underslab heating systems in accordance with NA7.10.1. The test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.10. The test requirements are described briefly in the following paragraph.

A. Electric Resistance Underslab Heating System

NA7.10.1

The acceptance requirements include functional tests that are to be performed to verify that the electric resistance underslab heating system automatically turns off during a test on-peak period.

10.6.3 Mechanical Systems Mandatory Requirements

10.6.3.1 **Overview**

This section addresses mandatory requirements for mechanical systems serving refrigerated spaces. Mechanical system components addressed by the Energy Standards include evaporators (air units), compressors, condensers, and refrigeration system controls. The requirements for each of these components are described in the following sections. The requirements apply to all system and component types with the exception of the specific exclusions noted in §120.6(a). The following figures identify some of the common system and component configurations that fall under §120.6(a).

Figure 10-32 is a schematic of a single stage system with direct expansion (DX) evaporator coils. Figure 10-33 identifies a single stage system with flooded evaporator coils; while Figure 10-34 shows a single stage system with pump recirculated evaporators. Figure 10-35 is a schematic of a typical two-stage system with an intercooler between the compressor stages. Figure 10-36 is a single-stage system with a water-cooled condenser and fluid cooler.

Figure 10-32: Single Stage System with DX Evaporator Coil

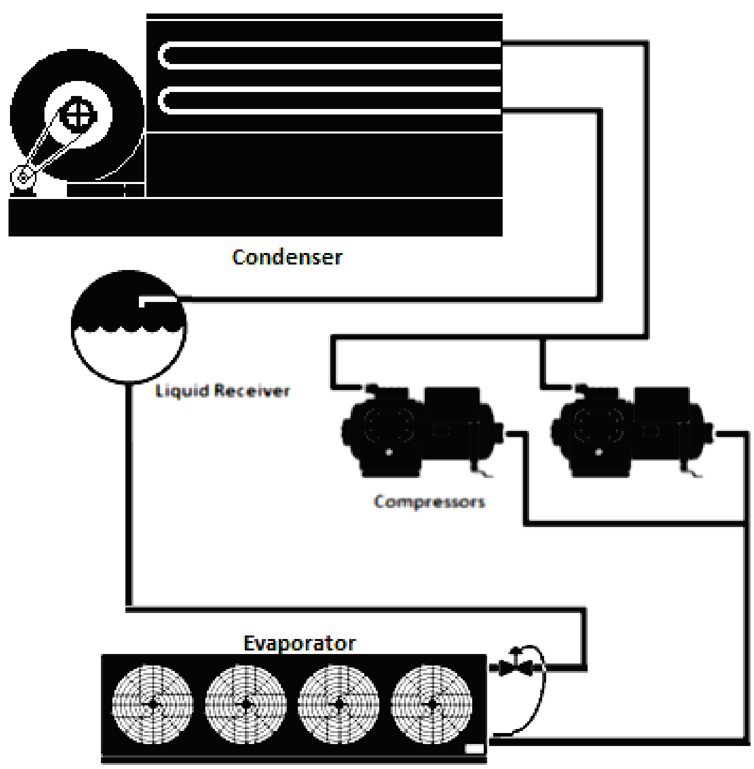


Figure 10-33: Single Stage System with Flooded Evaporator Coil

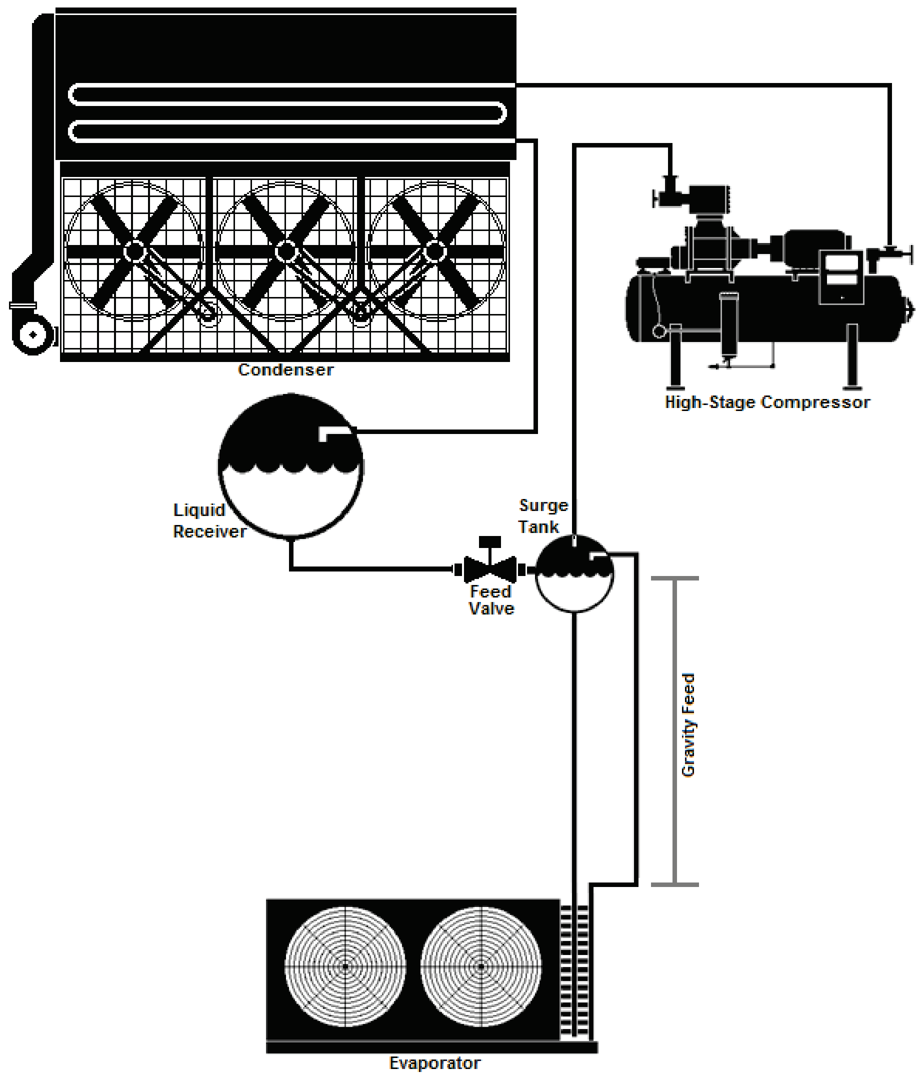


Figure 10-34: Single Stage System with Pump Recirculated Evaporator Coils

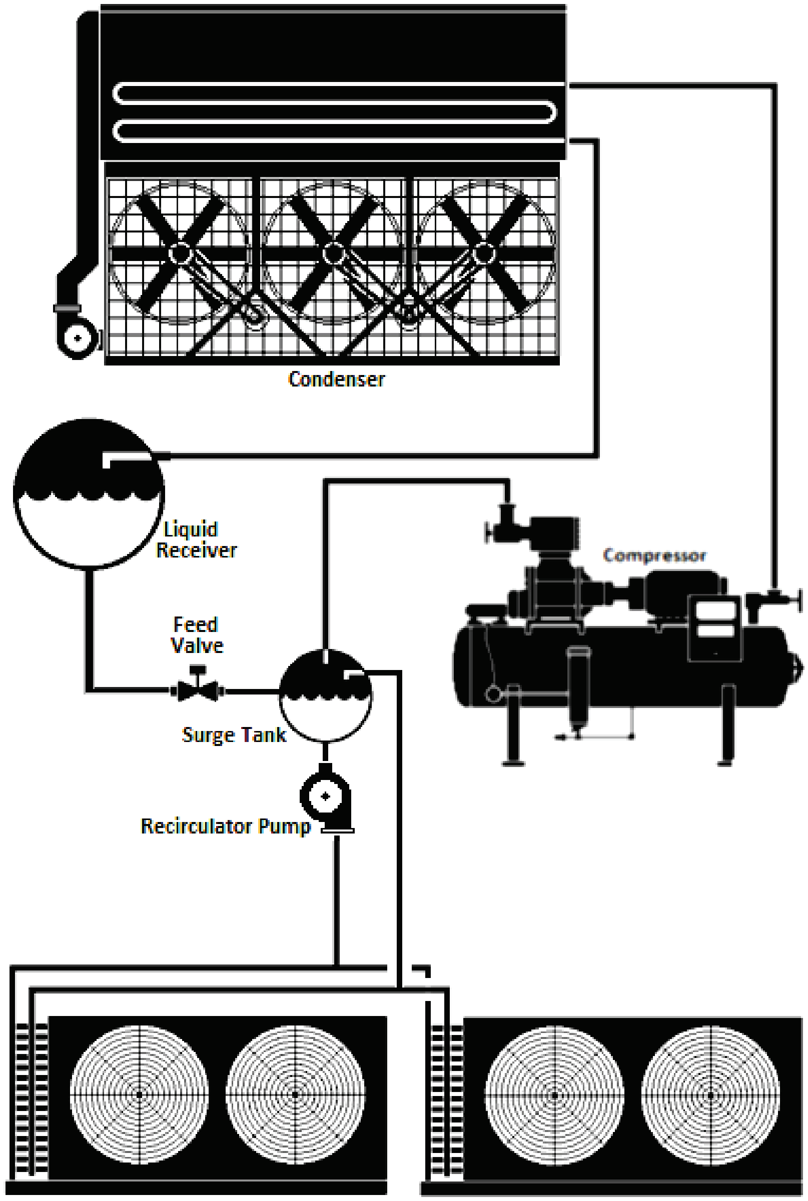


Figure 10-35: Two-Stage System with Flooded Evaporator Coil

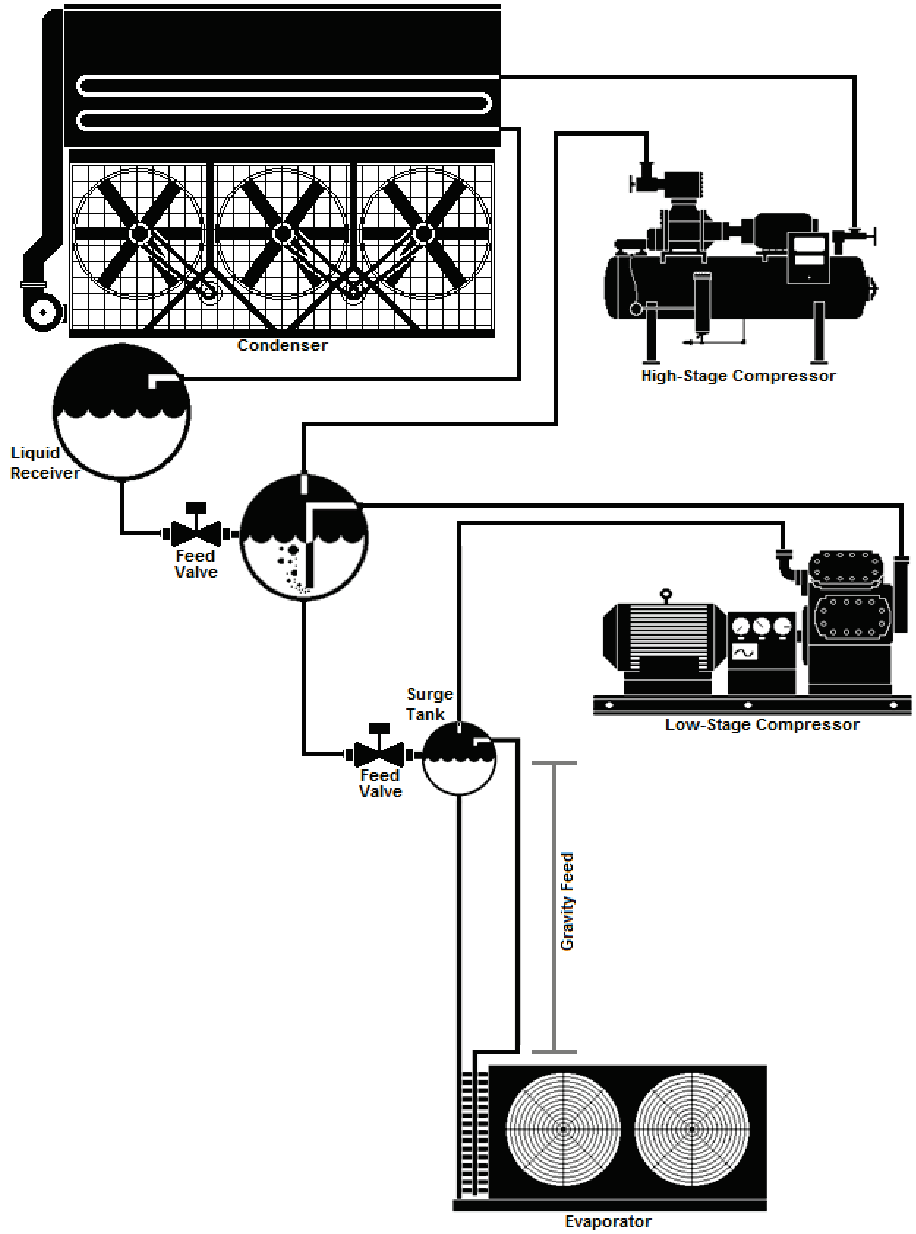
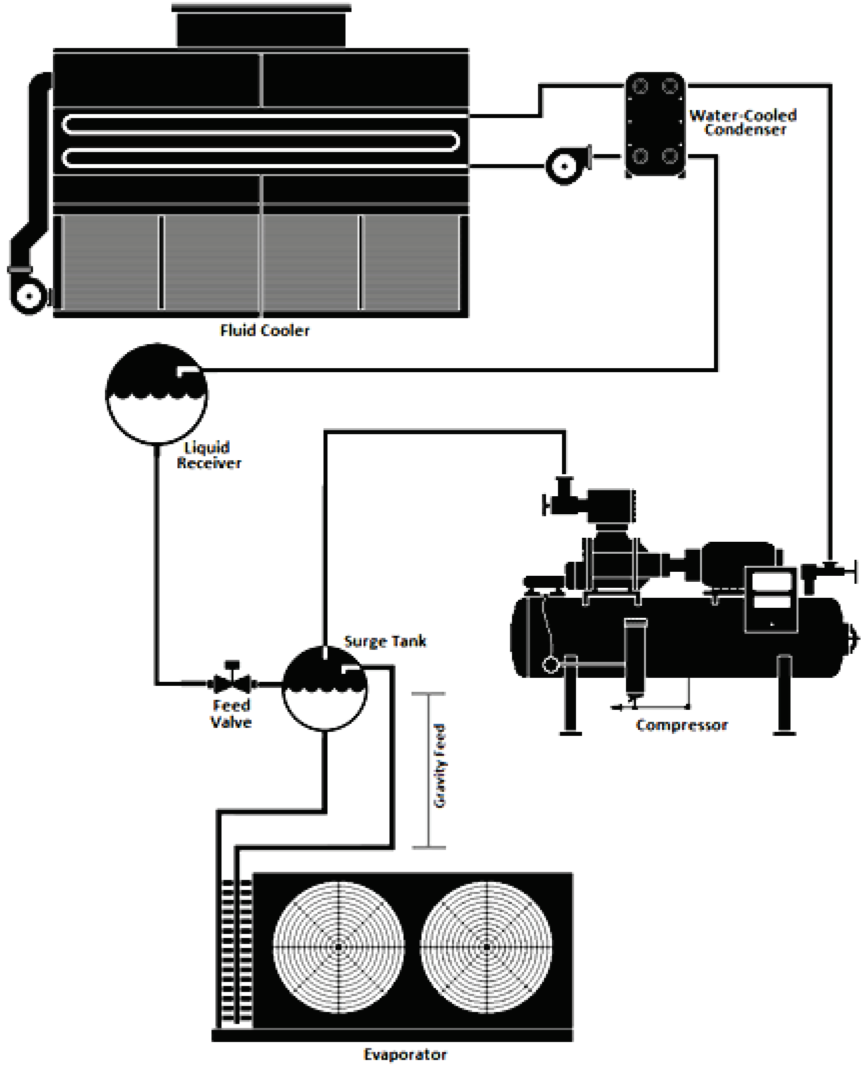


Figure 10-36: Single System with Water-Cooled Condenser Served by Fluid Cooler



10.6.3.2 Evaporators

§120.6(a)3

New fan-powered evaporators used in coolers and freezers must meet the fan motor type, efficiency, and fan control requirements outlined in the Energy Standards.

A. Allowed Fan Motor Types

Single phase fan motors less than 1 horsepower and less than 460 Volts must be either electronically-commutated (EC, also known as Brushless DC) or must have an efficiency of 70 percent or more when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions. This requirement is designed to reduce fan power in small evaporator fans.

B. Fan Motor Control

The speed of all evaporator fans served by either a suction group with multiple compressors or by a single compressor with variable capacity capability must be controlled in response to space temperature or humidity using a continuously variable speed control method. Two-speed control of evaporator fans is not an acceptable control method.

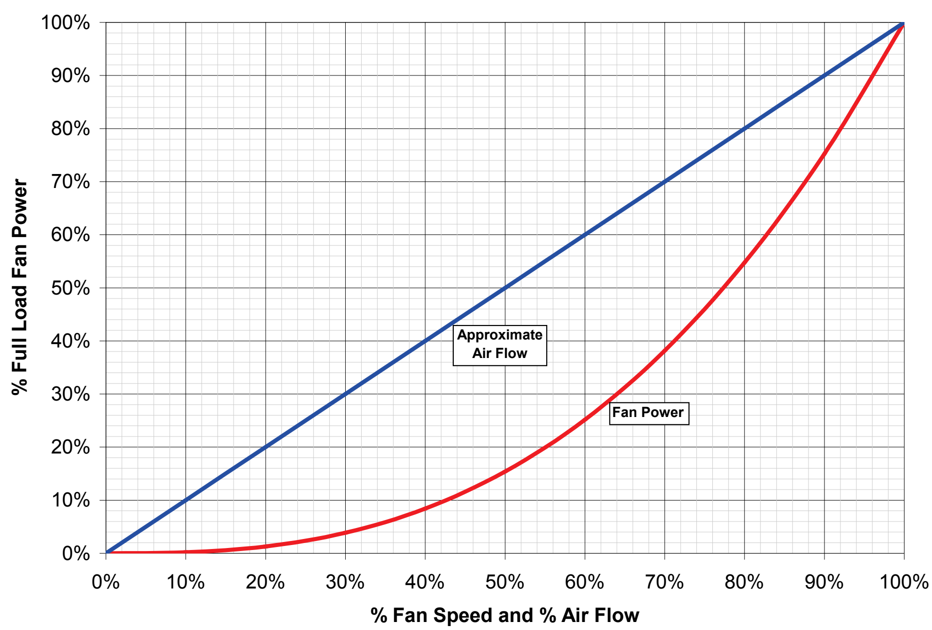
The fan speed is controlled in response to space temperature or humidity. Fan speed should increase proportionally when the space temperature is above setpoint and decrease when the space temperature is at or below setpoint, with refrigerant supply and pressure being maintained in the evaporator cooling coil. Fan speed is equivalent to air volume being circulated, resulting in direct control of cooling capacity, analogous to “variable air volume” cooling in commercial buildings. The control logic requires design and tuning to provide “variable” capacity operation.

The use of humidity as the control variable for speed control is very limited in practice but is included in the Energy Standards to accommodate special strategies for humidity-sensitive perishable product. Control logic is these applications often will employ humidity in conjunction with temperature.

The intent of this requirement is to take advantage of the “third-power” fan affinity law, which states that the percentage of required fan motor power is approximately equal to the cube of the percentage of fan speed, while the airflow is linearly proportional to the fan speed. For example, a fan running at 80 percent speed requires approximately 51 percent ($80\%^3 = 51\%$) power while providing approximately 80 percent airflow (Figure 10-37). Actual power is somewhat higher due to inefficiencies and drive losses. This shows the relationship between fan speed and both required fan power and approximate airflow.

There is no requirement in the Energy Standards for the minimum speed setting (i.e. how low the fan speed must go at minimum load). Variable speed controls of evaporator fans has commonly used minimum speeds of 80 percent or lower on direct expansion coils and 70 percent or lower on flooded or recirculated coils. The allowable minimum fan speed setting is to be determined by the refrigeration system designer. The fan speed may be adjusted or controlled to maintain adequate air circulation in order to ensure product integrity and quality.

Figure 10-37: Relationship between Fan Speed and Required Power



Correct fan speed control requires the associated system suction pressure to be controlled such that evaporator capacity is sufficient to meet space loads. If the evaporator suction pressure is too high relative to the desired room temperature, the evaporator fans will run at excessively high speed and energy savings will not be realized. If floating suction pressure automation is used to optimize the suction pressure setpoint, suction pressure should only be allowed to float up after fan speeds are at minimum and should be controlled to float back down prior to increasing fan speeds.

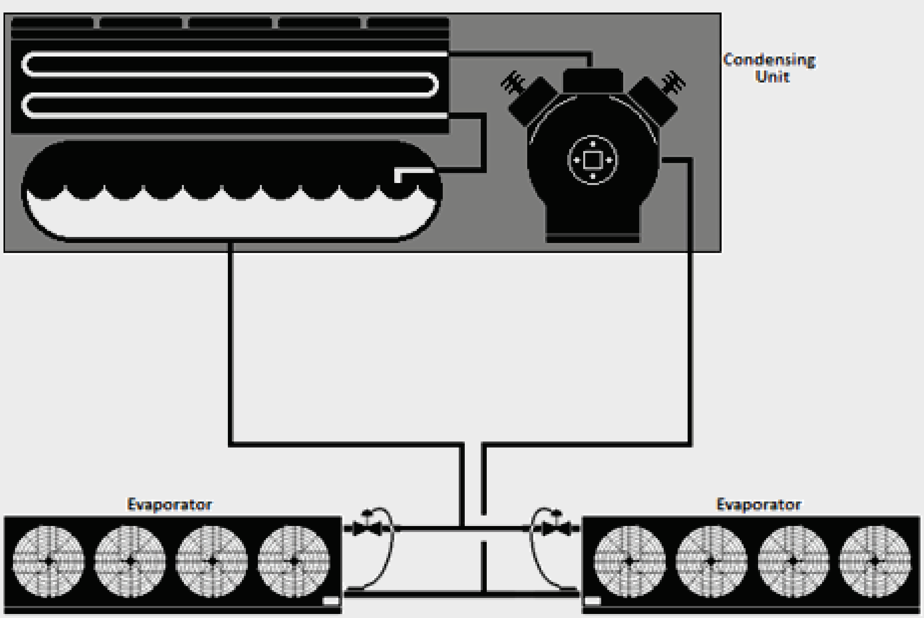
The Energy Standards have three exceptions to the evaporator variable speed requirement:

1. In case of a replacement, addition or alteration of existing evaporators with no variable speed control, the variable speed control of the evaporators is mandatory only if the replacement, addition or alteration is done for all the evaporators in an existing space. *[Exception 1 to §120.6(a)3B]*
2. A Controlled Atmosphere (CA) storage where products that require 100 percent of the design airflow at all times are stored may be exempt from the variable speed control requirement. A licensed engineer must certify that the products in the cooler require continuous airflow at 100 percent speed. Variable speed control must be implemented if the space will also be used for non-CA product or operation. *[Exception 2 to §120.6(a)3B]*
3. The variable speed control is not mandatory for spaces that are used solely for quick chilling or quick freezing of products. Such spaces have design cooling capacities that are greater than 240 Btu/hr-ft² of floor area, which is equivalent to 2 tons per 100ft² of floor area. However, variable speed control must be implemented if the spaces are used for storage for any length of time, regardless of how much refrigeration capacity is installed in the space. [Exception 3 to §120.6 (a) 3B].

Example 10-35

Question

A split system with a packaged air-cooled condensing unit with a single 30 HP compressor with unloaders serves two direct expansion evaporators in a 3,200 ft² cooler. Are the evaporator fans required to have variable speed control?



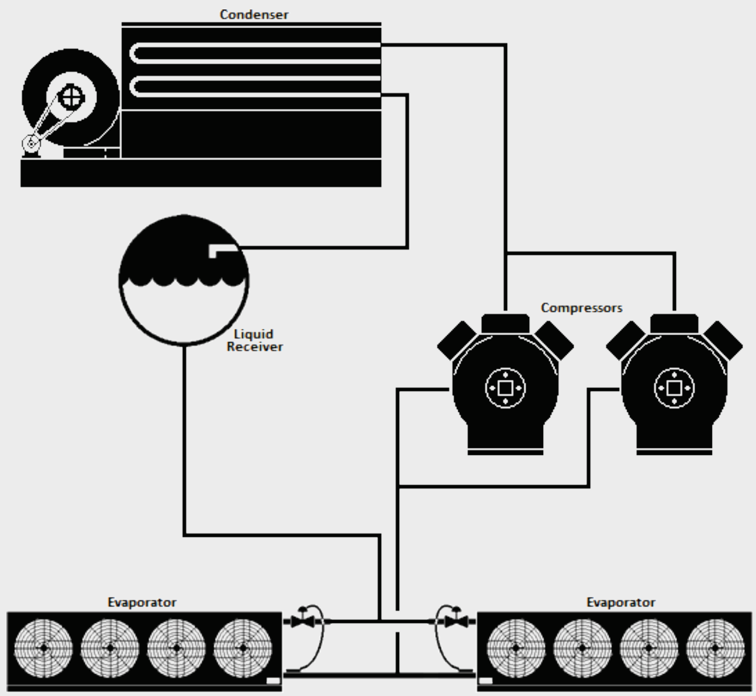
Answer

Yes. Since the compressor has a variable capacity capability in the form of unloaders, the evaporator fans are required to have variable speed control.

Example 10-36

Question

A refrigeration system utilizes two reciprocating compressors without variable capacity capability connected in parallel, and serves multiple evaporators in a 10,000 ft² cooler. Are the evaporator fans required to have variable speed control?



Answer

Yes. Since the evaporators are served by more than one compressor, they must have variable speed control, even though the compressors are not equipped with capacity control devices (e.g. unloaders).

In practice, the designer should consider the steps of capacity necessary to allow stable control. For small systems, the designer may consider use of control that proportionally controls both compressor capacity steps and speed steps in unison. As long as this control scheme is in response to space temperature, it would be consistent with the Energy Standards.

Example 10-37

Question

A -20°F (-29°C) freezer has a number of recirculated evaporator coils that were selected to meet the design load at a 10°F (5.5°C) temperature difference (TD). The evaporator fan motors utilize variable speed drives and the control system varies the fan speed in response to space temperature. What should the freezer saturated suction temperature be in order to achieve proper control and savings – by allowing fan speed control to act as the primary means of temperature control.

Answer

Since the coils were designed at a 10°F (5.5°C) TD and the target freezer temperature is -20°F (-29°C), the saturated evaporating temperature should be -30°F (-34°C) (-20°F minus 10°F); with the compressor controlled at a lower temperature, based on the design piping pressure drop. For example with 2°F (1°C) of piping losses, the compressor control setpoint would be -32°F (-36°C).

The purpose of this example is to show how evaporator temperature and coil capacity can be considered and maintained in order to achieve proper variable speed fan operation and savings. Settings could be further fine-tuned through observation of the required suction pressure to meet cooling loads and achieve minimum fan speeds average load periods, yet with a suction pressure no lower than necessary.

Example 10-38

Question

An existing refrigerated warehouse space has eight existing evaporators that do not have variable speed control. Six of the eight evaporators are being replaced with new evaporators. Do the new evaporators require variable speed control?

Answer

No. Since all the evaporators are not being replaced, the new evaporators do not require variable speed control.

The reason for this is that effective space temperature control would often require that the entire space utilize a consistent control scheme which could require a disproportional cost. While not required by the Energy Standards, in many instances it may still be very cost effective to add variable speed control to existing as well as new evaporators in this situation.

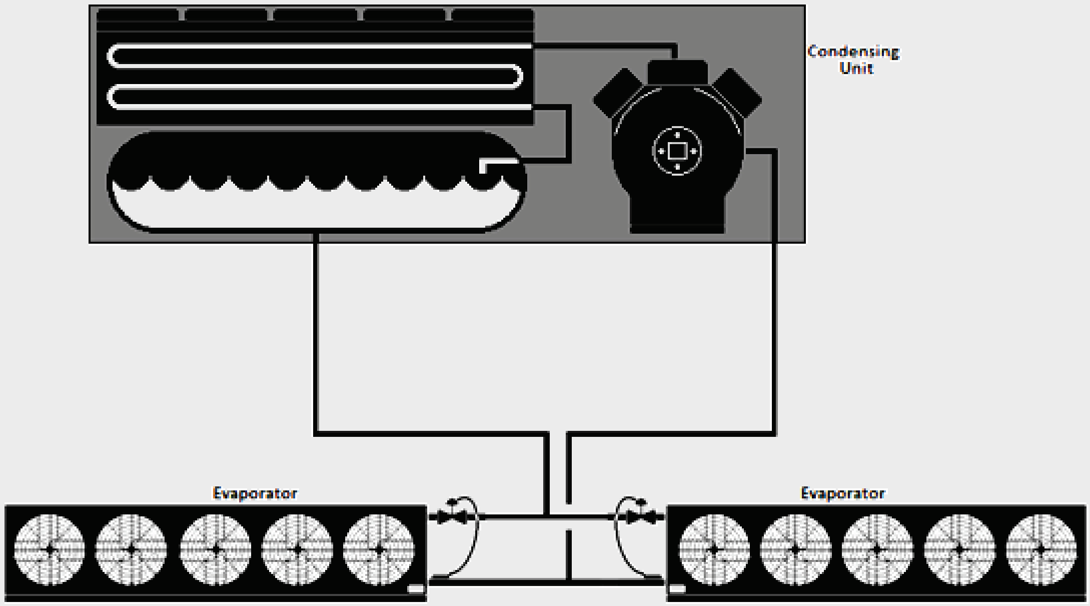
Continuously variable speed control is not mandatory for evaporators that are served by a single compressor that does not have variable capacity capability (i.e. the compressor cycles on and off in response to space temperature). For these systems, evaporator airflow must be reduced by at least 40 percent when the compressor is off. This can be accomplished in a number of ways, for example:

- Two speed evaporator fan control, with speed reduced by at least 40% when cooling is satisfied and the compressor is off.
- Turning off a portion of the fans in each evaporator to accomplish at least 40% reduction in fan power. Typically baffles are required to prevent reverse flow through fans that are turned off.
- Turning off all fans when the compressor is off. With this strategy a duty cycle can be employed to provide period forced fan operation to maintain air circulation, if the “on” period is limited to 25% of the duty cycle while the compressor is off.

Example 10-39

Question

A split system with a packaged air-cooled condensing unit utilizing a single cycling compressor without unloaders serves two evaporators in a cooler. Each evaporator has five fans. What options does the system designer have to meet the requirements for evaporator coils served by a single cycling compressor?



Answer

Multiple methods can be used to reduce airflow by at least 40% when the compressor is off, or turn all fans off with a 25% duty cycle.

Example 1: The designer may specify two-speed fans, or utilize variable frequency drives or other speed-reduction devices to reduce the fan speed to 60% or less when the compressor is off.

Example 2: The designer may utilize controls that cycle at least four of the ten fans off when the compressor is cycled off. This would most likely be accomplished by cycling two fans off on each evaporator.

10.6.3.3 Condensers

§120.6(a)4

New condensers on new refrigeration systems must follow the condenser sizing, fan control, and efficiency requirements as described in §120.6(a)4.

A. Condenser Sizing

§120.6(a)4A and §120.6(a)4B describe minimum sizing requirements for new condensers serving new refrigeration systems. Fan-powered evaporative condensers, as well as water-cooled condensers served by fluid coolers and cooling towers are covered in §120.6(a)4A. Fan-powered air-cooled condensers are covered by §120.6(a)4B.

Condensers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the refrigeration system saturated condensing temperature (SCT) and ambient temperature. The design condenser capacity shall be greater than the calculated combined Total Heat of Rejection (THR) of the dedicated compressors that are served by the condenser. If multiple condensers are specified, then the combined capacity of the installed condensers shall be greater than the calculated heat of rejection. When determining the design THR for the purpose of this requirement, reserve or backup compressors may be excluded from the calculations.

There is no limitation on the type of condenser that may be used. The choice may be made by the system designer, considering the specific application, climate, water availability, etc.

The Energy Standards include an exception to §120.6(a)4A and 4B for condensers serving refrigeration systems for which more than 20% of the design cooling load comes from quick chilling or freezing space, or process (non-space) refrigeration cooling. The Energy Standard defines quick chilling or freezing space as a space with a design refrigeration evaporator capacity greater than 240 Btu/hr-ft² of floor area, which is equivalent to 2 tons per 100ft² of floor area, at system design conditions.

The sizing requirements for air-cooled condensers (§120.6(a)4B) do not apply to the condensers included in air-cooled condensing units. Condensing units include compressor(s), condenser, liquid receiver, and control electronics are packaged in a single product. However, this exception applies only if the compressor(s) in the condensing units have a nameplate size totaling less than 100HP.

Example 10-40

Question

A new food processing facility is being constructed that will include an 800ft² blast freezer, a holding freezer, and a loading dock. The design evaporator capacity of the blast freezer is 40 TR (tons of refrigeration). The combined evaporator capacity of the freezer and loading dock is 60 TR. Does the condenser group have to comply with the sizing requirements in §120.6(a)4A?

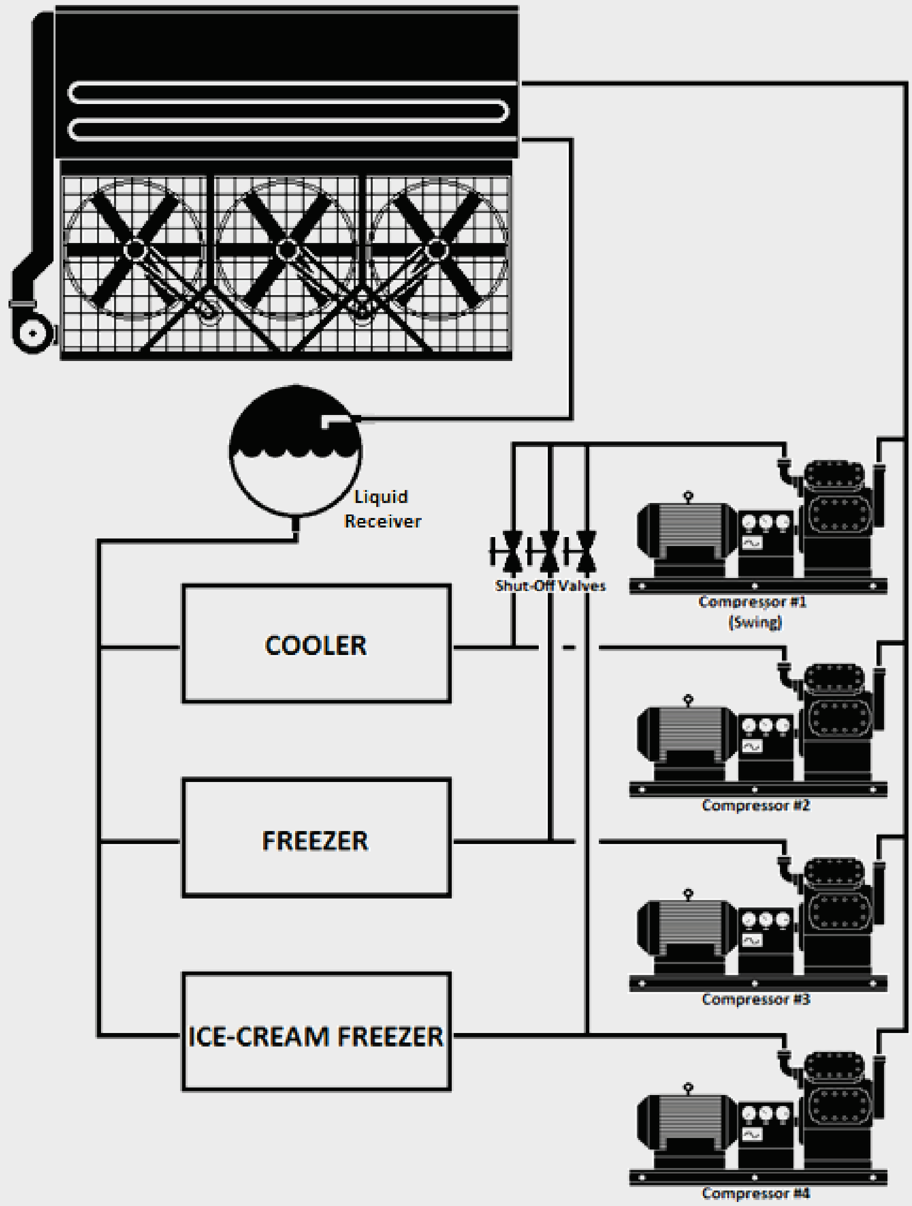
Answer

The blast freezer evaporator capacity divided by the floor area is 100TR/800ft², which is equal to 12.5 TR/100ft². That means this particular blast freezer is deemed quick freezing space by the Energy Standards. Therefore, the condenser group serving the refrigeration system does not have to comply with §120.6(a)4A, since 40% (i.e. greater than 20%) of the design refrigeration capacity is from quick freezing.

Example 10-41

Question

The refrigerated warehouse system shown below has a backup or “swing” compressor. Does the heat rejection from this compressor need to be included in the condenser sizing calculations?



Answer

It depends.

A swing compressor may be designed solely for back-up of multiple suction groups or it may be included in one suction group and necessary to meet the design load of that suction group, but in an emergency is also capable of providing back-up for other compressors. If the compressor is solely for use as back-up, it would be excluded from the heat rejection calculation for the purposes of the Energy Standards. In this case, the calculations would include the heat of rejection from Compressors 2, 3, and 4 and would exclude Compressor 1.

1. Sizing of Evaporative Condensers, Fluid Coolers, and Cooling Towers

§120.6(a)4A

§120.6(a)4A provides maximum design SCT values for evaporative condensers as well as systems consisting of a water-cooled condenser served by a cooling tower or fluid cooler. For the purpose of this Section, designers should use the 0.5 percent design wet-bulb temperature (WBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement. The maximum design SCT requirements are listed in Table 10-4 below.

Table 10-4: Maximum Design SCT Requirements for Evaporative Condensers and Water-Cooled Condensers Served by Cooling Towers and Fluid Coolers

0.5% DESIGN WET-BULB TEMPERATURE	MAXIMUM DESIGN SCT
≤ 76°F (24°C)	Design WBT plus 20°F (11°C)
Between 76°F (24°C) and 78°F (26°C)	Design WBT plus 19°F (10.5°C)
≥ 78°F (26°C)	Design WBT plus 18°F (10°C)

Example 10-42

Question

A refrigerated warehouse is being constructed in Fresno, California. The refrigeration system will be served by an evaporative condenser. What is the sizing requirement for the condenser selected for this system?

Answer

The 0.5% design wetbulb temperature (WBT) from Joint Appendix JA-2 for Fresno, California, is 73°F. Therefore, the maximum design SCT for the refrigerant condenser is 73°F + 20°F = 93°F. The selected condenser for this system must be capable of rejecting the total system design THR at 93°F SCT, and 73°F WBT.

Example 10-43

Question

What is the minimum size for a condenser for a refrigeration system with the following parameters?

Located in Fresno, California
Design SST: 10°F
Suction group: 3 equal-sized dedicated screw compressors (none are backup units)
Evaporative condenser
200 TR (tons refrigeration) cooling load

Answer

From the previous example, it was determined that the design wetbulb temperature (WBT) to demonstrate compliance for Fresno, California is 73°F and the maximum design SCT for the evaporative condenser is 93°F (73°F + 20°F). We will assume the system designer determined a 2°F loss between the compressors and condenser. The designer first calculates the total heat of rejection (THR) for the suction group at the design conditions of 10°F SST and 95°F SCT. The selected compressors each have a rated capacity of 240 tons of refrigeration and will absorb 300 horsepower at the design conditions. Therefore, the calculated THR for one compressor is:

240 TR /Compressor x 3 compressor x 12,000 Btuh/TR + 300HP x 2,545 Btuh/HP = 10,930,500 Btuh

To comply with the Energy Standards, a condenser (or group of condensers) must be selected that is capable of rejecting at least 10,930,500 Btu/hr at 93°F SCT and 73°F WBT.

2. Sizing of Air-Cooled Condensers

§120.6(a)4B

§120.6(a)4B provides maximum design SCT values for air-cooled condensers. For the purpose of this Section, Designers should use the 0.5 percent design dry-bulb temperature (DBT) from Table 10-4 – Design Day Data for California Cities in the Reference Joint Appendices JA2 to demonstrate compliance with this requirement.

Standard practice is for published condenser ratings to assume the capacity of air-cooled condensers is proportional to the temperature difference (TD) between SCT and DBT, regardless of the actual ambient temperature entering the condenser. For example, the capacity of an air-cooled condenser operating at an SCT of 80°F with a DBT of 70°F is assumed to be equal to the same unit operating at 110°F SCT and 100°F DBT, since the TD across the condenser is 10°F in both examples. Thus, unlike evaporative condensers, the requirement for air-cooled condensers does not have varying sizing requirements for different design ambient temperatures.

However, the Energy Standards have different requirements for air-cooled condensers depending on the space temperatures served by the refrigeration system. The maximum design SCT requirements are listed in Table 10-5 below:

Table 10-5: Maximum Design SCT Requirements for Air-Cooled Condensers

REFRIGERATED SPACE TYPE	SPACE TEMPERATURE	MAXIMUM SCT
Cooler	≥ 28°F (-2°C)	Design DBT plus 15°F (8.3°C)
Freezer	< 28°F (-2°C)	Design DBT plus 10°F (5.6°C)

Often, a single refrigeration system and its associated condenser will serve a mix of cooler and freezer spaces. In this instance, the maximum design SCT shall be a weighted average of the requirements for cooler and freezer spaces, based on the design evaporator capacity of the spaces served.

Example 10-44

Question

An air-cooled condenser is being sized for a system that has half of its installed capacity serving cooler space and the other half serving freezer space. What is the design TD to be added to the design dry bulb temperature?

Answer

Using air-cooled condensers for coolers have a design approach of 15°F (8.3°C) and for freezers a design approach of 10°F (5.6°C). When a system serves freezer and cooler spaces, a weighted average should be used based on the installed capacity. To calculate the weighted average, multiply the percent of the total installed capacity dedicated to coolers by 15°F (8.3°C). Next, multiply the percent of the total installed capacity dedicated to freezers by 10°F (5.6°C). The sum of the two results is the design condensing temperature approach. In this example, the installed capacity is evenly split between freezer and cooler space. As a result, the design approach for the air-cooled condenser is 12.5°F (6.9°C).

$(50\% \times 15^{o}F) + (50\% \times 10^{o}F) = 7.5^{o}F + 5^{o}F = 12.5^{o}F$

B. Fan Control

Condenser fans for new air-cooled or evaporative condensers, or fans on cooling towers or fluid coolers used to reject heat on new refrigeration systems, must be continuously variable speed. Variable frequency drives are commonly used to provide continuously variable speed control of condenser fans although controllers designed to vary the speed of electronically commutated motors may be used to control these types of motors. All fans serving a common high side, or cooling water loop for cooling towers and fluid coolers, shall be controlled in unison. Thus, in normal operation, the fan speed of all fans within a single condenser or set of condensers serving a common high-side should modulate together, rather than running fans at different speeds or staging fans off. However, when fan speed is at the minimum practical level usually no higher than 10-20%, the fans may be staged off to further reduce condenser capacity. As load increases, fans should be turned back on prior to significantly increasing fan speed, recognizing a control band is necessary to avoid excessive fan cycling.

To minimize overall system energy consumption, the condensing temperature setpoint must be continuously reset in response to ambient temperatures, rather than using a fixed setpoint value. This strategy is also termed ambient-following control, ambient-reset, wetbulb following and drybulb following—all referring to control logic which changes the condensing temperature target in response to ambient conditions at the condenser. The control system calculates a target saturated condensing temperature that is higher than the ambient temperature by a predetermined temperature difference (i.e. the condenser control TD). Fan speed is then modulated according to the calculated target SCT. The target SCT for evaporative condensers or water-cooled condensers (via cooling towers or fluid coolers) must be reset according to ambient wet bulb temperature, and the target SCT for air-cooled condensers must be reset according to ambient dry bulb temperature.

The condenser control TD is not specified in the Energy Standards. The nominal control value is often less than the condenser design TD; however the value for a particular system is left up to the system designer. Since the intent is to utilize as much condenser capacity as possible without excessive fan power, common practice for refrigerated warehouse systems is to optimize the control TD over a period of time such that the fan speed is in a range of approximately 60-80% during normal operation (i.e. when not at minimum SCT). While not required, evaporative condensers and systems utilizing fluid coolers and cooling towers may also vary the condenser control TD as a function of actual WBT, to account for the properties of moist air, which reduce the effective condenser capacity at lower wetbulb temperatures.

The minimum saturated condensing temperature setpoint must be 70°F (21°C) or less. For systems utilizing halocarbon refrigerants with glide, the SCT setpoint shall correlate with a midpoint temperature (between the refrigerant bubble-point and dew point temperatures) of 70°F (21°C) or less. As a practical matter, a maximum SCT setpoint is also commonly employed to set an upper bound on the control setpoint in the event of a sensor failure and to force full condenser operation during peak ambient conditions. This value should be set high enough that it does not interfere with normal operation.

Split air-cooled condensers are sometimes used for separate refrigeration systems, with two circuits and two rows of condenser fans. Each condenser half would be controlled as a separate condenser. If a condenser has multiple circuits served by a common fan or set of fans, the control strategy may utilize the average condensing temperature or the highest condensing temperature of the individual circuits as the control variable for controlling fan speed.

Alternative control strategies are permitted to the condensing temperature reset control required in §120.6(a)4E. The alternative control strategy must be demonstrated to provide equal or better performance, as approved by the Executive Director.

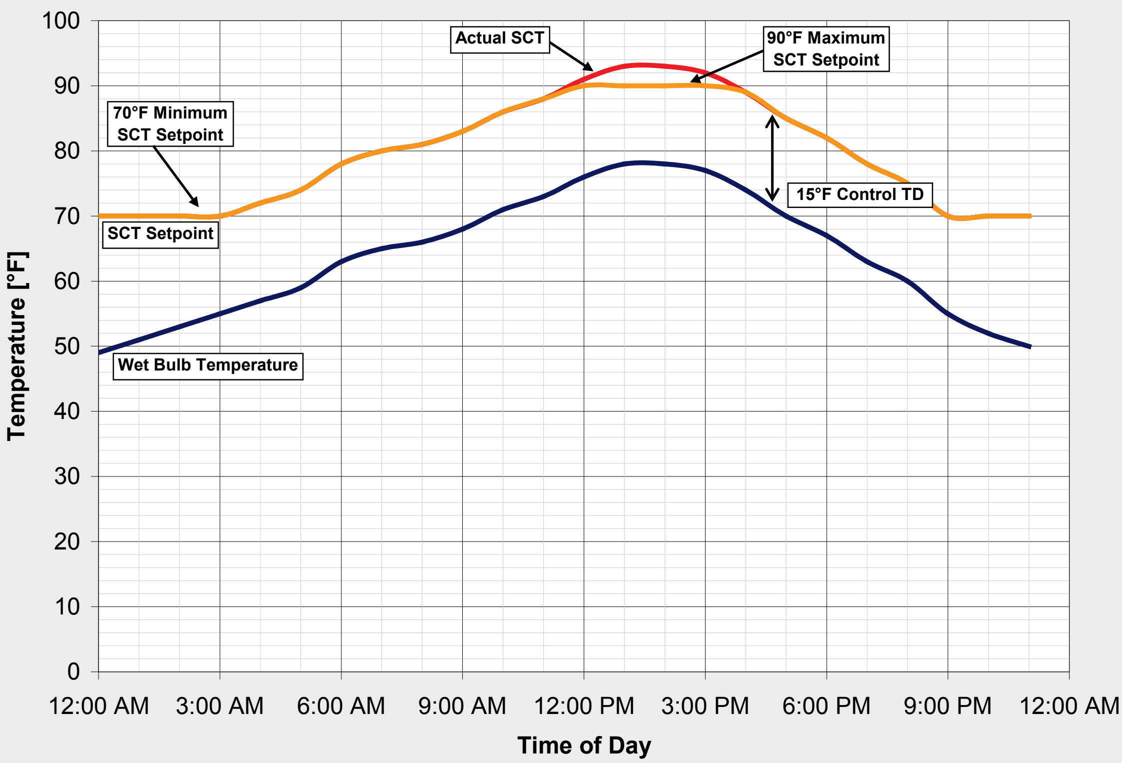
Example 10-45

Question

A refrigerated warehouse with evaporative condensers is being commissioned. The control system designer has utilized a wet bulb-following control strategy to reset the system saturated condensing temperature (SCT) setpoint. The refrigeration engineer has calculated that adding a TD of 15°F (8.3°C) above the ambient wet bulb temperature should provide a saturated condensing temperature setpoint that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT setpoint trends look like over an example day?

Answer

The following figure illustrates what the actual saturated condensing temperature and SCT setpoints could be over an example day using the wet bulb-following control strategy with a 15°F (8.3°C) TD and also observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT setpoint is continuously reset to 15°F (8.3°C) above the ambient wet bulb temperature until the minimum SCT setpoint of 70°F is reached. The figure also shows a maximum SCT setpoint (in this example, 90°F (32.2°C) which may be utilized to limit the maximum control setpoint, regardless of the ambient temperature value or TD parameter.



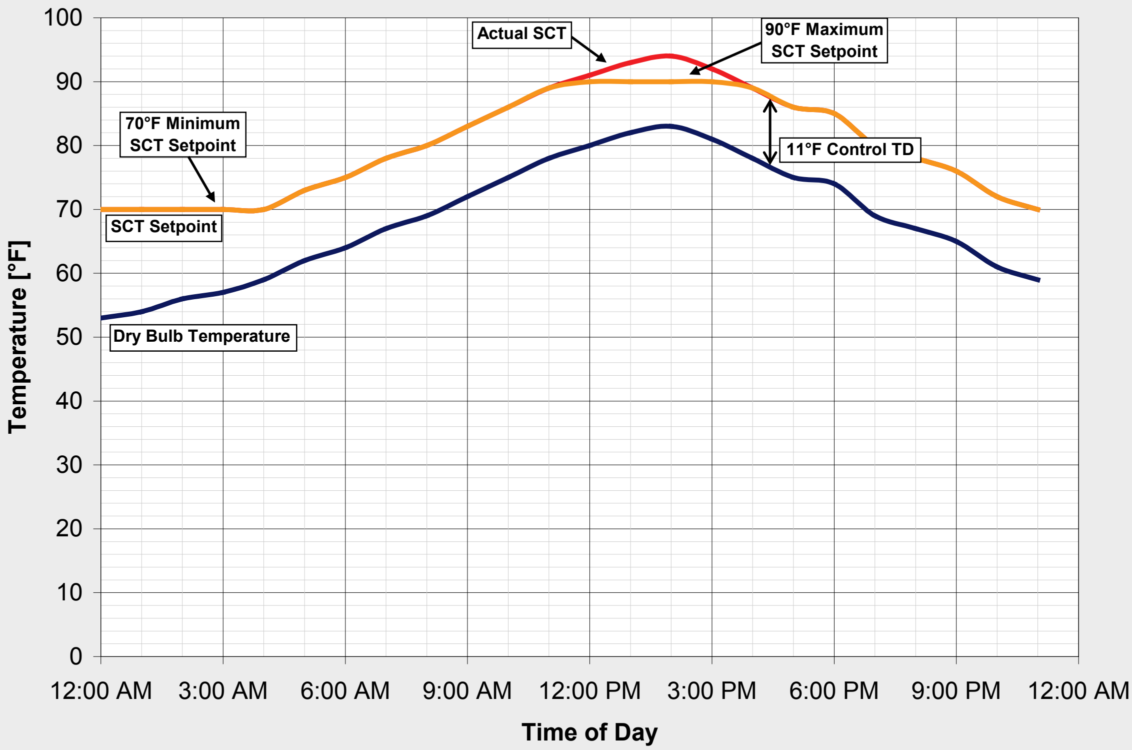
Example 10-46

Question

A cold storage facility with an air-cooled condenser is being commissioned. The control system designer has utilized a drybulb-following control strategy to reset the system saturated condensing temperature (SCT) setpoint. The refrigeration engineer has calculated that adding a TD of 11°F (6.1°C) above the ambient drybulb temperature should provide a saturated condensing temperature setpoint that minimizes the combined compressor and condenser fan power usage throughout the year. What might the system SCT and SCT setpoint trends look like over an example day?

Answer

The following figure illustrates the actual saturated condensing temperature and SCT setpoints over an example day using the drybulb-following control strategy with an 11°F (6.1°C) TD and also observing the 70°F (21°C) minimum condensing temperature requirement. As the figure shows, the SCT setpoint is continuously reset 11°F (6.1°C) above the ambient drybulb temperature, but is bounded by the minimum and maximum SCT setpoints. The figure also shows a maximum SCT setpoint (in this example, 90°F (32.2°C) which may be utilized to limit the maximum control setpoint, regardless of the ambient temperature value or TD parameter.



C. Condenser Specific Efficiency

§120.6(a)4F

Requirements for Design Condensing Temperatures relative to design ambient temperatures, as described above for §120.6(a)4A&B, help assure that there is enough condenser capacity to keeping condensing temperatures compressor head pressures at reasonable levels. However the sizing requirements do not address condenser efficiency. For example, rather than providing amply sized condenser surface area, a condenser selection could consist of a small condenser area using a large motor to blow a large amount of air through the heat exchanger surface to achieve the design condenser TD. However, this would come at the expense of excessive fan motor horsepower. Also, relatively high fan power consumption can result from using condenser fans that have poor fan efficiency or low fan motor efficiency. §120.6(a)4F addresses these and other factors affecting condenser fan power by setting minimum specific efficiency requirements for condensers.

All newly installed indoor and outdoor evaporative condensers, and outdoor air-cooled condensers to be installed on new refrigeration systems shall meet the minimum specific efficiency requirements shown in Table 10-6.

Table 10-6: Fan-powered Condensers – Minimum Specific Efficiency Requirements[1]

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM SPECIFIC EFFICIENCY	RATING CONDITION
Outdoor Evaporative-Cooled with THR Capacity > 8,000 MBH	All	350 Btuh/Watt	100°F Saturated Condensing Temperature (SCT), 70°F Outdoor Wetbulb Temperature
Outdoor Evaporative-Cooled with THR Capacity < 8,000 MBH and Indoor Evaporative-Cooled	All	160 Btuh/Watt	
Outdoor Air-Cooled	Ammonia	75 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Drybulb Temperature
	Halocarbon	65 Btuh/Watt	
Indoor Air-Cooled	All	Exempt	

Condenser specific efficiency is defined as:

Condenser Specific Efficiency = Total Heat Rejection (THR) Capacity / Input Power

The total heat rejection capacity is at the rating conditions of 100°F Saturated Condensing Temperature (SCT) and 70°F outdoor wetbulb temperature for evaporative condensers, and 105°F SCT and 95°F outdoor drybulb temperature for air-cooled condensers. Input power is the electric input power draw of the condenser fan motors (at full speed), plus the electric input power of the spray pumps for evaporative condensers. The motor power is the manufacturer's published applied power for the subject equipment, which is not necessarily equal to the motor nameplate rating. Power input for secondary devices such as sump heaters shall not be included in the specific efficiency calculation.

As shown in Table 10-6 the Energy Standards have different minimum efficiencies depending on the type of condenser that is being used. The different classifications of condenser are:

- Outdoor, evaporative, THR greater than 8,000 MBH at specific efficiency rating conditions
- Outdoor, evaporative, THR less than 8,000 MBH at specific efficiency rating conditions
- Indoor, evaporatively cooled
- Outdoor, air-cooled, ammonia refrigerant
- Outdoor, air-cooled, halocarbon refrigerant
- Indoor, air-cooled

The data published in the condenser manufacturer's published rating for capacity and power shall be used to calculate specific efficiency. For evaporative condensers, manufacturers typically provide nominal condenser capacity, and tables of correction factors that are used to convert the nominal condenser capacity to the capacity at various applied condensing temperatures and wetbulb temperatures. Usually the manufacturer publishes two sets of correction factors: one is a set of "heat rejection" capacity factors,

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[1] Table is copied directly from TABLE 120.6-B FAN-POWERED CONDENSERS – MINIMUM EFFICIENCY REQUIREMENTS

while the others are “evaporator ton” capacity factors. Only the “heat rejection” capacity factors shall be used to calculate the condenser capacity at the efficiency rating conditions for the purpose of determining compliance with this section.

For air-cooled condensers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and drybulb temperature. Manufacturers typically assume that air-cooled condenser capacity is linearly proportional to TD; the catalog capacity at 20°F TD is typically twice as much as at 10°F TD. The condenser capacity for air-cooled condensers at a TD of 10°F shall be used to calculate efficiency. If the capacity at 10°F TD is not provided, the capacity shall be scaled linearly.

Depending on the type of condenser, the actual manufacturer’s rated motor power may vary from motor nameplate in different ways. Air cooled condensers with direct-drive OEM motors may use far greater input power than the nominal motor horsepower would indicate. On the other hand, evaporative condenser fans may have a degree of safety factor to allow for higher motor load in cold weather conditions (vs. the 100°F SCT/70°F WBT specific efficiency rating conditions). Thus, actual motor input power from the manufacturer must be used for direct-drive air-cooled condensers while for large (i.e. > 8,000 MBH) evaporative condensers and other belt drive condensers, the full load motor rating is generally conservative but manufacturer’s applied power should be used whenever possible to more accurately determine specific efficiency.

Example 10-47

Question

An evaporative condenser is being considered for use in an outdoor application on a new refrigerated warehouse. The refrigerant is ammonia. The condenser manufacturer’s catalog provides the following information:

Model Number	Base Heat Rejection (MBH)
A441	4410
B487	4866
C500	4998
D551	5513
E559	5586
F590	5895
G591	5909
H598	5983
I631	6306
J637	6365

Condensing Temperature (°F)	Entering Wetbulb Temperature (°F)					
	62	64	66	68	70	72
95	0.88	0.92	0.97	1.02	1.08	1.16
96.3	0.84	0.88	0.92	0.97	1.02	1.09
97	0.83	0.86	0.90	0.94	0.99	1.05
98	0.80	0.83	0.87	0.91	0.96	1.01
99	0.77	0.80	0.84	0.87	0.92	0.97
100	0.75	0.78	0.81	0.84	0.88	0.93

For this example, model number D551 is being considered. Elsewhere in the catalog, it states that condenser model D551 has two 7.5 HP fan motors and one 5 HP pump motor. Fan motor efficiencies and motor loading factors are not provided. Does this condenser meet the minimum efficiency requirements?

Answer

First, the condenser capacity must be calculated at the efficiency rating condition. From Table 10-4, we see that the rating conditions for an outdoor evaporative condenser are 100°F SCT, 70°F WBT. From the Base Heat Rejection table above, we see the nominal capacity for model D551 is 5,513 MBH. From the Heat Rejection Capacity Factors table, we see that the correction factor for 100°F SCT, 70°F WBT is 0.88. The capacity of this model at specific efficiency rating conditions is 5,513 MBH / 0.88 = 6,264 MBH. Since 6,264 MBH is less than 8,000 MBH, we can see from Table10-4 that the minimum specific efficiency requirement is 160 (Btu/hr)/Watt.

To calculate input power, we will assume 100% fan and pump motor loading and minimum motor efficiency since the manufacturer has not yet published actual motor input power at the specific efficiency rating conditions. We look up the minimum motor efficiency from Nonresidential Appendix NA-3: Fan Motor Efficiencies. For a 7.5 HP 4-pole open fan motor, the minimum efficiency is 91.0%. For a 5 HP 6-pole open pump motor, the minimum efficiency is 89.5%. The fan motor input power is calculated to be:

2 Motors x 7.5 HP/Motor x 746 Watts/HP x 100% assumed loading/ 91% Efficiency = 12.297 Watts

The pump motor input power is calculated to be:

1 Motors x 5 HP/Motor x 746 Watts/HP x 100% assumed loading/ 89.5% Efficiency = 4.168 Watts

The combined input power is therefore:

12.297 Watts + 4.168 Watts = 16.464 Watts

Note: Actual motor power should be used when available (see notes in text).

Finally, the efficiency of the condenser is:

(6,264 MBH x 1000 Btuh/MBH) / 16.464 Watts = 381 Btuh/Watt

381 Btu/hr per Watt is higher than the 160 Btu/hr per Watt requirement. This condenser meets the minimum efficiency requirements.

D. Condenser Fin Spacing

According to §120.6(a)4G air-cooled condensers shall have a fin density no greater than 10 fins per inch. Condensers with higher fin densities have a higher risk of fouling with airborne debris. This requirement does not apply to air-cooled condensers that utilize a micro-channel heat exchange surface, since this type of surface is not as susceptible to permanent fouling in the same manner as traditional tube-and-fin condensers with dense fin spacing.

10.6.3.4 **Compressors**

§120.6(a)5

Compressors on new refrigeration systems must follow the design and control requirements as described in §120.6(a)5.

A. Minimum Condensing Temperature

Floating head control is one of the largest energy savings measures applied to refrigeration systems. This control attempts to keep condensing temperatures as low as possible (while not consuming too much condenser fan energy) as this reduces compressor head pressure which directly impact compressor energy. When ambient temperatures are low the primary constraint on how low the condensing temperature can be reset is the design requirements of the compressor and associated system components.

§120.6(a)5A addresses the compatibility of the compressor design and components with the requirements for floating head control. All compressors that discharge to the condenser(s) and all associated components (coalescing oil separators, expansion valves for liquid injection oil cooling, etc.) must be capable of operating at a condensing temperature of 70°F (21°C) or less. Note that oil separator sizing is often governed by the minimum condensing temperature as well as other factors, such as the maximum suction temperature. Suction temperatures above the design value may occur under floating suction temperature control schemes.

The system designer should also keep in mind that other design parameters such as piping run-lengths or evaporator defrost requirements must be considered to meet this requirement.

B. Screw Compressor Control at Part-Load

New open-drive screw compressors in new refrigeration systems with a design saturated suction temperature (SST) of 28°F or lower shall vary compressor speed as the primary means of capacity control. The compressor speed shall reduce to the manufacturer-specified minimum speed before unloading via slide valve. Similarly, when the load increases, the compressor shall increase to 100% slide valve before increasing speed. This requirement applies only to compressors discharging to the condenser (i.e. single stage or the high stage of a two-stage system) and only to suction groups that consist of a single compressor.

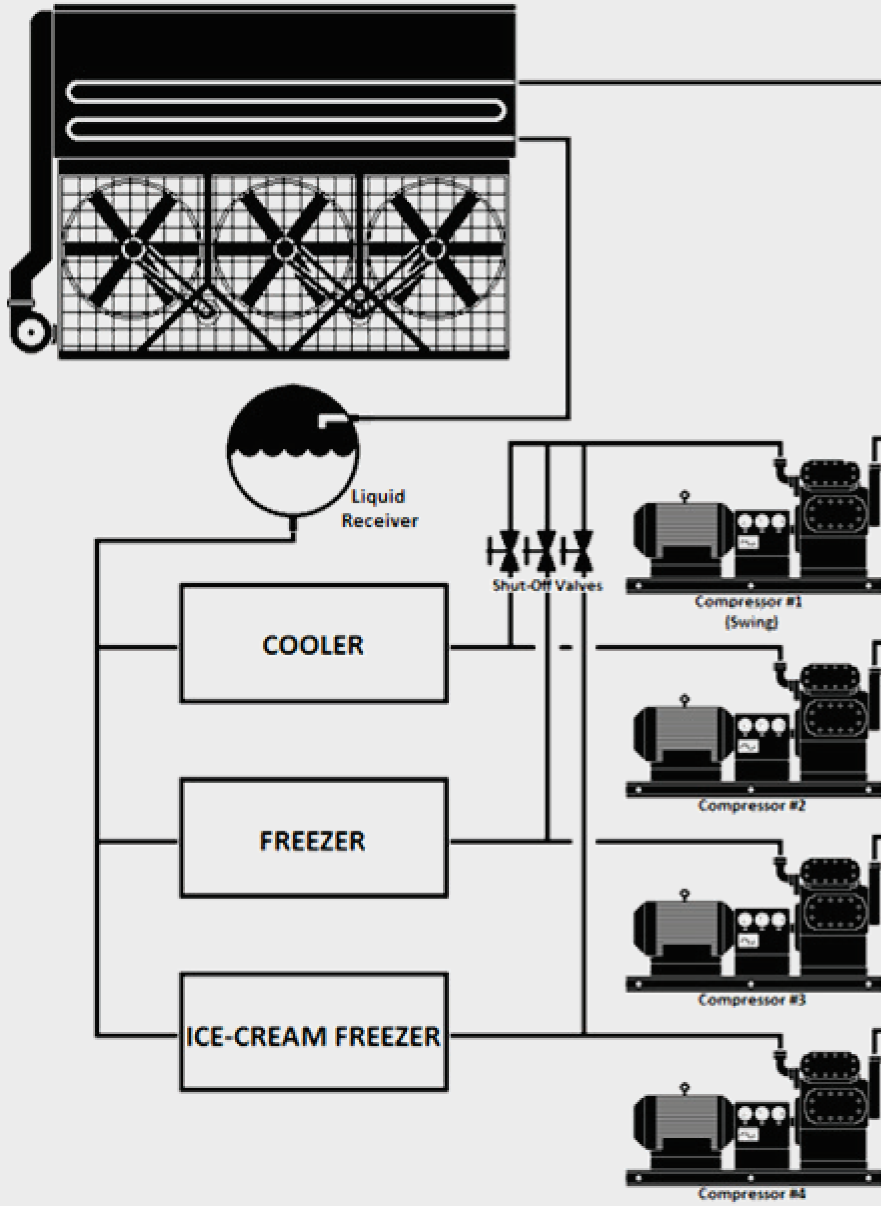
An exception to §120.6(a)5 is provided for compressors on a refrigeration system with more than 20% of the design cooling load from quick chilling or freezing space, or non-space process refrigeration cooling. The “refrigeration system” refers to the entire associated system, (i.e. the refrigerant charge) not the suction group. While variable speed compressor control may be cost effective in many instances and may be considered by the system designer, this exception exists to allow for situations such as seasonal processes with low operating hours or loads that may be precisely matched to a fully loaded compressor.

New screw compressors with a motor nameplate power greater than 150HP shall incorporate the capability to automatically vary the volume ratio (i.e. variable Vi) in order to optimize efficiency at off-design operating conditions.

Example 10-48

Question

The system shown below has three 200 HP open-drive screw compressors serving three different suction levels and one 200 HP backup or swing open-drive screw compressor that can be connected by valve into any of the three suction lines. Does this count as having more than one compressor per suction group and exempt the compressors from the requirements in §120.6(a)5B?



Answer

Probably not. The Exception 1 to §120.6(a)5B only applies when a suction group has two or more dedicated compressors. A compressor that is used solely as backup does not count as a dedicated compressor. As a result, all compressors (1, 2, 3, and 4) in the example above must comply with §120.6(a)5B and use variable speed control as the primary means of capacity control.

However, if Compressor 1 is actually required to meet the design load of one of the suction groups, it could be considered part of that suction group and variable speed control would not be required. Whether a swing compressor is really a back-up compressor or part of a suction group should be apparent from the design loads and capacities listed in the design documents.

10.6.3.5 Acceptance Requirements

§120.6(a)7

The Energy Standards have acceptance test requirements for:

- Electric underslab heating controls.
- Evaporator fan motor controls.
- Evaporative condensers.
- Air-cooled condensers.
- Variable speed compressors.

These test requirements are described in Chapter 13 and the Reference Nonresidential Appendix NA7.10. They are described briefly in the following paragraphs.

A. Electric Underslab Heating Controls

NA7.10.1

Controls for underslab electric heating controls, when used for freeze protection on freezer floors, are tested to ensure heat is automatically turned off during summer on-peak electric periods.

B. Evaporator Fan Motor Controls

NA7.10.2

Evaporator equipment and controls are checked for proper operation. The controls are tested to ensure the fan speed automatically varies in response the temperature and/or humidity of the space.

C. Evaporative Condensers

NA7.10.3.1

Evaporative condensers and variable speed fan controls are checked to ensure the required minimum SCT setpoint of 70°F or lower is implemented, and the condenser fans continuously vary in unison to maintain a target temperature difference between the SCT and the wet bulb temperature. Trends of wet bulb temperature and SCT can be used to verify the controls over time.

The condenser control TD or offset is a key parameter in fine-tuning the operation of the fans and maximizing the energy savings. In best practice, this control setting should be adjusted during average loaded so that the fan average 60-80% speed when in the control range (i.e. between the minimum and maximum SCT setpoints).

D. Air-cooled Condensers

NA7.10.3.2

Air-cooled condensers and variable speed fan controls are checked to ensure the required minimum SCT setpoint of 70°F or lower is implemented, and the condenser fans continuously vary in unison to maintain a target temperature difference between the SCT and dry bulb temperature. Trends of dry bulb temperature and SCT can be used to verify the controls over time.

The condenser control TD is a key parameter in fine-tuning the operation of the fans and maximizing the energy savings. This control setting should be adjusted during average loaded so that condenser capacity is effectively utilized but fan speed is not excessive.

E. Variable Speed Compressors

NA7.10.4

The controls and equipment for the variable speed control of screw compressors is checked and certified as part of the acceptance requirements. The compressor should unload capacity by reducing speed to the minimum speed setpoint before unloading by slide valve or other means. Control system trend screens can also be used to verify that the speed varies automatically in response to the load.

10.6.4 Additions and Alterations

§140.9

10.6.4.1 Requirements

Requirements related to refrigerated warehouse additions and alterations are covered by the Energy Standards in §141.1(a). The specific requirements for additions and alterations for commercial refrigeration are included in §120.6(a). Definitions relevant to refrigerated warehouses include:

- An addition is a change to an existing refrigerated warehouse that increases refrigerated floor area and volume. Additions are treated like new construction.
- When an unconditioned or conditioned building; or unconditioned or conditioned part of a building adds refrigeration equipment so that it becomes refrigerated, this area is treated as an addition.
- An alteration is a change to an existing building that is not an addition or repair. An alteration could include installing new evaporators, a new lighting system, or a change to the building envelope, such as adding insulation.
- A repair is the reconstruction or renewal of any part of an existing building or equipment for the purpose of its maintenance. For example, a repair could include the replacement of an existing evaporator or condenser.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration.

Example 10-49

Question

The new construction is an addition to an existing refrigerated warehouse. The new space is served by an existing refrigeration plant. Does the refrigeration plant need to be updated to meet the Energy Standards?

Answer

No. The new construction must comply with the Energy Standards; however, the existing refrigeration plant equipment is exempt from the Energy Standards.

Example 10-50

Question

The new construction includes an addition to refrigerated space and expansion of the existing refrigeration plant. Is the existing refrigeration equipment subject to the Energy Standards requirements?

Answer

No. Only the new equipment installed in the added refrigerated space and any new compressors added to the existing plant are subject to the requirements of the Energy Standards. If a new refrigeration system was installed with a new condenser for the addition then the new condenser must also comply with the Energy Standards.

Example 10-51

Question

An upgrade to an existing refrigerated storage space includes replacing all of the existing evaporators with new evaporators. Do the new evaporators need to comply with the Energy Standards?

Answer

Yes. A complete renovation of the evaporators in the space is considered to be an alteration. The alteration requirements apply when all of the evaporators in the space are changed.

Example 10-52

Question

An existing refrigerated storage space is adding additional evaporators to meet an increase in the refrigeration load. Do the new evaporators need to comply with the Energy Standards?

Answer

No. The alteration requirements apply only when all of the evaporators in the space are changed.

Example 10-53

Question

An existing evaporator is being replaced by a new evaporator as part of system maintenance. Does the new evaporator need to comply with the Energy Standards?

Answer

No. Replacement of an evaporator during system maintenance is considered a repair. However, the energy consumption of the new evaporator must not exceed that of the equipment it replaced.

10.7 Laboratory Exhaust

10.7.1 Overview

In the climates of California, laboratories have average annual energy intensities 10 to 20 times larger than offices when normalized by building area. The energy use of laboratories is driven from long hours of operation and the large quantities of outside air. Many lab buildings also have large internal loads.

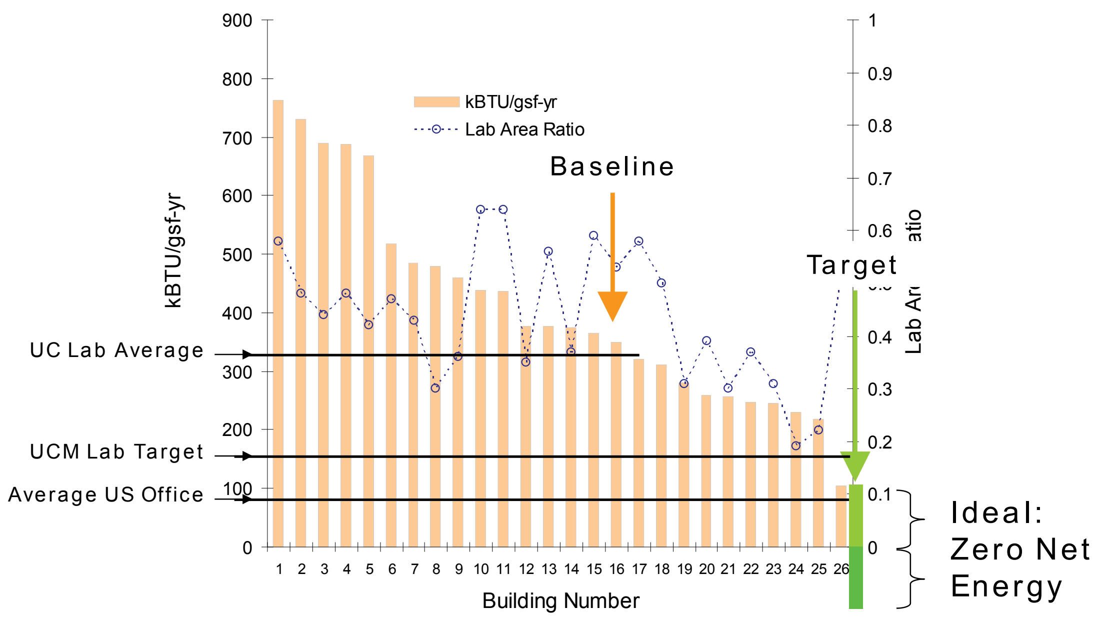
Research in the climates of California showed annual cost of lab air at ~$3 to $5 per cfm/yr or $5 to $10/ft2/yr. At these costs the paybacks on retrofitting constant volume labs to variable air volume have been less than 10 years. With new construction the paybacks are much shorter.

The energy and demand savings are strongly dependent on the facility's characteristics, including the following:

- The ratio of lab to non-lab space.
- The minimum airflow required by code or the facility EH&S department. These range from 4 air-changes per hour (ACH) to 18 ACH or higher.
- The climate.

Figure 10-38 below shows benchmarking data from Labs 21 for lab buildings in the San Francisco Bay area. The total energy use intensity in kBtu/gsf/yr is shown on the left access. The 26 labs are arranged from highest to lowest normalized energy use. The right access is the "Lab Area Ratio" the ratio of lab area to total building area. There are three reference lines on this graph: the University of California campus wide average laboratory building end use intensity; the University of California Merced campus goal for their laboratories; and the average national energy end use for office buildings.

Figure 10-38: Laboratory Benchmarking from Labs 21 for San Francisco Bay Area



Using the criteria for cost effectiveness in the Standard and very conservative estimates of the first costs (using costs from VAV retrofits not new construction) this measure was shown to be cost effective in all California Climate Zones up to 14 ACH of minimum ventilation

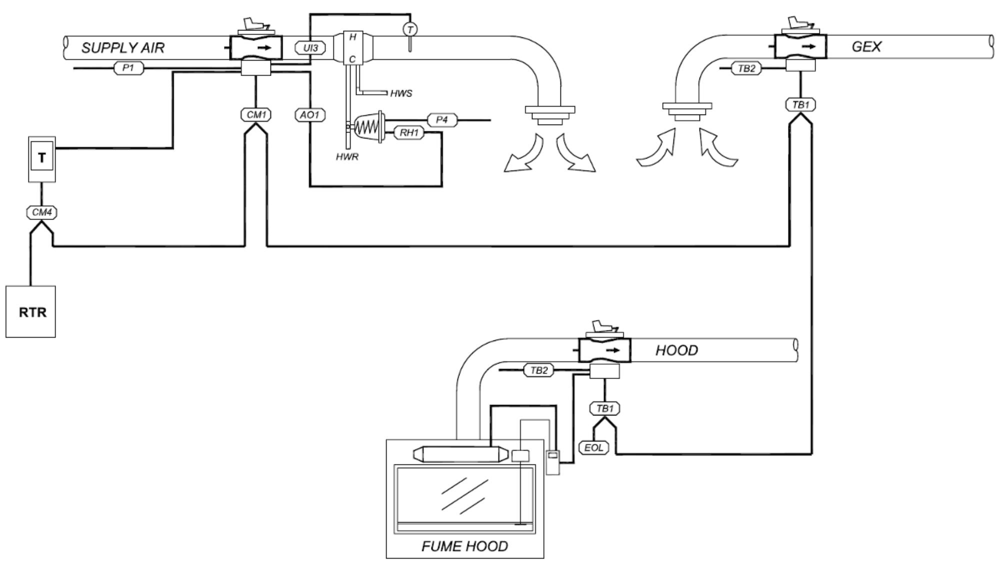
Using off the shelf variable air volume controls can greatly reduce the energy use in laboratory buildings. The Energy Standards requires VAV controls on all zones not required to be constant volume by the AHJ, facility EH&S department or other applicable health and safety code. Furthermore in ANSI/AIHA Z9.5 and NFPA 45 would allow lower minimum airflows in many hoods which would further increase the savings from variable air volume design.

Figure 10-39 below show the zone components for a variable air volume (VAV) laboratory. There are three zone valves shown in this image: one each on the supply air to the zone;

the fume hood (if one exists), and; the general exhaust valve (GEX) if one is needed. These zone valves can be venturi type valves as shown in this image or standard dampers like those used for VAV boxes in offices. The dampers or venturi valves must be designed to resist corrosion and damage from the exhaust. The hood valve when it is used is controlled to automatically maintain the design sash face velocity as the hood sash is opened or closed. The role of the supply valve is to maintain space pressurization by tracking the sum of the hood and general exhausts in the space. The supply valves are typically provided with a reheat coils to maintain space comfort for heating. The GEX is typically used to control the cooling, on call for cooling it opens, and the supply valve in turn opens to maintain space pressure. In some systems the supply modulates like a typical VAV box in response to the thermostat and the GEX modulates to maintain space pressure.

All three valves are made to control as either variable volume or constant volume depending on the application. A hood might for instance be required to be constant volume for dilution. If this is the case, a constant volume bypass hood should be employed. Even with a constant volume hood you will need a pressure independent hood valve if the exhaust it is attached to includes any variable volume zones. The same is true for constant volume supply or general exhaust: if any zone on a supply or exhaust duct is variable volume, all zone ducts on it must have pressure independent controls.

Figure 10-39: Zone Components for A VAV Lab



The fume exhaust is generally blown out of a stack. The design of the stack and the velocity of the discharge is selected to disperse all contaminants so that they are sufficiently dilute by the time they are near any occupants. For contaminants like radio isotopes for which there is no acceptable level of dilution, the exhaust system typically has some form of filtration that captures the particles of concern. On general lab exhaust there is typically an inlet bypass damper on the exhaust fan that modulates to keep a constant volume of exhaust moving at the stacks. Using multiple stacks in parallel you can stage off stacks and fans to save more energy.

10.7.2 Mandatory Measures

There are no mandatory measures specific to laboratory exhaust. The equipment efficiencies in §110.1 and §110.2 apply.

10.7.3 Prescriptive Measures

§140.9(c) requires that all laboratory exhaust with minimum circulation rates of 10 ACH or lower shall be designed for variable volume control on the supply, fume exhaust and general exhaust.

An exception is provided for laboratory exhaust systems where constant volume is required by code, the Authority Having Jurisdiction (AHJ), or the facility Environmental Health and Safety (EH&S) division (Exception 1 to §140.9(c)). Examples include: hoods using perchloric acid; hoods with radio isotopes; and exhaust systems conveying dust or vapors that need a minimum velocity for containment.

A second exception is provided for new zones added to an existing constant volume exhaust system (Exception 2 to §140.9(c)).

10.7.4 Additions and Alterations

As noted in the previous section variable volume controls are not required if you are adding zones to an existing constant volume system.

10.8 Compressed Air Systems

§120.6(e)

10.8.1 Overview

§120.6(e) applies to all new compressed air systems and all additions or alterations to a compressed air system with a total installed compressor capacity of ≥ 25 hp. For alternations there is an exception for systems that include one or more centrifugal compressors.

Before discussing the requirements these key terms must be understood:

A. **Online compressors:** all compressors that are available to serve peak load. Online compressors do not include back-up compressors whose only purpose is to be available when a compressor fails. Online compressors are all compressors that are physically connected to compressed air piping excluding back-up compressors.

B. **Back-up compressors:** are those compressors not used to meet peak compressed air flow loads. Back –up compressors can be physically connected to the compressed air piping system and can be automatically controlled to turn on if one of the other compressors on the system fails. Back-up compressors do not normally operate.

C. **Online capacity:** total combined capacity in actual cubic feet per minute (acfm) of compressed air at a given pressure during times of peak compressed air load.

D. **Trim compressor:** is a compressor that is designated for part-load operation, handling the short term variable trim load of end uses, in addition to the fully loaded base compressor. In general the trim compressor will be controlled by a VSD but it also can be a compressor with good part load efficiency. If the trim compressor does not have good part load efficiency broadly across its operating range, then it will take more compressors to meet the Energy Standards requirements.

E. **Base compressor:** the opposite of a trim compressor, a base compressor is expected to be mostly loaded. If the compressed air system has only one compressor, the requirements of the Energy Standards require that the single compressor be treated as a trim compressor.

F. **Specific power:** the ratio of power to compressed air flow rate at a given pressure typically given the units of kW/100 acfm. The lower the specific power the more efficient the compressor is at a given compressed air loads.

G. **Total effective trim capacity:** the combined effective trim capacity of all trim compressors where effective trim capacity for each compressor is the range of capacities in acfm which are within 15 percent of the specific power at its most efficient operating point. This is displayed in Figure 10-42.

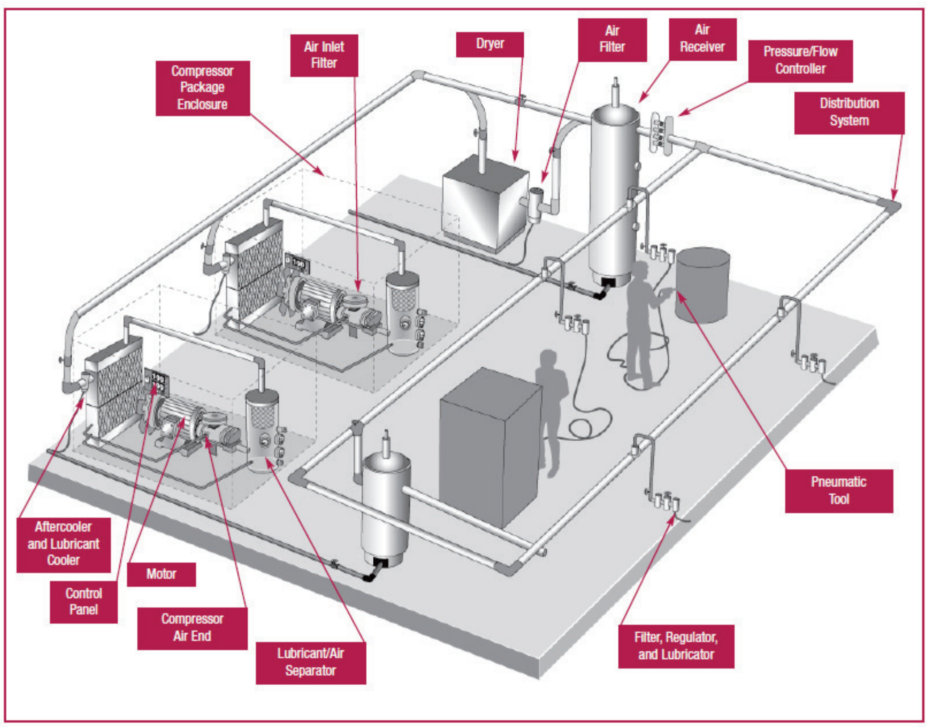
H. **Largest net capacity increment:** is the largest increase in capacity when switching between combinations of base compressors that is expected to occur under the compressed air system control scheme. See Example 10-54.

I. **Primary Storage:** are tanks or other devices that store compressed air capacity. Also known as an air receiver, they reduce peak air demand on the compressor system and reduce the rate of pressure change in a system. As primary storage these devices are near the air compressors and are differentiated from remote storage that might be out near an end use device.

As described in the following paragraphs, there are 3 main requirements in this section:

- Trim Compressor and Storage - §120.6(e)1.
- Controls - §120.6(e)2.
- Acceptance - §120.6(e)3.

Figure 10-40: Zone Components for A VAV Lab



Source: Improving Compressed Air System Performance: A Sourcebook for Industry, USDOE 2003

10.8.2 Mandatory Measures

§120.6(e)

10.8.2.1 Trim Compressor and Storage

§120.6(e)1

This requirement targets the performance of a compressed air system across its full range.

There are two alternate paths to comply with this requirement:

1. Using a variable speed drive (VSD) controlled compressor(s) as the Trim Compressor (§120.6(e)1A):
   - The VSD trim compressor(s) must have a capacity (acfm) of at least 1.25 times the largest net capacity increment (see Example 10-54).
   - Primary storage of at least one gallon per acfm (1 gal/acfm) of the largest trim compressor.
2. Using a compressor or set of compressors as the Trim Compressor (§120.6(e)1B) without requiring a VSD controlled compressor:
   - The trim compressor(s) must have a total effective trim capacity no less than the largest new capacity increment.
   - Primary storage of at least two gallons per acfm (2 gal/acfm) of the largest trim compressor.
   - Effective trim capacity is the rang of compressed air flow rates where the specific power (W/acfm) is no greater than 115% of the minimum specific power (see Figure 10-42).

Both of these paths aim to reduce the amount of cycling of fixed speed compressors by utilizing a better-suited compressor that operates well in part-load.

A. Compliance Option 1: VSD-controlled Trim Compressor

§120.6(e)1A

Many base load compressors are designed to provide peak efficiency near their rated capacity with a significant drop off in efficiency at lower flow rates (in acfm). Compressed air systems often avoid the losses in efficiency associated with part load compressed air flows by staging multiple compressors so that in most cases base compressors operate near full load. A trim compressor is designed to have close to peak efficiency over a broad range of compressed air flow rates. To make sure the compressed air system is operating efficiently over its entire range, it is important to have a trim compressor sized to handle the gaps between base compressors. The minimum size of the trim compressor(s) is determined calculating the *Largest Net Capacity Increment* - the biggest step increase between combinations of base compressors.

With equally sized compressors this is fairly intuitive: in a system with two-100 hp (434 acfm) rotary screw compressor system, the largest step increase would be the size of one of the compressors (434 acfm). For systems with uneven compressor sizes, it requires going through the following steps:

1. Determine all combinations of base compressors (including all compressors off).
2. Order these combinations in increasing capacity.
3. Calculate the difference between every adjacent combination.
4. Choose the largest difference.

This largest difference is what must be covered by the trim compressor(s) in order to avoid a control gap.

Once the *Largest Net Capacity Increment* is calculated, this value can be used to satisfy the first compliance option. Option 1 mandates that the rated capacity of the VSD compressor(s) be at least 1.25 times the largest net increment.

For compliance option 1, the system must include primary storage that has a minimum capacity of 1 gallon for every acfm of capacity of the largest trim compressor.

Example 10-54

Question

Given a system with three base compressors with capacities of 200 acfm (Compressor A), 400 acfm (Compressor B) and 1,000 acfm (Compressor C), what is the *Largest Net Capacity Increment?*

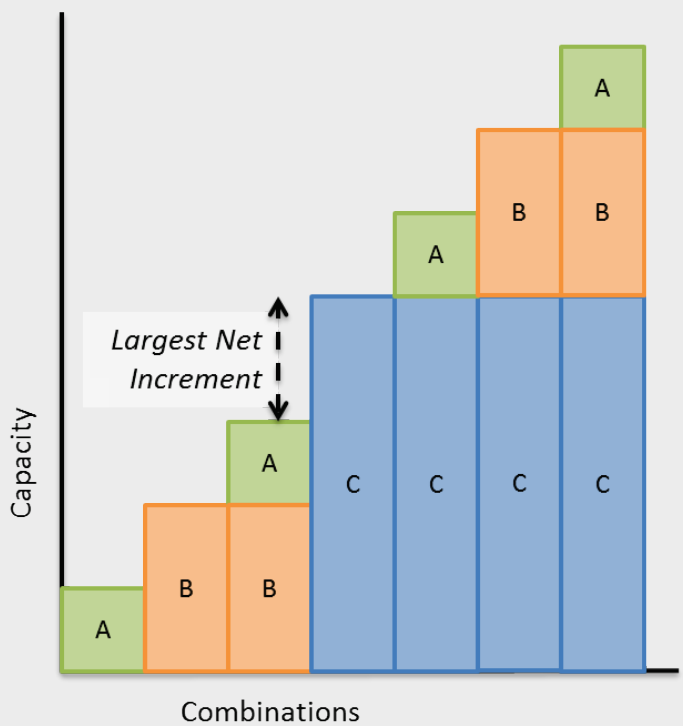
Answer

As shown in the image below there are 8 possible stages of capacity ranging from 0 acfm with no compressors to 1,600 acfm with all three compressors operating. The largest net increment is between stage 4 with compressors A and B operating (200+400=600 acfm) to stage 5 with compressor C operating (1,000 acfm)

Combinations of Base Compressors

Base Compressors	
A	200
B	400
C	1000

Capacity	Combination
0	None
200	A
400	B
600	A + B
1000	C
1200	A + C
1400	B + C
1600	A + B + C



For this system the *Largest Net Capacity Increment* is 1,000 acfm-600 acfm = 400 acfm

Example 10-55

Question

Using the system from the previous example, what is the minimum rated capacity of VSD compressor(s) that are needed to comply with Option 1?

Answer

As previously shown, the *Largest Net Capacity Increment* is 1,000 acfm-600 acfm = 400 acfm. The minimum rated capacity for VSD compressor(s) is 400 acfm X 1.25 = 500 acfm.

Example 10-56

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 1?

Answer

Assuming there is a VSD compressor with a rated capacity of 500 acfm, per §120.6(e)1A it must have 1 gallon of storage per acfm of rated capacity or 500*1 = 500 gallons of storage.

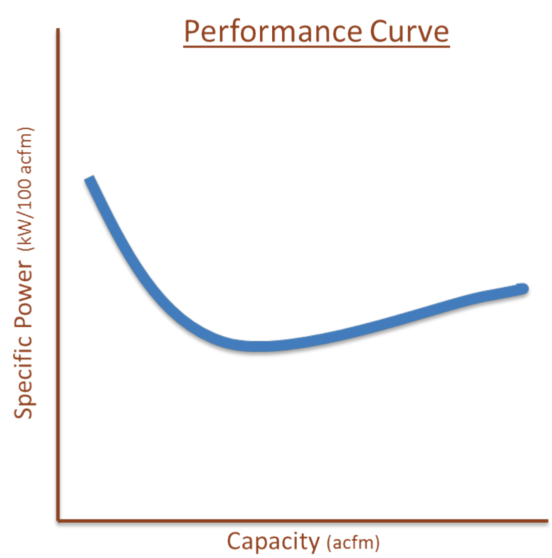
B. Compliance Option 2: Other Compressors as Trim Compressor

§120.6(e)1B

The second compliance option offers more flexibility but requires looking at both the *Largest Net Capacity Increment* of the system, as well as the *Effective Trim Capacity* of the trim compressor(s).

The *Effective Trim Capacity* is the range across which a trim compressor has adequate part-load performance. Performance is measured in power input over air volume output or specific power (kw/100 acfm). Many VSD compressors come with a compressor performance graph in a CAGI data sheet that looks similar to the graph in Figure 10-41.

Figure 10-41: Example Compressor Power vs. Capacity Curve



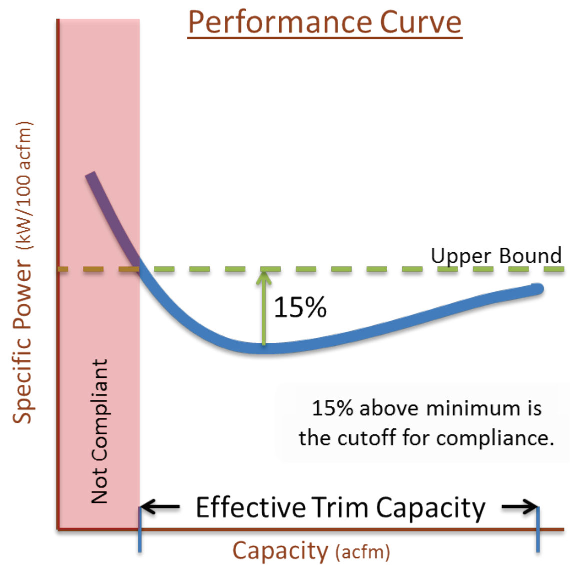
The capacity of the compressor is along the x-axis, while the power is on the y-axis. The curve in Figure 10-41 is a typical shape of a performance curve for a VSD compressor. The lower the specific power, the more energy efficient the compressor is at that condition.

The *Effective Trim Capacity* uses the minimum of the compressor power vs. capacity curve to determine the range of adequate part-load performance. This can be done in the following steps and is illustrated in the graph below.

1. Find the minimum specific power across the range.
2. Find the upper bound by calculating 1.15 times the minimum specific power.
3. Determine the endpoints of the capacity (acfm) where the specific power is less than or equal to the upper bound.

4. The capacity difference in units of acfm between these two endpoints is the effective trim capacity.

Figure 10-42: Determination of Effective Trim Capacity from a Compressor Curve



This definition of *Effective Trim Capacity*, along with the *Largest Net Capacity Increment* of the system, will be used to assist in sizing the trim compressor appropriately in the next section.

For compliance option 2, the system must include primary storage that has a minimum capacity of 2 gallons for every acfm of capacity of the largest trim compressor.

Example 10-57

Question

Continuing with the system from the previous examples, what is the required minimum *Effective Trim Capacity* of the trim compressor(s) to comply with Option 2*?*

Answer

As previously shown, the *Largest Net Capacity Increment* is 1,000 acfm-600 acfm = 400 acfm. Per §120.6(e)1 the minimum *Effective Trim Capacity* is equal to the *Largest Net Capacity Increment* or 400 acfm.

Example 10-58

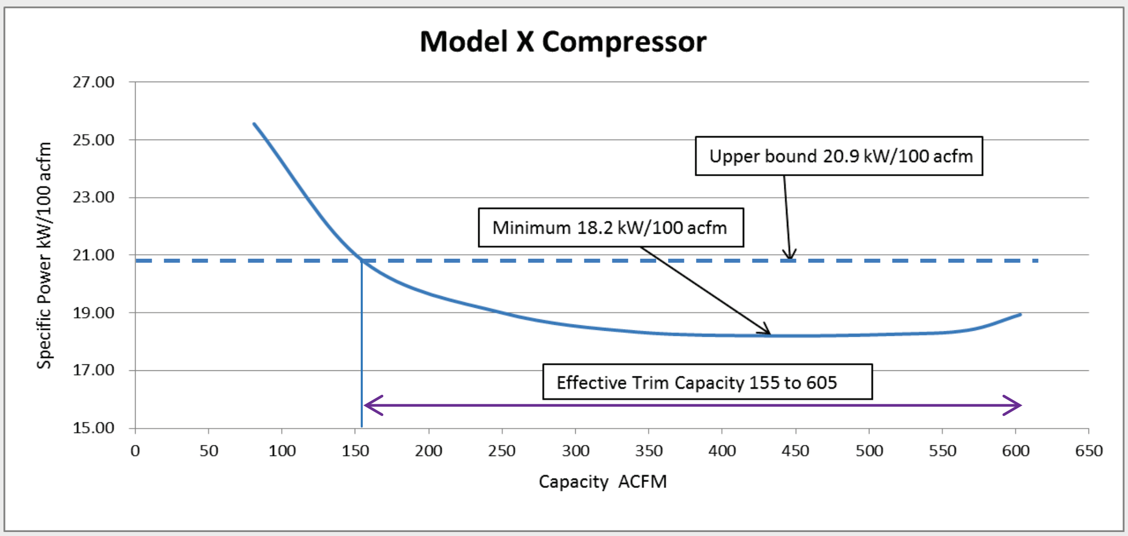
Question

A manufacturer provided the following data for their compressor; would this provide the minimum *Effective Trim Capacity* for this system to comply with Option 2?

Input Power (kW)	Capacity (acfm)[a,d]	Specific Power (kW/100 acfm)[d]
20.7	81.0	25.56
32.4	156.0	20.77
47.5	250.0	19.00
62.7	342.0	18.33
79.0	434.0	18.20
94.2	516.0	18.26
104.3	567.0	18.40
114.2	603.0	18.94

Answer

From the manufacturer's data the minimum specific power is 18.2 kW/100 acfm. The upper limit would be 18.2 * 1.15 = 20.9 kW/100 acfm. Interpolating from the manufacturer's data this appears to go from 155 acfm to 605 acfm for an Effective Trim Capacity of 605-155= 450 acfm. This is larger than the *Largest Net Capacity Increment* of 400 acfm so this compressor would comply as a trim compressor for this system.



Example 10-59

Question

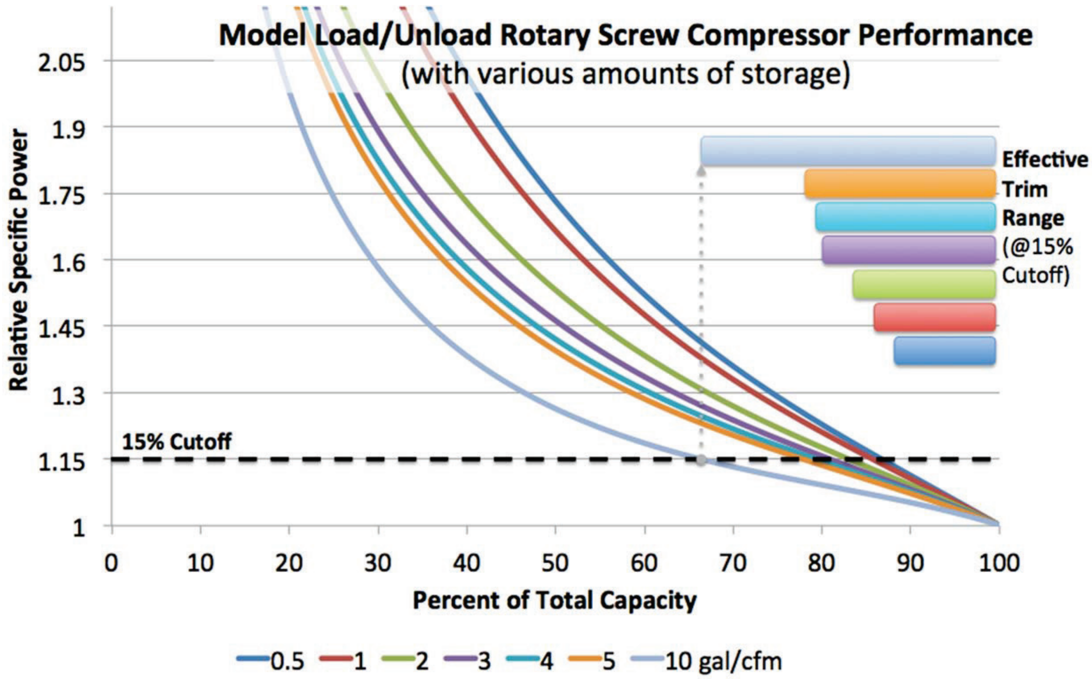
What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

This compressor has a rated capacity of 603 acfm, per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 603*2 = 1,206 gallons of storage.

The last example used a VSD compressor, but other technologies can be used for compliance option 2 such as a compressor with unloaders and sufficient compressed air storage to achieve relatively high part load efficiencies over a broad range of compressed air flow rates. Generally, higher levels of storage improve part-load performance. The following data in Figure 10-43 and for this example was generated from theoretical curves used in AirMaster+, a tool created by the U.S. Department of Energy.

Figure 10-43: Normalized efficiency curves for a screw compressor with load/unload controls for various amounts of storage



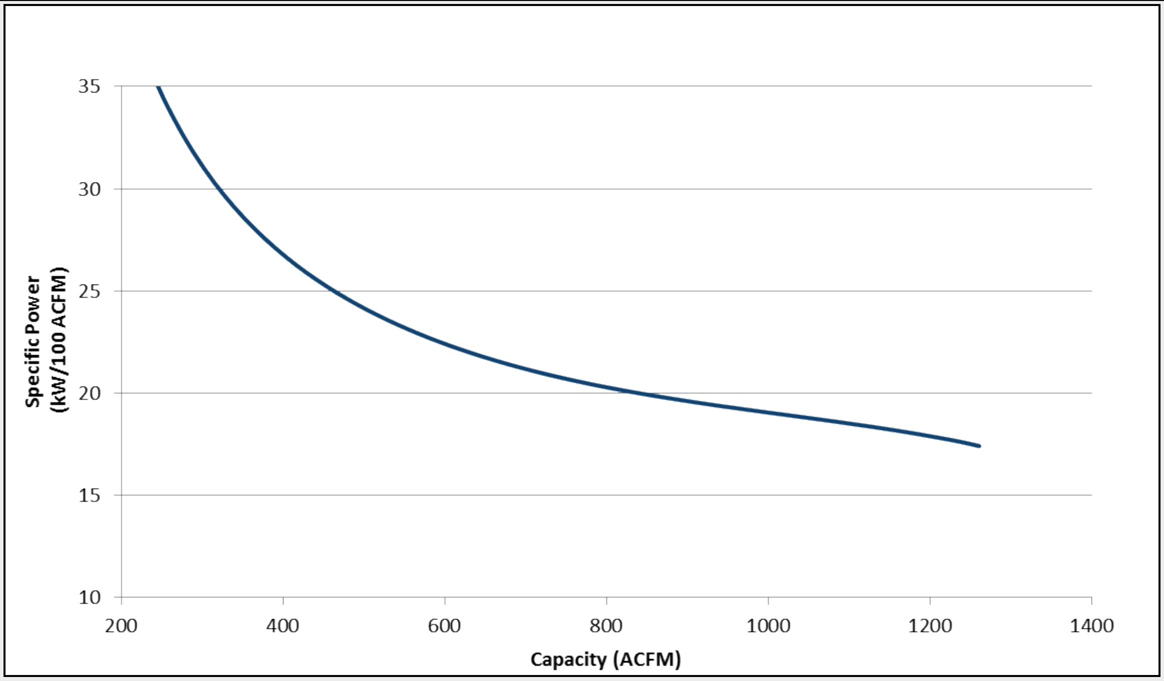
Source: Derived from Fact Sheet 6 – Compressed Air Storage, Improving Compressed Air Storage: a Sourcebook for Industry, U.S. Department of Energy, 2003

The next example examines a 250-hp load-unload, single stage, rotary screw compressor coupled with 10 gallons/cfm of storage. This combination of compressor and storage was chosen to meet the part-load performance mandated by code.

Example 10-60

Question

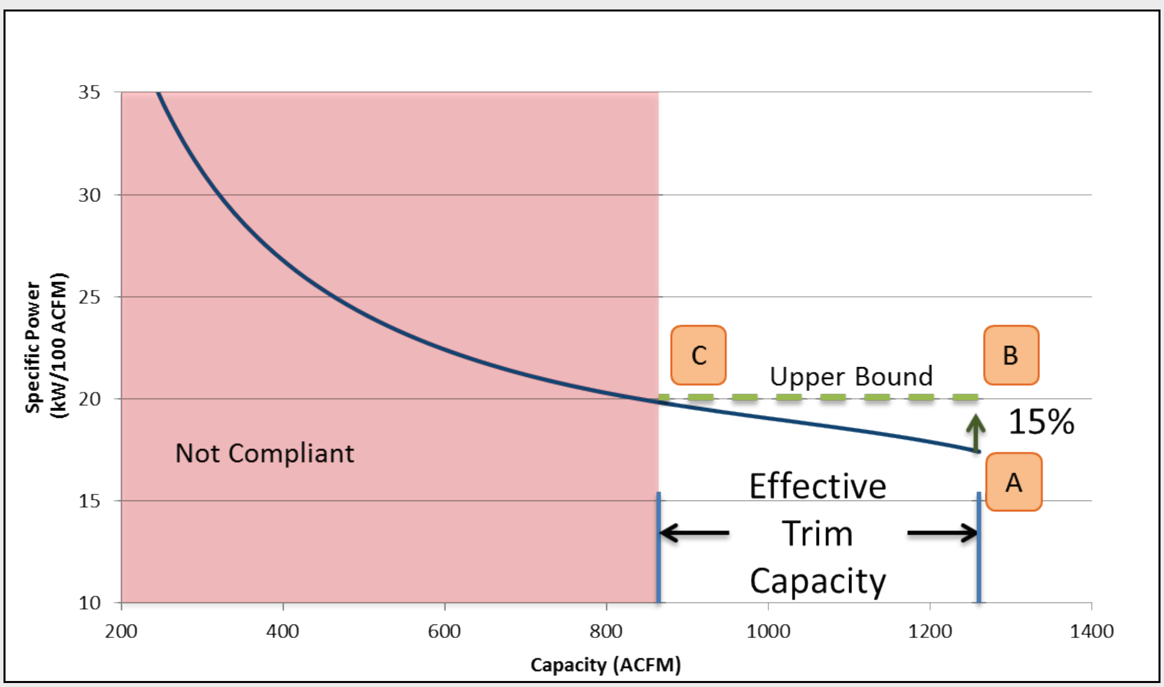
Part-load data was approximated below for a 250-hp load-unload, single stage, rotary screw compressor (with a capacity of 1,261 acfm) coupled with 10 gallons/cfm of storage; would this provide the minimum *Effective Trim Capacity* for this system to comply with Option 2?



Answer

Using the previous examples, a compressor with an effective trim capacity of at least 400 acfm is necessary.

Looking at the graph, the minimum specific power (labeled as A below) occurs at full load - a capacity of 1261 acfm, with a specific power of 17.4 kW/100 acfm. Using this minimum specific power, the upper bound is 17.4 * 1.15 = 20.01 kW/100acfm or 15% higher than the minimum specific power. This puts the ends of the effective trim capacity at 1261 acfm (labeled as B) and 845 acfm (labeled as C), resulting in an effective trim capacity of 1261 – 845 = 416 acfm. This is larger than the Largest Net Capacity Increment of 400 acfm so this compressor would comply as a trim compressor for this system.



Example 10-61

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

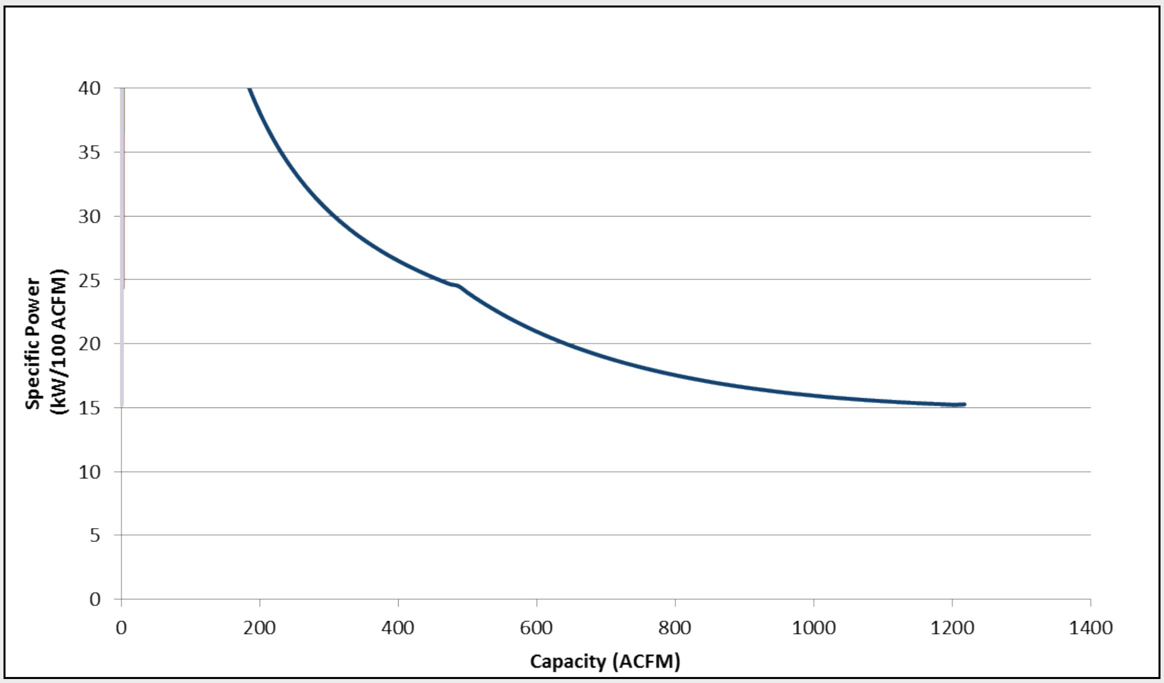
This compressor has a rated capacity of 1261 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1261 * 2 = 2,522 gallons of storage.

However, a minimum of 10 gallons of storage per acfm was needed for the screw compressor with a load/unload controls to have a large enough Effective Trim Capacity. The minimum required primary storage to meet both the Effective Trim Capacity and storage requirements in §120.6(e)1B, is 10 gal per acfm of rated trim compressor capacity, thus the minimum primary storage capacity required is 1261 * 10 = 12,610 gallons.

Example 10-62

Question

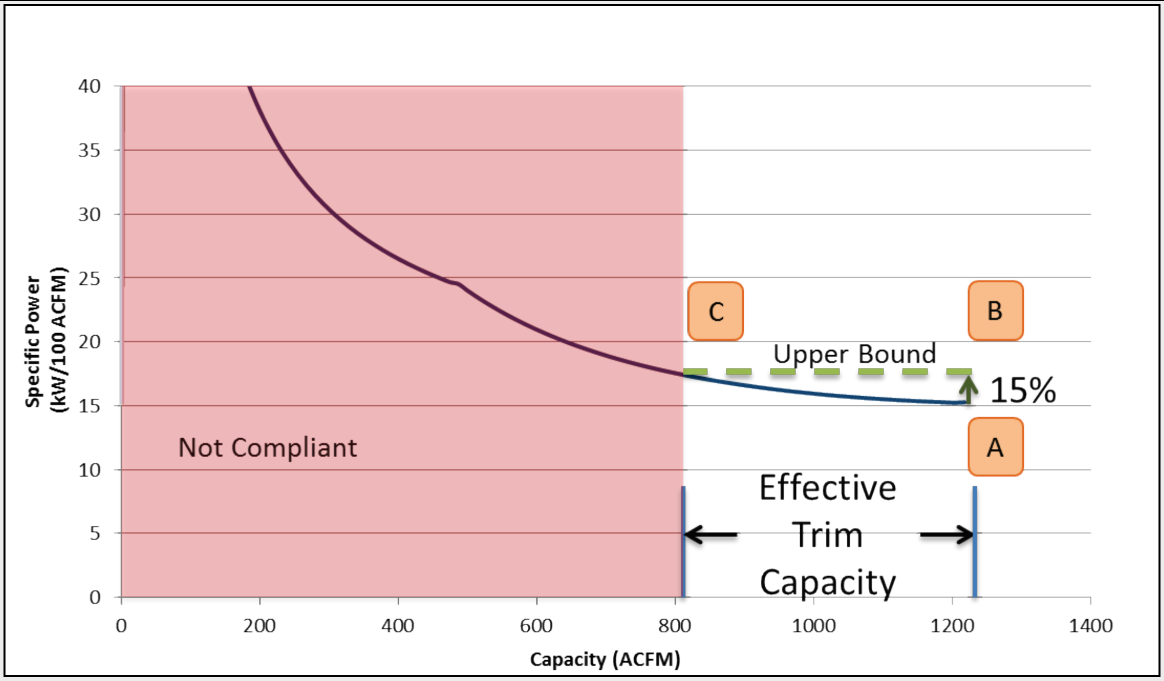
Part-load data was approximated below for a 250-hp variable capacity compressor; would this provide the minimum *Effective Trim Capacity* for this system to comply with Option 2?



Answer

Using the previous examples, a compressor with an effective trim capacity of at least 400 acfm is necessary.

Looking at the graph, the minimum specific power (labeled as A below) occurs at full load - a capacity of 1218 acfm, with a specific power of 15.3 kW/100 acfm. Using this minimum specific power, the upper bound is 15.3 * 1.15 = 17.56 kW/100 acfm or 15% higher than the minimum specific power. This puts the ends of the effective trim capacity at 1218 acfm (labeled as B) and 804 acfm (labeled as C), resulting in an effective trim capacity of 1218 – 804 = 414 acfm. This is larger than the Largest Net Capacity Increment of 400 acfm so this compressor would comply as a trim compressor for this system.



Example 10-63

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

This compressor has a rated capacity of 1218 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1218 * 2 = 2,236 gallons of storage.

10.8.2.2 Controls

§120.6(e)2

This requirement applies to new facilities that are being altered with ≥100 hp of installed compressor capacity. The section requires an automated control system which will optimally stage the compressors to minimize energy for the given load. With new systems, this ideally means that at any given load, the only compressors running at part-load are the trim compressors. Because not all systems are required to upgrade the trim compressor, the installed controls must stage the compressors in the most efficient manner.

This requirement also mandates the measurement of air demand. The control system must be able to measure or calculate the current system demand (in terms of actual cubic feet per minute of airflow). There are two ways to accomplish this, including but not limited to the following sensors:

- A flow meter.
- A combination of pressure transducers and power meters.

10.8.2.3 Acceptance

§120.6(e)3

New systems and altered systems which are subject to the trim compressor requirements of §120.6(e)1 or the staging control requirements of §120.6(e)2 must be tested per NA7.13.

10.8.3 Prescriptive Measures

§140.9

There are no prescriptive measures for compressed air systems.

10.8.4 Additions and Alterations

These requirements apply to existing systems which are being altered and which have a total compressor capacity of ≥ 25 hp. These requirements will be triggered by replacing a compressor, adding a compressor, or removing a compressor.

These requirements will not apply to:

- Adding a VFD to a fixed speed compressor
- Repairing a compressor
- Replacing a compressor drive motor
- Adding compressed air controls
- Adding air dryers
- Adding oil separators
- Adding compressed air storage capacity
- Removing an air compressor without adding any air compressors

For alterations or additions to an existing compressed air system, the requirements for trim compressor size and storage only apply when the combined capacity of compressor replacements and/or additions are 50 percent or more of the existing online capacity (not including back-up compressor capacity) of the compressed air system. Since the capacity of a compressor is closely correlated to its horsepower, for simplicity of compliance and enforcement, the combined horsepower of the alterations and/or additions can be used to determine the total combined capacity.

Example 10-64

Question

If a 50 hp compressor was added to a compressed air system with only one existing 100 hp compressor, would the requirements of §120.6(e) apply?

Answer

Yes, because 50 hp is equal to or greater than 50 percent of the existing 100 hp capacity.

Example 10-65

In some cases after a compressed air assessment, it is recognized that the online compressor capacity can be downsized. As an example, a plant has a system with 100 hp online compressor and a 100 hp back-up compressor. After the assessment, it is identified that the maximum hp needed to meet the air demand is only 50 hp. The project scope calls for the installation of one 50 hp compressor and to leave both existing 100 hp compressors as back-up compressors.

Question

What requirements of §120.6(e) apply?

Answer

After the retrofit, the online compressor horsepower is 50 hp. Since the total online compressor hp is greater than 25 hp, the requirements of §120.6(e) 1, 2 and 3 must be considered. The new 50 hp compressor accounts for 50 percent of the preexisting online capacity. Thus the trim compressor requirements of §120.6(e)1 would apply.

Since this system only has one on-line compressor, the requirements for a load controller that optimizes compressor selection as described in §120.6(e)2 is not required.

Since this system was required to install a trim compressor, the acceptance test requirement of §120.6(e)3 would apply.

The requirements for a staging control only apply if after the alterations/additions, there is more than one online compressor and their total combined horsepower is greater than 100 hp.

The acceptance testing mentioned in §120.6(e)3 test for system blow-off and short cycling. These issues are impacted by sizing and specification of the trim compressor or the selection and programming of an optimal staging control. Thus the acceptance tests are required only for alterations/additions where a trim compressor and/or staging controls are required.

10.9 Process Boilers

10.9.1 Overview

A process boiler is a type of boiler with a capacity (rated maximum input) of 300,000 Btus per hour (Btu/h) or more that serves a process. A process is an activity or treatment that is not related to the space conditioning, service water heating, or ventilating of a building as it relates to human occupancy.

10.9.2 Mandatory Measures

§120.6(d)

10.9.2.1 Combustion Air

§120.6(d)1

Combustion air positive shut-off shall be provided on all newly installed process boilers as follows:

- All process boilers with an input capacity of 2.5 MMBtu/h (2,500,000 Btu/h) and above, in which the boiler is designed to operate with a non-positive vent static pressure. This is sometimes referred to as natural draft or atmospheric boilers. Forced draft boilers, which rely on a fan to provide the appropriate amount of air into the combustion chamber, are exempt from this requirement.
- All process boilers where one stack serves two or more boilers with a total combined input capacity per stack of 2.5 MMBtu/h (2,500,000 Btu/h). This requirement applies to natural draft and forced draft boilers.

Combustion air positive shut-off is a means of restricting air flow through a boiler combustion chamber during standby periods, and is used to reduce standby heat loss. A flue damper and a vent damper are two examples of combustion air positive shut-off devices.

Installed dampers can be interlocked with the gas valve so that the damper closes and inhibits air flow through the heat transfer surfaces when the burner has cycled off, thus reducing standby losses. Natural draft boilers receive the most benefit from draft dampers because they have less resistance to airflow than forced draft boilers. Forced draft boilers rely on the driving force of the fan to push the combustion gases through an air path that has relatively higher resistance to flow than in a natural draft boiler. Positive shut-off on a forced draft boiler is most important on systems with a tall stack height or multiple boiler systems sharing a common stack.

10.9.2.2 **Combustion Air Fans**

§120.6(d)2

Combustion air fans with motors 10 horsepower or larger shall meet one of the following for newly installed boilers:

- The fan motor shall be driven by a variable speed drive, or
- The fan motor shall include controls that limit the fan motor demand to no more than 30 percent of the total design wattage at 50 percent of design air volume.

Electricity savings result from run time at part-load conditions. As the boiler firing rate decreases, the combustion air fan speed can be decreased.

10.9.2.3 **Excess Oxygen ≥ 5 MMBtu/h to ≤ 10 MMBtu/h**

§120.6(d)3 and 4

Newly installed process boilers with an input capacity of 5 MMBtu/h (5,000,000 Btu/h) to 10 MMBtu/h (10,000,000 Btu/h) shall maintain excess (stack-gas) oxygen concentrations at less than or equal to 5.0 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to firing rate or measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

One way to meet this requirement is with parallel position control. Boilers mix air with fuel (usually natural gas although sometimes diesel or oil) to supply oxygen during combustion. Stoichiometric combustion is the ideal air/fuel ratio where the mixing proportion is correct, the fuel is completely burned, and the oxygen is entirely consumed. Boilers operate most efficiently when the combustion air flow rate is slightly higher than the stoichiometric air-fuel ratio. However, common practice almost always relies on excess air to insure complete combustion, avoid unburned fuel and potential explosion, and prevent soot and smoke in the exhaust. Excess air has a penalty, which is increased stack heat loss and reduced combustion efficiency.

Parallel positioning controls optimize the combustion excess air to improve the combustion efficiency of the boiler. It includes individual servo motors allowing the fuel supply valve and the combustion air damper to operate independently of each other. This system relies on preset fuel mapping (i.e., a pre-programmed combustion curve) to establish proper air damper positions (as a function of the fuel valve position) throughout the full range of burner fire rate. Developing the combustion curve is a manual process, performed in the field with a flue-gas analyzer in the exhaust stack, determining the air damper positions as a function of the firing rate/fuel valve position. Depending on type of burner, a more consistent level of excess oxygen can be achieved with parallel position compared to single-point positioning control, since the combustion curve is developed at multiple points (firing rates), typically 10 to 25 points. Parallel positioning controls allow excess air to remain relatively low throughout a burner's firing range. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while still maintaining a safe margin of excess air to insure complete combustion.

10.9.2.4 **Excess Oxygen > 10 MMBtu**

§120.6(d)4

Newly installed process boilers with an input capacity greater than 10 MMBtu/h (10,000,000 Btu/h) shall maintain excess (stack-gas) oxygen concentrations at less than or equal to 3.0 percent by volume on a dry basis over firing rates of 20 percent to 100 percent. Combustion air volume shall be controlled with respect to measured flue gas oxygen concentration. Use of a common gas and combustion air control linkage or jack shaft is prohibited.

One way to meet this requirement is with oxygen trim control. This control strategy relies on parallel positioning hardware and software as the basis but takes it a step further to allow operation closer to stoichiometric conditions. Oxygen trim control converts parallel positioning to a closed-loop control configuration with the addition of an exhaust gas analyzer and PID controller. This strategy continuously measures the oxygen content in the flue gas and adjusts the combustion air flow, thus continually tuning the air-fuel mixture.

Detecting and monitoring excess air is easy because oxygen not consumed during combustion is present in the exhaust gases. Detecting and monitoring carbon monoxide assures the air/fuel ratio is not too rich as the excess air is trimmed. Based on the exhaust gas analysis, a controller maintains close to stoichiometric combustion by commanding a servo motor to adjust the combustion air damper and another servo motor to adjust the fuel supply valve.

10.9.3 Prescriptive Measures

There are no prescriptive measures for process boilers.

10.10 Elevators

10.10.1 Overview

§120.6(f) applies to all nonresidential new construction elevators, as well existing elevators undergoing major alterations involving mechanical equipment, lighting and/or controls. The goal behind this measure is to save energy by reducing light power density of the elevator cab lighting and requiring a minimum wattage per cfm for ventilation fans in cabs without air conditioning. Both the lighting and ventilation fans are to be controlled in such a way to shut off when the elevator has been unoccupied for an extended period of time.

10.10.2 Mandatory Measures

§120.6(f)

10.10.2.1 Elevator Lighting Power Density

§120.6(f)1

The lighting power density of an elevator cab shall not exceed 0.6 watts per square foot (W/sq ft). This is determined by taking the total wattage of the elevator lighting and dividing by the area of the elevator in square feet. Interior signal lighting and interior display lighting are not included in the total wattage of the elevator lighting.

Example 10-66

Question

An elevator with a length of 6 ft and a width of 8 ft has 9 LED lamps at 3 Watts each. Does this comply with §120.6(f).1?

Answer

Yes. 9 Lamps * 3 Watts/Lamp = 27 Watts. The square footage of the cab is 6ft*8ft = 48 ft^2. The lighting power density is equal to 27 Watts/48 ft^2 = 0.56 W/ft^2, which is less than 0.6 W/ft^2.

10.10.2.2 Elevator Ventilation CFM Fan Performance

§120.6(f)2

Ventilation fans for cabs without space conditioning shall not exceed 0.33 watts per cubic feet per minute of airflow (W/cfm) at maximum speed. Elevator cabs with space conditioning are excluded from this measure.

10.10.2.3 Elevator Lighting and Fan Shutoff Control

§120.6(f)3

When the elevator cab is stopped and unoccupied with doors closed for over 15 minutes, the cab interior lighting and ventilation fans shall automatically switch off until elevator cab operation resumes. This can be accomplished with an occupancy sensor, or more elaborate built in elevator controls.

10.10.3 Prescriptive Measures

There are no prescriptive measures for elevators.

10.10.4 Additions and Alterations

- An elevator installation is considered an addition when the location of the installation did not previously contain an elevator.
- An alteration is a change to an existing elevator system that is not an addition or repair. An alteration could include installing new controls or a new lighting system.
- A repair is the reconstruction or renewal of any part of an existing elevator system for the purpose of its maintenance. For example, the replacement of lights or cosmetic features.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration.

10.11 Escalators and Moving Walkways

10.11.1 Overview

§120.6(g) applies to nonresidential new construction escalators and moving walkways in airports, hotels, and transportation function areas, as well as existing escalators and moving walkways undergoing major alterations involving mechanical equipment or controls in the same locations. The goal behind this measure is to save energy by reducing the full speed run time of the escalator by slowing it down when unoccupied.

10.11.2 Mandatory Measures

§120.6(g)

10.11.2.1 Escalator and Moving Walkway Speed Control

§120.6(g)1

Escalators and moving walkways located in airports, hotels, and transportation function areas shall automatically slow to the minimum permitted speed in accordance with ASME A17.1/CSA B44 when not conveying passengers.

The ASME A17.1/CSA B44 2013 requirements for intermittent speed control on escalators and moving walkways are summarized below. These requirements are necessary to ensure maximum passenger safety when speeding up or slowing down escalators and moving walkways. In order to be compliant with the Energy Standards, the escalator or moving walkway must also be compliant with ASME A17.1/CSA B44 2013. Additional safety requirements may exist in Title 8.

Variation of the escalator and moving walkway speed after start-up shall be permitted provided the escalator and moving walkway installation conforms to all of the following:

1. The acceleration and deceleration rates shall not exceed 0.3 m/s² (1.0 ft/s²).
2. The rated speed is not exceeded.
3. The minimum speed shall be not less than 0.05 m/s (10 ft/min).
4. The speed shall not automatically vary during inspection operation.
5. Passenger detection means shall be provided at both landings of the escalator such that:
    a. Detection of any approaching passenger shall cause the escalator or moving walkway to accelerate to, or maintain the, full speed conforming to (1) through (4) above.
    b. Detection of any approaching passenger shall occur sufficiently in advance of boarding to cause the escalator or moving walkway to attain full operating speed before a passenger walking at normal speed [1.35 m/s (270 fpm)] reaches the combplate.
    c. Passenger detection means shall remain active at the egress landing to detect any passenger approaching against the direction of escalator or moving walkway travel and shall cause the escalator or moving walkway to accelerate to full rated speed

and sound the alarm at the approaching landing before the passenger reaches the combplate.

6. Automatic deceleration shall not occur before a period of time has elapsed, since the last passenger detection that is greater than 3 times the amount of time necessary to transfer a passenger between landings.
7. Means shall be provided to detect failure of the passenger detection means and shall cause the escalator or moving walkway to operate at full rated speed only.

Figure 10-44: Example of Pedestrian Detection Method using Motion Sensors

Source: wwwtelcosensors.com/solutions/industries/elevators

Escalator speed control is required only in airports, hotels, and transportation function areas. A transportation function area is defined in §100.1 of the Energy Standards as the ticketing area, waiting area, baggage handling areas, concourse, in an airport terminal, bus or rail terminal or station, subway or transit station, or a marine terminal. The reason behind limiting the scope of this measure was to focus on escalators and moving walkways that experience pedestrian flow rates in waves, and are more likely to operate 24 hours a day. An escalator in a busy shopping mall that only operates 12 hours a day may experience a constant pedestrian flow rate throughout the day and would rarely slow down and therefore save little energy. For these continuously busy applications during the operating hours of the escalator, the speed control would not be cost effective.

10.11.3 Prescriptive Measures

There are no prescriptive measures for escalators or moving walkways.

10.11.4 Additions and Alterations

- An escalator or moving walkway installation is considered an addition when the location of the installation did not previously contain an escalator.
- An alteration is a change to an existing escalator or moving walkway system that is not an addition or repair. An alteration could include installing new controls or motor.
- A repair is the reconstruction or renewal of any part of an existing escalator or moving walkway system for the purpose of its maintenance. For example, a repair could include the replacement of a damaged step or handrail.

Any addition or altered space must meet all applicable mandatory requirements. Repairs must not increase the preexisting energy consumption of the repaired component, system, or equipment; otherwise, it is considered to be an alteration.

Table of Contents

11. Performance Approach

11.1 Overview

This chapter summarizes the whole building performance approach to compliance. It includes a discussion of computer methods, the procedures involved in determining the energy budget and the proposed building’s energy use, and how to plan check performance compliance. The basic procedure is to show that the Time Dependent Valuation (TDV) energy of the proposed design is less than or equal to the TDV energy of the standard design. The standard design is a building with the same geometry as the proposed design, but the envelope and lighting features are defined by the prescriptive package requirements while the mechanical system is defined by a specific system-type as described in the Nonresidential ACM Reference Manual.

The performance method is the most detailed and flexible compliance path. The energy performance of a proposed building design can be calculated according to actual building geometry and site placement. Credit for certain energy features, such as a high efficiency mechanical system, cannot be taken in the prescriptive approach, but can be evaluated with an approved compliance software program utilizing the performance approach.

11.2 Performance Method Description

The Nonresidential Alternative Calculation Method (ACM) Approval Manual describes the application and approval process for submitted compliance software. The Nonresidential ACM Approval Manual is adopted as part of the Building Energy Efficiency Standards (Energy Standards) rule making process. The Nonresidential ACM Reference Manual is approved by the California Energy Commission (Energy Commission) that includes explanations of the instructions that all compliance software programs use to model the energy performance of the Proposed Design Building and the Standard Design Building. The reference manual also includes an explanation of the reference method and certification tests used by the Energy Commission to approve compliance software tools. Since the Nonresidential ACM is approved by the Energy Commission (just like the residential and nonresidential compliance manuals), it can be updated from time to time to allow for corrections and enhancements during the 2016 Energy Standards cycle.

11.2.1 Performance Concepts

The Warren-Alquist Act requires “performance standards” that establish an energy budget for the building in terms of energy consumption per ft^2 of floor space. This requires a complex calculation of the estimated energy consumption of the building and the calculation is only suited for a computer. The Energy Commission has developed a public domain computer program to do these calculations. For compliance purposes, it also approves the use of privately developed computer programs as alternatives to the public domain computer program. The public domain computer program and the Energy Commission-approved privately developed programs are officially called alternative calculation methods. It is easiest to refer to these programs as "compliance software," which will be the term used throughout this manual.

11.2.2 Minimum Capabilities

Compliance software must simulate or model the thermal behavior of buildings including envelope surfaces, lighting, space conditioning and service water heating systems. The calculations take into account:

- Conductive and convective heat gain and heat loss through walls, roof/ceilings, doors, floors, windows, and skylights.
- Solar radiant heat gain from windows, skylights, and opaque surfaces.
- Heat storage effects of different types of thermal mass.
- Building operating schedules for people, lighting, equipment and ventilation.
- Space conditioning system operation including equipment part load performance.
- Covered process mechanical equipment (kitchens, laboratories, parking garages).

11.2.3 California Energy Commission Approval

11.2.3.1 **Alternative Calculation Methods (Compliance Software)**

Compliance software must be approved by the Energy Commission. Approval involves the demonstration of minimum modeling capabilities, required input and output, and adequate user documentation. The compliance software must be able to:

1. Automatically calculate the energy budget of the standard design.
2. Calculate the energy use of the proposed design in accordance with specific fixed and restricted inputs.
3. Print the appropriate standardized compliance documents with the required information and format when a proposed building complies. Other reports that do not resemble documents may be printed for buildings that do not comply.

11.2.3.2 **Input and Output Requirements**

Input and output requirements and modeling capabilities are tested by using the compliance software to calculate the energy use of certain prototype buildings under specific conditions. These results are compared with the results from a reference computer program, which is EnergyPlus. This is explained in detail in the Nonresidential ACM Reference Manual.

11.2.4 Time Dependent Valuation (TDV)

Beginning with the 2005 Energy Standards, the metric or “currency” for assessing building performance is time dependent valued (TDV) energy. TDV energy replaced source energy that had been the compliance metric since the Energy Commission first adopted the Energy Standards in 1978.

As the name implies, TDV values energy differently depending on the day of the year and hour of the day that a specific type of energy is used. This means that electricity saved on a hot summer afternoon will be worth more in the compliance process than the same amount of electricity saved on a winter morning. The value assigned to energy savings through TDV more closely reflects the market for electricity, gas, propane and other energy sources and provides incentives for measures, such as thermal storage or advanced daylighting that are more effective during peak periods.

Reference Appendix JA3 provides more information on TDV energy and detailed TDV data is available from the Energy Commission upon request. §100.2 states: “TDV multipliers for propane shall be used for all energy obtained from depletable sources other than electricity and natural gas." A sample of the TDV values is shown below in Figure 11-1.

Figure 11-1: Annual TDV Energy Use Summary (Sample from NRCC-PRF-01-E)

B. COMPLIANCE RESULTS FOR PERFORMANCE COMPONENTS				§ 140.1
BUILDING COMPLIES				
1. Energy Component	2. Standard Design (TDV)	3. Proposed Design (TDV)	4. Compliance Margin (TDV)	5. Percent Better than Standard
Space Heating	5.8	5.7	0.1	1.7%
Space Cooling	6.6	13.3	-6.7	-101.5%
Indoor Fans	6.3	1.2	5.1	81.0%
Heat Rejection	1.3	--	1.3	--
Pumps & Misc.	4.2	--	4.2	--
Domestic Hot Water	23.3	24.8	-1.5	-6.4%
Indoor Lighting	41.2	41.2	--	0.0%
COMPLIANCE TOTAL	**88.7**	**86.2**	**2.5**	**2.8%**
Receptacle	42.6	42.6		0.0%
Process	--	--		--
Process Ltg	--	--		--
TOTAL	**131.3**	**128.8**		**1.9%**

11.2.4.1 **Professional Judgment**

Certain modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. That is, there is little or no freedom to choose input values for energy compliance modeling purposes. However, there are other aspects of energy modeling where some professional judgment may be necessary. In those instances, the compliance software user must decide whether a given input is appropriate.

Enforcement agencies have discretion to question a particular input if the permit applicant cannot substantiate the value with supporting documentation or cannot demonstrate that appropriate judgment has been applied.

Two questions may be asked in order to resolve whether appropriate judgment has been applied correctly in any particular case:

1. Is a simplified input or assumption appropriate for a specific case? If simplification reduces the predicted energy use of the proposed building or reduces the compliance margin when compared to a more explicit and detailed modeling assumption, then the simplification is not acceptable. That is, simplification must reflect the same or higher energy use than a more detailed model and reflect the same or lower compliance margin when comparing the standard and proposed TDV energy.
2. Is the approach or assumption used in modeling the proposed design consistent with the approach or assumption used by the compliance software when generating the standard design energy budget? One must always model the proposed design using the same assumption and/or technique used by the compliance software when calculating the energy budget unless drawings and specifications indicate specific differences that warrant energy compliance credits or penalties.

Any unusual modeling approach, assumption, or input value should be documented with published data and, when applicable, should conform to standard engineering practice.

Example 11-1

Question

Three different sized windows in the same wall of a new one-story office building are designed without exterior shading, and they have the exact same NFRC-rated U-factors and SHGC values. Is it acceptable professional judgment to simplify the computer model by adding the areas of the three windows together and inputting them as a single fenestration area?

Answer

Yes. The compliance software will produce the same energy results whether or not the windows are modeled individually or together as one area because the orientation, fenestration U-factors and SHGC values of the windows are identical. However, if overhangs and side-fins are modeled, the correct geometry of fixed shades must be modeled for each window.

11.3 Analysis Procedure

§140.1

This section is a summary of the analysis procedures used in demonstrating compliance with approved compliance software programs. Software users and those checking for enforcement should consult the most current version of the compliance software user's manual and/or on-line help and associated compliance supplements for specific instructions on the operation of the compliance software. Although there are numerous requirements for each software input, the data entered into each software version may be organized differently from one vendor to the next. As a result, it is not possible in this summary to present all variables in their correct order or hierarchy for any one software version. The aim is to identify the procedures used to calculate the standard design energy budget and the TDV energy use of the proposed building.

11.3.1 General Procedure

Any compliance software version approved by the Energy Commission may be used to comply with the Energy Standards. The following steps are a general outline of the process:

1. All detailed data for the building component(s) must be collected including fenestration areas and energy properties, wall, door, roof/ceiling, and floor areas, construction assemblies, mass characteristics, equipment specifications, lighting, and service water heating information from the drawings and specifications.
2. Although most compliance software requires the same basic data, some information and the manner in which it is organized may vary according to the particular software used. Refer to the compliance supplement that comes with each version of compliance software for additional details.
3. Be sure that the correct climate information has been selected for the building site location (see Reference Appendix JA2). Compliance software also adjusts outside heating and cooling design temperatures for local conditions using ASHRAE design data that is also located in Reference AppendixJA2.
4. Prepare an input file that describes the other thermal aspects of the proposed design according to the rules described in the software's compliance supplement.
5. Input values and assumptions must correctly correspond to the proposed design and conform to the required mandatory measures.
6. Run the compliance software to automatically generate the energy budget of the standard design and calculate the energy use of the proposed design.

11.3.1.1 Computer Input Files

When creating any computer input file, use the space provided for the project title information to concisely and uniquely describe the building being modeled. User-designated names should be clear and internally consistent with other buildings being analyzed in the same project. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement process.

11.3.2 Basic Data Entry

11.3.2.1 Elements Used in Compliance Software

The following elements are used by compliance software programs. These elements must be consistent with plans and specifications submitted in the building permit application:

1. **Opaque Walls**: Each opaque exterior wall construction assembly, wall area, orientation, and tilt. Heat capacities, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior walls, must be included. Interior demising wall area and characteristics must also be input.
2. **Doors**: All doors must be included.
3. **Opaque Roofs/Ceilings**: Each opaque exterior roof/ceiling construction assembly, roof/ceiling area, solar reflectance, thermal emittance, orientation, and tilt. Heat capacity, or characteristics necessary to determine the heat capacity (conductivity, mass, volume) of opaque exterior roof/ceilings, must be included.
4. **Raised Floors and Slab Floors**: Each floor construction assembly, including floor area.
5. **Fenestrations in Walls and Shading**: Each vertical glass area, orientation, tilt, U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT).
6. **Horizontal (Skylight) Glass and Shading**: Each horizontal or skylight glass area, orientation, tilt, U-factor and SHGC.
7. **Ventilation (Outside) Air**: Ventilation (or outside air) values in cfm/ft².
8. **Fan Power**: Fan power must be included. Fan power should be based on either brake horsepower (HP) at ARI conditions, nominal HP at ARI conditions, or brake horsepower at actual operating conditions (modeled horsepower must be substantiated by information contained in the construction documents).
9. **Cooling and Heating Efficiency**: The actual efficiency of the equipment included in the proposed design.
10. **HVAC System Type**: The basic type of the cooling and heating system (multiple zones or single zone) and the heating system fuel type (fossil fuel or electric). Note that some projects may have different system types serving separate zones.
11. **Sensible and Total Cooling System Capacity**: Sensible and total output capacity of the cooling system at ARI conditions.
12. **Heating System Capacity**: The output capacity of the heating system.
13. **Indoor Lighting:** Lighting loads and modeling non-mandatory controls for credit.
14. **Water Heating:** The water heating capacity, volume, and efficiency (including any solar thermal contribution).

15. **Other System Values**: All other space conditioning system components, process loads, or any other mechanical system that impacts the building energy performance must be included in the input file.

Refer to the compliance software user's manual for more detailed information on how each of the above values is used by the software.

11.3.3 Calculating TDV Energy

The compliance software calculates TDV energy for three main components:

1. The space conditioning energy use.
2. The indoor lighting energy use.
3. The service water heating energy use.

It does not allow energy credits or penalties for plug loads (even though a default value for the internal gains from plug loads is modeled in the hourly computer simulation), vertical transportation (elevators), outdoor lighting or other miscellaneous energy uses.

The proposed building energy budget is defined by §140.1(b) and includes the envelope, space conditioning and ventilation, indoor lighting, and water heating systems assigned to the building. The key component of calculating the TDV energy use of the proposed building is that if a feature of the building is not included in the building permit application, the energy use of that feature is equal to that of the standard energy budget defined in §140.1(a). That means that if a permit is submitted for a building shell (envelope only), and the performance approach is used to demonstrate compliance, trade-offs cannot be made between the envelope and the mechanical or lighting system.

The standard design budget is defined by replacing all of the energy features of the proposed building with a combination of the envelope features listed in the prescriptive package requirements in Tables 140.3 B or C of the Energy Standards. Lighting and mechanical values associated with the building occupancy and design are defined in the Nonresidential ACM Reference Manual.

11.3.3.1 **Space Conditioning Energy Budget**

The space conditioning energy budget is automatically determined from the software's user inputs and the corresponding elements of the proposed design. This budget is automatically re-calculated with each compliance run.

11.3.3.2 **Lighting Energy Budget**

The indoor lighting budget consists of the lighting power used by a building based on one of the following criteria:

1. When no lighting plans or specifications are submitted for permit and the occupancy of the space is not known, the standard lighting power density is 0.5 W/ft².
2. When no lighting plans or specifications are submitted for permit and the occupancy of the space is known, the standard lighting power is equal to the corresponding watt per ft² value derived in the Area Category Method of §140.6(c)2.
3. When lighting plans and specifications are submitted for permit, the standard lighting power is equal to the corresponding total allowed lighting power (in watts) that was used in calculating the proposed lighting level which can be based on either the Area Category Method or the Tailored Method (§140.6(c)2 or 3). A complete set of lighting plans and prescriptive documents are required to use the Tailored Lighting Method in

the performance approach. When this method is used to justify an increase in the allowed lighting watts, a lower lighting load in the proposed design cannot be modeled for credit. The standard design building uses the lesser of allowed Watts per ft² or actual lighting power to be installed in the building. The proposed design building uses the actual lighting power to be installed as detailed on the lighting plans. This value must be equal to or greater than the allowed Watts per ft².

For all occupancies except hotel guest rooms and high-rise residential living quarters, the proposed lighting power is input into the software. For residential occupancies (hotel guest rooms or high-rise residential buildings), the compliance software will automatically set the proposed lighting power and the standard design lighting power at the same value as specified in the Nonresidential ACM Reference Manual.

11.3.3.3 Service Water Heating Energy Budget

The service water heating budget consists of the service water heating energy used by a building assuming the service water heating system meets both the mandatory and prescriptive requirements for water heating.

The service water heating TDV energy use is calculated using one of two methods:

1. For nonresidential occupancies, a method described in the Nonresidential ACM Reference Manual uses the proposed design with minimal efficiency equipment as the standard design.
2. For hotels, motels and high-rise residential buildings, the water heating TDV energy budget is calculated using the methods and assumptions documented in the Residential ACM Reference Manual. This method sets the standard design based on gas fired equipment using a central system plus the solar thermal contribution. The installed system must be consistent with plans and specifications submitted in the building permit application.

11.4 Application Scenarios

The performance approach may be used for whole building permit applications; or for permit applications that involve any combination of building envelope, indoor lighting, and/or mechanical system. The performance method may be used to demonstrate compliance with the envelope alone or the mechanical system alone but cannot be used to show lighting compliance alone. A permit stage is when less than a whole building is being considered (e.g. the building envelope would be constructed in one permit phase, the mechanical system in another, etc).

11.4.1 Whole Building Compliance

Whole buildings are projects involving buildings where the applicant is applying for permits and submitting plans and specifications for all the major components of the building (envelope, mechanical, indoor lighting, and service water heating). This could be a first time tenant improvement that involves envelope, mechanical and lighting compliance, where plans and specifications for the entire building are being submitted for permit.

When a whole building is modeled using the performance approach, trade-offs can be made between the envelope, space conditioning, service water heating, and indoor lighting systems that are included in the permit application.

11.4.2 Compliance by Permit Stage

Compliance with only one or more building permit stages can be done using the performance approach except that indoor lighting cannot be done alone. A permit stage is a portion of a whole building permit: either envelope, mechanical, or lighting. This means that trade-offs in energy use are limited to only those features, or a single feature in the case of envelope or mechanical, included in the building permit application.

There are two basic scenarios that occur when performing compliance by permit stage:

1. Modeling future construction features that are not included in the permit application
2. Modeling existing construction that has complied with the Energy Standards.

11.4.2.1 **Modeling Future Construction by Permit Stage**

When a feature of a building is not included in the permit application, it is required to default to a feature automatically determined in the compliance software. The defaults vary for envelope, mechanical, and indoor lighting. The Nonresidential ACM Reference Manual and the software vendor’s compliance supplements contain additional information on the default values.

The default envelope features do not apply when modeling future construction. Usually, this is the first permit requested and this feature must be modeled at a minimum. The proposed building's envelope features are input and an energy budget is automatically generated based on the proposed building's envelope, and/or space conditioning and indoor lighting system.

The default space conditioning system features are fixed if no space conditioning system is being permitted. The default space conditioning system is based on the standard design as determined in the Nonresidential ACM Reference Manual.

The default lighting system features depend on whether or not the occupancy of the space is known. If the space occupancy is known, the allowed lighting power is determined using the Area Category Method for each zone that the occupancy is known. If the space occupancy is not known, 0.5 W/ft² is assumed for both the proposed energy use and the energy budget

The default service water heating system features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type. For nonresidential occupancies other than hotels, motels and high-rise residential buildings the default is a gas-fired storage type system.

11.4.2.2 **Modeling Existing Construction by Permit Stage**

When existing indoor lighting or an existing mechanical system is not included in the permit application, the compliance software may use default values for certain inputs. The Nonresidential ACM contains additional information on the default values.

The envelope features are based on the compliance software user's inputs to the compliance software. The user inputs the proposed building's conditioned floor area, glazing, wall, floor/soffit, roof/ceiling, and display perimeter features. The compliance software then applies the proposed building's features to the standard design in order to calculate the energy budget. If an application for an envelope permit is not being sought, the compliance software will automatically default the features of the standard design to be the same as the features of the proposed design.

Default space conditioning system features are fixed based on the building's existing space conditioning system. The user inputs the existing space conditioning system, including actual sizes and types of equipment. The compliance software then applies the proposed building's space conditioning features to create a standard design mechanical system used to calculate the energy budget. This means that if an application is not being sought for a mechanical permit, the compliance software will automatically default the features of the standard design to become the proposed design.

Default service water heating system features are fixed based on building occupancy. Default service water heating systems are specified for each occupancy type. Water heating information will only be listed as "Existing".

Default lighting system features are based on the known occupancy of the building. The allowed lighting power is determined based on the Area Category lighting power for the proposed design, or an existing modeled lighting power from field data. The compliance software then applies the proposed building's indoor lighting power to the standard design in order to calculate the energy budget. This means that if an application for a lighting permit is not being sought, the compliance software will automatically default the lighting features of the standard design to be the same as the lighting features of the proposed design.

11.4.3 Additions Performance Compliance

An addition that consists of both new conditioned floor area and added volume will be treated similar to a new building in the performance approach. All systems serving the addition will require compliance to be demonstrated; and either the prescriptive or performance approach can be used for each stage of the construction of the addition.

Note: When existing space conditioning or water heating is extended from the existing building to serve the addition, those systems do not need to comply with new construction energy efficiency requirements; however, all applicable mandatory measures must be met for new components and controls.

11.4.3.1 **Addition Only**

Additions that show compliance with the performance approach independent of the existing building must meet the requirements for new buildings. §141.0(a) states that the envelope and indoor lighting of the addition, any newly installed space conditioning, electrical power distribution system, or water heating system must meet mandatory measures and the applicable energy budget:

1. If the permit is done in stages, the rules for each permit stage apply to the addition’s performance run.
2. If the whole addition (envelope, lighting and mechanical) is included in the permit application, the rules for whole buildings apply.

11.4.3.2 **Existing Plus Addition**

Additions may also show compliance by either:

1. Demonstrating that efficiency improvements to the envelope component of the existing building, as well as certain indoor lighting and mechanical improvements, offset substandard addition performance (see §141.0(a)2Bii).
2. Showing that the existing building combined with the addition meet the requirements of §141.0(b) as new construction.

§141.0(a)2 states that the envelope and indoor lighting in the conditioned space of the addition, and any newly installed space conditioning, electrical power distribution system or service water heating system, must meet the mandatory measures. The energy use of the combination of the altered existing building plus the proposed addition shall be equal to or less than the energy use of the existing building with all alterations meeting the requirements of §141.0(b)2 plus the standard energy budget of an addition that complies with §140.1.

This approach allows the applicant to improve the energy efficiency of the existing building so that the entire building meets the energy budget that would apply if the existing building were unchanged, and the addition complied on its own. Changes to features in the existing building are considered alterations.

For a full description of when and how altered components in the existing building are counted as a credit or penalty in the performance calculation, as well as basic energy modeling rules for alterations, see Section 11.4.4.2 below.

Example 10-2

Question

3,000 ft² of conditioned space is being added to an existing office building. 25% of the lighting fixtures in the existing office space are being replaced with more efficient fixtures. Can credit be taken for the improved lights in the existing building to comply through the existing-plus-addition performance approach?

Answer

Credit can only be taken for lighting efficiency improvements resulting in a lower lighting power than is required to meet §140.6. Otherwise, credit may be taken for improvement(s) to the envelope components only. Lighting in the existing building must meet all prescriptive requirements in this case (more than 10% of the lighting fixtures are replaced or the connected load is increased).

11.4.4 Alterations Performance Compliance

Using the performance approach for an alteration is similar to demonstrating compliance with an addition.

11.4.4.1 **Alterations of the Permitted Space**

Altered spaces can show compliance with the performance approach independent of the remainder of the existing building, but must still meet the requirements for the altered components of the building as specified in §141.0(b)2. These require that envelope and lighting alterations, as well as any new or replacement space conditioning or service water heating system serving the alteration, meet the mandatory measures. The permitted space alone may comply with the energy budget determined using approved compliance software.

If the permit is done in stages, the rules for each permit stage apply to the alteration performance run.

11.4.4.2 **Alterations in Existing Buildings without an Addition**

Alterations may also show compliance by demonstrating that the energy use of the proposed design -- including all energy efficiency improvements to the existing building -- is equal to or less than the standard design energy budget which is based on the alterations meeting the requirements of §141.0(b)2 and Table 141.0-D of the Energy Standards. Note that §141.0(a)1 also requires that envelope, lighting, space conditioning and service water heating system alterations meet the applicable mandatory measures.

This approach allows the applicant to improve the energy efficiency of the existing building so that it meets the energy budget that would apply to the entire building if the existing building other than the portion being altered was unchanged. Changes to features in the existing building are considered alterations.

An energy penalty is assigned to any altered component that does not meet or exceed the requirements of §141.0(b)2B. A credit is assigned to an alteration (improvement) that exceeds the requirements in §141(b)2B as summarized in Table 141.0-D of the Energy Standards and further detailed in the Nonresidential ACM Reference Manual. The compliance software sets the standard design for the altered component as listed in Table 141.0-D of the Energy Standards.

This compliance approach includes the entire building which means the ensemble of all enclosed space in a building, including the space for which a permit is sought, plus all conditioned and unconditioned space within the structure. The inclusion of the characteristics of unconditioned spaces have an effect on the overall performance budget of the building due to the loads of the unconditioned spaces adjacent to the conditioned spaces which can be beneficial to the overall compliance margin.

When using this compliance approach it is important to take into account all changes in the building's features that are:

- **EXISTING** (that remain unchanged);
- **ALTERED** (improved or replacement); and
- **NEW** (all new).

Note that surfaces which are being completely removed from the existing building – roofs/ceilings, exterior walls and floors, and all glazing removed within those surfaces – are not modeled. Except for replacement fenestration with third party verification of the existing glazing type allowed for trade-off by improving the existing building, which is limited to the amount a particular improvement exceeds the applicable prescriptive requirements of §141.0(b)2.

To show compliance with this approach you need to follow the instructions in the compliance software user’s manual. Documentation of the existing building’s glazing areas is required to be submitted with the permit application if this method is used for replacement fenestration credit.

Example 11-3

Question

Alterations to an existing office building in Climate Zone 12 includes replacing all single clear metal frame operable windows with new NFRC-rated windows (U-factor =0.45, SHGC=0.31.) What standard design values will the compliance software use for the replacement fenestration area?

Answer

The standard design will use the values in Table 141.0-A (U=0.47, SHGC=0.31 and VT=0.32) of the Energy Standards regardless of whether the replacement windows’ values exceed those Table 141.0-A values of the Energy Standards.

11.4.4.3 Existing-Plus-Addition-Plus-Alteration

For additions, the most flexible compliance method is to consider the entire existing building along with the addition (Existing + Addition + Alteration)[1]. The combination of additions and alterations to the existing building may be shown to comply by demonstrating that the proposed design energy use is equal to or less than the standard design energy budget based on the alterations meeting the requirements of §141.0(b)2 summarized in Table 141.0-D of the Energy Standards and additions meeting the requirements of §141.0(a)2.

For a full description of when and how altered components in the existing building are counted as a credit or penalty in the performance calculation, see Section 11.4.4.2.

Using this compliance method, credit may be taken for energy efficiency features added to the existing building. When the prescriptive approach is used, compliance can be demonstrated if the altered component meets or exceeds the requirements of §141.0(b)1 for that component. When the performance approach is used, the altered component must meet or exceed the requirements in §141.0(b)2, or another alteration(s) must be made to the existing building that exceeds the requirements of §141.0(b)2 and saves the additional energy necessary to make up for the alteration(s). Alternatively, when there is an addition, the addition can be designed to exceed prescriptive requirements to offset proposed existing building alterations that do not meet prescriptive requirements.

Alterations may include previous fenestration improvements that were made to the building after original permit (when the existing building was first constructed). The upgraded efficiency values of the current fenestration must be documented as the proposed design; and the standard design is based on the current Energy Standards. The permit applicant must provide evidence that the previous glazing improvements were made subsequent to the original construction of the building and documentation to confirm the glazing type of the previously existing fenestration. Such evidence may involve a receipt, a signed statement from previous owners, or in case where previous owners are not available, a signed statement of the current owner or other record. Note that previous fenestration improvements that have been used to achieve compliance for previous additions and alterations cannot be considered for compliance for subsequent additions and alterations.

11.4.5 Alternate Performance Compliance Approach

Any addition, alteration or repair may demonstrate compliance by meeting the requirements applicable to new buildings for the entire building. Using this method, the entire building could be shown to comply in permit stages or as a whole building. The rules for new buildings permit stage compliance (Section 11.4.1) and whole building compliance (Section 11.4.2) would apply.

Documentation of the existing building's features is required to be submitted with the permit application if this method is used.

[1]This method may also is be used whenever an alteration is made to existing buildings, whether or not there is an addition to the building at the same time.

11.5 Enforcement and Compliance

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation. This section describes the documents and procedures for documenting compliance with the performance requirements. The Nonresidential ACM has specific and detailed output/reporting requirements for all approved compliance software.

Compliance software output is required to specify the run initiation time, a unique run code, and the total number of pages of documents printed for each proposed building run on each page whenever a building complies with the Energy Standards. The plan checker is strongly encouraged to verify these output features for a performance compliance submittal to ensure that the submittal is a consistent set of compliance documentation. The Nonresidential ACM Reference Manual forbids compliance software from printing valid compliance documents for a proposed building design that does not comply. The plan checker should pay special attention to the PRF-01 document and the Exceptional Conditions List on that document. Every item on the Exceptional Conditions List deserves special attention and may require additional documentation, such as manufacturer's cut sheets or special features on the plans and in the building specifications.

The compliance software requirements will automatically produce and reiterate the proper set of documents that correspond to the particular proposed building submitted for a permit. However, the plan checker should verify the type of compliance and the required documents. Whenever an existing building or existing building components are involved in the compliance calculation, the plan checker should look for the term EXISTING that identifies EXISTING building components that remain unchanged. Similarly if the compliance document indicates a component is ALTERED these changes should be verified. In the types of permit applications where some building components are unknown, the unknown components cannot be entered by the user and cannot be reported on output documents. The PRF-01 document will show all the pertinent information required for a complete submittal.

The compliance documents associated with the performance approach are generated automatically and the entire printout is called the PRF-01.

Unless minimal efficiency and default capacities are used in the performance analysis, design drawings or specifications must be provided to document the differences in the capacities and efficiencies of the proposed equipment.

Other documentation supporting each non-standard or non-default value used in the performance approach and indicated in the Exceptional Conditions list on the PRF-01 document must also be included.

11.5.1 Performance Inspection

Performance approach inspection is identical to other inspections required by the Energy Standards. For information on inspection of envelope, mechanical and lighting systems, refer to Chapter 2, Compliance and Enforcement.

Table of Contents

12. Building Commissioning Guide

For all newly constructed nonresidential buildings, commissioning shall be included in the design and construction process of the project to verify that the building's energy systems and components meet the owner's or owner representative's project requirements. For buildings less than 10,000 square feet, only the Design Phase Design Review requirements (see Section 12.4) and Commissioning Measures Shown in the Construction Documents (see Section 12.5) shall be completed.

Note: For hotel/motel or high-rise residential buildings that are considered mixed-use, the occupancies designated as nonresidential shall comply with these commissioning requirements when applicable.

This chapter is organized as follows:

12.1 Introduction

The purpose of this code is to improve public health, safety, and general welfare by enhancing the design and construction of buildings through the use of concepts that reduce negative and increase positive environmental impacts. Commissioning is a vital element in this effort.

The following acronyms will be used throughout this Chapter:

Acronyms

- BOD - Basis of Design
- Cx - Commissioning
- FPT - Functional Performance Test
- HVAC - Heating, Ventilating, and Air Conditioning
- O&M - Operations and Maintenance
- OPR - Owner's Project Requirements

Glossary

- **Acceptance Criteria -** The conditions that must be met for systems or equipment to meet defined expected outcomes.
- **Commissioning (Cx) -**-Building commissioning as required in this code involves a quality assurance process that begins during design and continues to occupancy. Commissioning verifies that the new building and its systems are planned, designed, installed, tested, operated and maintained as the owner intended, and the building staff are prepared to operate and maintain its systems and equipment.
- **Commissioning Coordinator–** The person who plans, schedules and coordinates the commissioning team to implement the commissioning process. This can be either a third-party commissioning provider or an experienced member of the design team or owner's staff.
- **Commissioning Process –** A quality-focused process for enhancing the delivery of a project. The process focuses on verifying and documenting that all its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the Owner's Project Requirements.
- **Commissioning Team -** The key members of each party involved with the project designated to provide insight and carry out tasks necessary for a successful commissioning project. Team members may include the commissioning coordinator, owner or owner's representative, building staff, design professionals, contractors or manufacturer's representatives, and testing specialists.
- **Independent Third-Party Commissioning Professional (Authority/Agent/Provider/Lead) –** An entity contracted directly by the owner who is not responsible or affiliated with any other member of the design and construction team and who leads, plans, schedules, and coordinates the Commissioning Team to implement the Commissioning Process.
- **Operation and Maintenance (O&M**) **Manuals -** Documents that provide information necessary for operating and maintaining installed equipment and systems.
- **Owner -** The individual or entity holding title to the property on which the building is constructed.
- **Owner Representative –** An individual or entity assigned by the owner to act and sign on the owner's behalf.
- **Sequence of Operation –** A written description of the intended performance and operation of each control element and feature of the equipment and systems.
- **Scope of the Commissioning Requirements -** All building systems and components covered by §110.0, §120.0, §130.0, and §140.0 shall be included in the scope of the commissioning requirements, excluding covered processes.

12.1.1 Selecting Trained Personnel for Commissioning

It is essential that there is a single person designated to lead and manage the commissioning activities. In practice, this individual has been referenced by various identifiers such as commissioning authority, agent, provider, coordinator, and lead. In this manual, the term commissioning coordinator is used.

The commissioning coordinator shall manage and facilitate the commissioning process, including managing the development and implementation of the commissioning tasks and associated documentation. Trained personnel shall execute the tasks and may include appropriate members of the owner's staff, contractors, and design team, as well as independent commissioning professionals.

The designated commissioning coordinator may be an independent third-party commissioning professional, a project design team member (e.g. engineer or architect), an owner's engineer, contractor, or specialty sub-contractor. Methods of evaluating the designated commissioning coordinator and trained personnel include review of the following:

- Technical knowledge.
- Relevant experience.
- Potential conflict of interest.
- Professional certifications and training.
- Communication and organizational skills.
- Reference and sample work products.

12.2 Owner's Project Requirements (OPR)

§120.8(b)

The energy-related expectations and requirements of the building shall be documented before the design phase of the project. This documentation shall include the following:

1. Energy efficiency goals.
2. Ventilation requirements.
3. Project program, including facility functions and hours of operation, and need for after-hours operation.
4. Equipment and systems expectations.

12.2.1 Intent

The Owner's Project Requirements (OPR) documents the functional requirements of a project and expectations of the building use and operation as it relates to systems being commissioned. The document describes the physical and functional building characteristics desired by the owner and establishes performance and acceptance criteria. The OPR is most effective when developed during pre-design and used to develop the BOD during the design process. The level of detail and complexity of the OPR will vary according to building use, type and systems.

12.2.2 Compliance Method

Compliance is demonstrated by the owner or owner's representative developing and/or approving the OPR document before the design phase begins. At a minimum, the following components should be included in the OPR:

A. ***Energy Efficiency Goals –*** Establish goals and targets affecting energy efficiency which may include:

1. Overall energy efficiency (exceeding Title 24 by %).

2. Lighting system efficiency (exceeding Title 24 by %).
3. HVAC equipment efficiency & characteristics.
4. Any other measures affecting energy efficiency desired by the owner
   a. Building orientation and siting
   b. Daylighting
   c. Facade, envelope and fenestration
   d. Roof
   e. Natural ventilation
   f. Onsite renewable power generation and zero net energy use
   g. Landscaping and shading

B. ***Ventilation Requirements*** **-** Describe indoor ventilation requirements including intended use and anticipated schedule for each program space.

C. ***Project Program, including facility functions and hours of operation, and need for after-hours operation*** **–** Describe primary purpose, program, and use of proposed project, such as:

1. Building size, number of stories, construction type, occupancy type, and number.
2. Building program areas including intended use and anticipated occupancy schedules.
3. Future expandability and flexibility of spaces.
4. Quality and/or durability of materials and building lifespan desired.
5. Budget or operational constraints.
6. Applicable codes.

D. ***Equipment and Systems Expectations*** **–** For each system commissioned describe the following:

1. Level of quality, reliability, equipment type, automation, flexibility, maintenance and complexity desired.
2. Specific efficiency targets, desired technologies, or preferred manufacturers for building systems.
3. Degree of system integration, automation, and functionality for controls (i.e. load shedding, demand response, and energy management)

E. ***Building Envelope Performance Expectations*** **–** For each assembly that contains a special feature describe the following:

1. Assembly type, such as, floors, foundations, walls, ceilings, and roofs.
2. Characteristic that merits special attention.

F. ***Enforcement -*** At their discretion, the building official confirms demonstrated compliance at *Plan Review* by either:

1. Receipt of a copy of the OPR document (optional).
2. Receipt of a completed NRCC-CXR-01-E indicating the OPR was reviewed at the Design Review Kickoff.

12.3 Basis of Design (BOD)

§120.8(c)

A written explanation of how the design of the building systems meets the OPR shall be completed at the design phase of the building project, and updated as necessary during the design and construction phases. The Basis of Design (BOD) document shall cover the following systems and components:

1. HVAC systems and controls.
2. Indoor lighting system and controls.
3. Water heating systems and controls.
4. Any building envelope component considered in the OPR.

12.3.1 Intent

The BOD describes the building systems to be commissioned and outlines design assumptions not indicated in the design documents. The design team develops the BOD to describe how the building systems design meets the OPR, and why the systems were selected. The BOD is most effective when developed early in the project design and updated, when necessary, throughout the design process.

12.3.2 Compliance Method

Compliance requires the completion of the BOD document, which should include the following:

A. HVAC Systems and Controls

1. Provide narrative description of system – system type, location, control type, efficiency features, outdoor air ventilation strategy, indoor air quality features, environmental benefits, and other special features.
2. Describe reasons for system selection – why chosen system is better than alternatives, considering issues such as comfort, performance, efficiency, reliability, flexibility, simplicity, cost, owner preference, site constraints, climate, maintenance, and acoustics.
3. Provide design criteria including the following:
   a. Load calculation method/software.
   b. Summer outdoor design conditions, °F drybulb and °F wetbulb.
   c. Winter outdoor design conditions, °F drybulb and °F wetbulb.
   d. Indoor design conditions, °F drybulb cooling, %RH cooling; °F drybulb heating, % RH heating.
   e. Applicable codes, guidelines, regulations and other references used.
   f. Load calculation assumptions.
4. Sequence of Operations – operating schedules, setpoints (may refer to plans or specifications).
5. Describe how the system meets the OPR.

B. Indoor Lighting System and Controls

1. Provide narrative description of system – type of fixtures, lamps, ballasts, and controls.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as visual comfort, performance, efficiency, reliability, cost, flexibility, owner preference, color rendering, integration with daylighting, and ease of control.
3. Provide design criteria for each type of space including the following:
   a. Applicable codes, guidelines, regulations and other references used.
   b. Illumination design targets (footcandles) and lighting calculation assumptions.
4. Provide lighting power design targets for each type of space
   a. Lighting power allowance and lighting power design target (watts/ft^2).
5. Describe how system meets the OPR.

C. Water Heating Systems and Controls

1. Provide narrative description of system – system type, control type, location, efficiency features, environmental benefits, and other special features.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as performance, efficiency, reliability, space constraints, cost, utility company incentives, owner preference, and ease of maintenance
3. Water heating load calculations.
4. Describe how system meets the OPR.

D. Building Envelope Components

1. Provide narrative description of system – type, energy savings, and payback period.
2. Describe reason for system selection – why chosen system is better than alternatives, considering issues such as performance, efficiency, reliability, flexibility, simplicity, expandability, cost, payback period, utility company incentives, and owner preference.
3. Describe how system meets the OPR.

12.3.3 Enforcement

At their discretion, the building official confirms demonstrated compliance at *Plan Review* by either:

1. Receipt of a copy of the BOD document (optional).
2. Receipt of a completed NRCC-CXR-01-E indicating the BOD was reviewed at the Design Review Kickoff attesting that the BOD has been completed and meets the requirements of the OPR.

12.4 Design Phase Review

§120.8(d)

1. Design reviewer requirements are based on the project size and complexity of the mechanical systems, as follows:
   a. For newly constructed buildings less than 10,000 square feet, design phase review may be completed by the design engineer.
   b. Newly constructed buildings between 10,000 and 50,000 square feet, it may be completed by either an in-house engineer to the design firm but not associated with the building project, or a third party design engineer.
   c. For newly constructed buildings larger than 50,000 square feet or buildings with complex mechanical systems, an independent review by a third party design engineer id required.
2. Design Review. During the schematic design phase of the building project, the owner or owner's representative, design team and design reviewer must meet to discuss the project scope, schedule and how the design reviewer will coordinate with the project team. The building owner or owner's representative shall include the Design Review Checklist in the Certificate of Compliance documentation (see §10-103).
3. Construction Documents Design Review. The design review compliance documents list the items that shall be checked by the design reviewer during the construction document review. The completed compliance documents shall be returned to the owner and design team for review and sign-off. The building owner or owner's representative shall include the design review compliance documents in the Certificate of Compliance documentation (see §10-103).

12.4.1 Intent

The intent of design phase review is to improve compliance with the Energy Standards, encourage adoption of best practices in design, and lead to designs that are constructible and maintainable.

12.4.2 Compliance Method

Compliance requires completion of the Design Review Kickoff and Construction Document checklists by the design reviewer. Requirements for the design reviewer are provided in §120.8(d)1. The following steps are required to complete this requirement:

A. Design Review Kickoff - Initial Schematic Review

1. An in-person meeting is held between the project owner (or owner's representative), design team representatives (including mechanical and electrical design engineers, project architect), commissioning coordinator, and design reviewer.
2. Meeting topics to be discussed include the following:
   a. Discuss Project Coordination, including design reviewer involvement.
   b. Identify Project Scheduling, including design review.
   c. Review Project scope.
   d. Review OPR and BOD.
   e. Discuss Design Elements and Assumptions.

f. Discuss HVAC System Selection.
g. Identify Construction Documents Design Review checklists to be completed.
h. Discuss Energy Efficiency Measures.
i. Complete and Sign Certificate of Compliance – Cx Design Review Kickoff NRCC-CXR-01-E.

B. Construction Document Review

1. The design team provides the design reviewer with a set of drawing plans and specifications late in design as agreed upon in Design Review Kickoff meeting, typically around 90 percent construction document completion.
2. The Design reviewer provides a review of the construction documents:
   a. NRCC-CXR-02-E. This compliance document is used as a checklist for all projects that require a Construction Documents Design Review.
   b. NRCC-CXR-03-E. This compliance document is used as a supplement to the NRCC-CXR-02-E for simple mechanical systems.
   c. NRCC-CXR-04-E. This compliance document is used as a supplement to the NRCC-CXR-02-E for complex mechanical systems.
3. Completed compliance documents are submitted to the design team and project owner for consideration.
4. The designer provides a response on the Construction Document compliance documents. The design reviewer is not required to provide a second review of the construction documents for compliance purposes.
5. Certification of Completion - The design reviewer, design engineer, and owner/owner's representative sign the Certificate of Compliance – Cx Design Review Signature Page, NRCC-CXR-05-E, indicating that the construction documents design review has been completed.

The commissioning coordinator who meets the requirements may also complete the construction documents design review.

12.4.3 Enforcement

Compliance is demonstrated by completion of the compliance documents NRCC-CXR-01-E through NRCC-CXR-04-E, as applicable, and signature page, NRCC-CXR-05-E.

12.5 Commissioning Measures

§120.8(e)

This section includes commissioning measures or requirements in the construction documents (plans and specifications) for newly constructed nonresidential buildings. Commissioning measures or requirements should be clear, detailed and complete to clarify the commissioning process. These requirements should include:

- The list of systems and assemblies commissioned.
- Testing scope.
- Roles and responsibilities of contractors.

- Requirements for meetings.
- Management of issues.
- The commissioning schedule.
- O&M manual development and training.
- Checklist and functional test compliance document development, execution and documentation.
- Roles of non-contractor parties (for information only).

12.5.1 Intent

Include commissioning measures or requirements in the construction documents (plans and specifications). Commissioning measures or requirements should be clear, detailed and complete to clarify the commissioning process.

12.5.2 Existing Law or Regulation

The Energy Standards require that specific functional test compliance documents (Certificate of Acceptance) be included in the construction documents. These functional test compliance documents are a subset of the broader commissioning requirements described in this chapter.

12.5.3 Compliance Method

Compliance is achieved by including commissioning requirements in the project plans and specifications. The commissioning specifications should include the following:

A. Primary (and optionally all) commissioning requirements are included in the general specification division (typically Division 1) and clear cross references of all commissioning requirements to and from the general division are included to ensure all subcontractors are held to them.

B. A list of the systems and assemblies covered by the commissioning requirements.

C. Roles and responsibilities of all parties including:

   1. General contractor and subcontractors, vendors, and construction manager.
   2. Commissioning coordinator.
   3. Owner, facility staff.
   4. Architect and design engineers.
   5. Non-contractor parties (for information only to provide the contractor with context for their work).
   6. The individual who writes checklists and tests, reviews and approves functional test compliance documents, directs tests and executes tests, documents test results, and approves completed tests. These roles may vary by system or assembly.

D. Meeting requirements.

E. Commissioning schedule management procedures.

F. Issue and non-compliance management procedures.

G. Requirements for execution and documentation of installation, checkout, and start up, including control point-to-point checks and calibrations.

H. Specific testing requirements by system, including:

   1. Monitoring and trending.
   2. Opposite season or deferred testing requirements, functions and modes to be tested.
   3. Conditions of test.
   4. Acceptance criteria and any allowed sampling.
   5. Details of the format and rigor of the functional test compliance documents required to document test execution.
   6. Example compliance documents (recommended).

I. Submittal review requirements and approval process.

J. Content, authority and approval process of the commissioning plan.

K. Commissioning documentation and reporting requirements.

L. Facility staff training requirements and verification procedures.

M. O&M manual review and approval procedures.

N. System's manual development and approval requirements and procedures.

O. Definitions section.

12.5.4 Enforcement

At their discretion, the building official confirms demonstrated compliance at *Plan Review* by a receipt of a copy of the commissioning specifications.

12.6 Commissioning Plan

§120.8(f)

Prior to permit issuance, a commissioning plan shall be completed to document how the project will be commissioned and shall be started during the design phase of the building project. The Commissioning Plan shall include the following:

A. General project information.

B. Commissioning goals.

C. Systems to be commissioned.

D. Plans to test systems and components, which shall include:

   1. An explanation of the original design intent.
   2. Equipment and systems to be tested, including the extent of tests.
   3. Functions to be tested.
   4. Conditions under which the test shall be performed.
   5. Measureable criteria for acceptable performance.

6. Commissioning team information including roles.
7. Commissioning process activities, schedules and responsibilities. Plans for the completion of commissioning requirements listed in §120.8(g) through §120.8(i) shall be included.

12.6.1 Intent

The Commissioning Plan (Cx Plan) establishes the commissioning process guidelines for the project and commissioning team's level of effort. It identifies the required Cx activities to ensure that the OPR and the BOD are met. The Cx Plan also includes a commissioning schedule from design to occupancy.

12.6.2 Existing Law or Regulation

Review local county, city, or jurisdiction ordinances for any applicable commissioning planning requirements.

12.6.3 Compliance Method

Compliance is demonstrated by preparation of a project specific Cx Plan that includes the elements listed in the code section above. The following gives guidance for developing the components of the Commissioning Plan:

A. ***General project information* -** Provide project identifying information, including, but not limited to the following:

1. Project name, owner, and location.
2. Building type and area.
3. Project Schedule.
4. Contact information of individual/company providing the commissioning services.

B. ***Commissioning Goals* –** Document the commissioning goals, including, but not limited to:

1. Meeting code requirements for commissioning.
2. Meeting OPR and BOD requirements.
3. Carrying out requirements for commissioning activities as specified in plans and specifications.

C. ***Systems to be commissioned*** – See BOD

1. *An explanation of the original design intent* - Document the performance objectives and design intent for each system listed to be commissioned in a written narrative
   a. Refer to the OPR and BOD documents.
2. *Equipment and systems to be tested, including the extent of tests*
   a. Provide a list of equipment and systems to be tested.
   b. Describe the range and extent of tests to be performed for each system component, and interface between systems
3. *Functions to be tested* - Provide example functional test procedures to identify the level of testing detail required.

4. *Conditions under which the test shall be performed* - Identify the conditions under which the major operational system functions are to be tested, including:
   a. Normal and part-load operations.
   b. Seasonal testing requirements.
   c. Restart of equipment and systems after power loss.
   d. System alarm confirmations.
5. *Measurable criteria for acceptable performance* - Include measurable criteria for acceptable performance of each system to be tested.

D. ***Commissioning Team Information*** **-** Provide a contact list for all Commissioning team members, including but not limited to:

1. Owner and/or owner's representative.
2. Architect and engineers.
3. Designated commissioning representative.
4. General contractor, sub-contractors, and construction manager.

E. ***Commissioning process activities, schedules and responsibilities***

1. Establish prescribed commissioning process steps and activities to be accomplished by the Cx team throughout the design to occupancy.
2. Define the roles and responsibilities for each member of the Cx team for each phase of the work,
3. List the required Cx deliverables, reports, compliance documents, and verifications expected at each stage of the commissioning effort.
4. Include the confirmation process for the O&M manual, systems manual and the facility operator and maintenance staff training.

12.6.4 Enforcement

At their discretion, the building official confirms demonstrated compliance at *Plan Review* by a receipt of a copy of the Commissioning Plan

12.7 Functional Performance Testing

§120.8(g)

Functional performance tests shall demonstrate the correct installation and operation of each component, system, and system-to-system interface in accordance with the acceptance test requirements. Functional performance testing reports shall contain information addressing each of the building components tested, the testing methods utilized, and include any readings and adjustments made.

12.7.1 Intent

Develop and implement the functional performance tests to document (as set forth in the Commissioning Plan) that all components, equipment, systems, and system-to-system interfaces were installed as specified, and operate according to the OPR, BOD, and plans and specifications.

The following systems to be functionally tested are listed in the BOD:

1. HVAC systems and controls.
2. Indoor lighting system and controls.
3. Water heating system and controls.
4. Building Envelope Components.

12.7.2 Existing Law or Regulation

Acceptance testing requirements call for functional testing of some systems and equipment. Refer to Chapter 13, Acceptance Requirements, in this manual for further guidance.

Although functional performance testing for commissioning under §120.8 is related to acceptance testing, the systems to be functionally tested are based upon systems described in the BOD. Not all of the systems described in the BOD will have acceptance testing requirements per the Energy Standards. Conversely, there may be systems listed in the BOD which do have acceptance testing requirements, such as lighting controls. To meet the acceptance testing requirements, acceptance tests must be performed by a certified Acceptance Test Technician as described in Chapter 13.

12.7.3 Compliance Method

Compliance is demonstrated by developing and implementing test procedures for each piece of commissioned equipment and interfaces between equipment and systems according to the building-specific Commissioning Plan. Tests should include verification of proper operation of all equipment features, each part of the sequence of operation, overrides, lockouts, safeties, alarms, occupied and unoccupied modes, loss of normal power, exercising a shutdown, startup, low load through full load (as much as possible) and back, staging and standby functions, scheduling, energy efficiency strategies, and loop tuning. Acceptance Requirements, discussed in Chapter 13, are required and will contribute toward compliance with §120.8(g), but do not cover all necessary testing.

Elements of acceptable test procedures include:

1. Date and Party – Identification of the date of the test and the party conducting the test.
2. Signature Block – Signature of the designated commissioning lead and the equipment installing contractor attesting that the recorded test results are accurate.
3. Prerequisites – Any conditions or related equipment checkout or testing that needs to be completed before conducting this test.
4. Precautions – Identification of the risks involved to the test team members and the equipment and how to mitigate them.
5. Instrumentation – Listing of the instrumentation and tools necessary to complete the test.
6. Reference – In each procedure item, identify the source for what is being confirmed (e.g., sequence of operation ID, operating feature, specification requirement, etc.).
7. Test Instructions – Step-by-step instructions of how to complete the test, including functions to test and the conditions under which the tests should performed.
8. Acceptance Criteria – Measurable pass / fail criteria for each step of the test, as applicable.

9. Results – Expected system response and space to document the actual response, readings, results and adjustments.
10. Return to Normal – Instructions that all systems and equipment are to be returned to their as-found state at the conclusion of the tests.
11. Deficiencies – A list of deficiencies and how they were mitigated.

12.7.4 Enforcement

At their discretion, the building official confirms demonstrated compliance during *Field Inspection* by either:

1. Receipt of a copy of the completed and signed Functional Performance Tests that indicate any deficiencies have been corrected (optional).
2. Review of acceptance certificates (NRCA's) attesting that the Functional Performance Tests have been completed and any deficiencies corrected. Although there are no field forms for commissioning requirements, authorities having jurisdiction can review issues logs or the certificates of acceptance to verify field testing was completed and issues resolved.

12.8 Documentation and Training

§120.8(h), Documentation and Training.

A Systems Manual and Systems Operations Training are required.

§120.8(h)1, Systems Manual.

Documentation of the operational aspects of the building shall be completed within the Systems Manual and delivered to the building owner or representative and facilities operator. The Systems Manual shall include the following:

1. Site information, including facility description, history, and current requirements.
2. Site contact information.
3. Instructions for basic O&M, including general site operating procedures, basic troubleshooting, recommended maintenance requirements, and a site events log.
4. Description of major systems.
5. Site equipment inventory and maintenance notes.

A copy of all special inspection verifications required by the enforcing agency or the Energy Standards.

12.8.1 Intent

The Systems Manual documents information focusing on the operation of the building systems. This document provides information needed to understand, operate, and maintain the equipment and systems and informs those not involved in the design and construction of the building systems. This document is in addition to the record construction drawings, documents, and the O&M Manuals supplied by the contractor. The Systems Manual is assembled during the construction phase and available during the contractors' training of the facility staff.

The systems operation training verifies that a training program is developed to provide training to the appropriate maintenance staff for each equipment type and/or system and this training program is documented in the commissioning report. The systems operations training program is specified in the project specifications for the major systems listed. The System Manual, O&M documentation, and record drawings are prepared and available to the maintenance staff prior to implementation of any training or the development of a written training program. The training program is to be administered by the commissioning coordinator or other responsible party when the appropriate maintenance staff is made available to receive training.

12.8.2 Compliance Method

Compliance is demonstrated by providing the Systems Manual. The information in the Systems Manual includes the following information:

A. *Site information, including facility description, history and current requirements*

1. Site Information
    a. Location of property - Address
    b. Site acreage
    c. Local utility information:
        i. Water service provider
        ii. Natural/LPG gas service provider
        iii. Electrical service provider
        iv. Telecommunications service provider
        v. Other service provider
2. Facility Description
    a. Use/Function
    b. Square footage
    c. Occupancy Type
    d. Construction Type
    e. BOD
    f. Location of major systems & equipment
3. Project History
    a. Project requirements
        i. Owner’s Project Requirements (OPR)
        ii. Basis of Design (BOD)
    b. Project undocumented events
    c. Record Drawings & Documents
    d. Final control drawings and schematics
    e. Final control sequences
    f. Construction documents - Location or delivery information:
        i. Mechanical & electrical drawings
        ii. Specifications
        iii. Submittals

iv. Project change orders and information

4. Current requirements
   a. Building operating schedules
   b. Space temperature, humidity, & pressure, CO_2 setpoints
   c. Summer and winter setback schedules
   d. Chilled & hot water temperatures
   e. As-built control setpoints and parameters

B. *Site contact information*

1. Owner information
2. Emergency contacts
3. Design Team: architect, mechanical, engineer, electrical engineer, etc.
4. Prime contractor contact information
5. Subcontractor information
6. Equipment supplier contact information

C. *Basic operation & maintenance, including general site operating procedures, basic trouble shooting, recommended maintenance requirements site events log*

1. Basic operation
   a. Written narratives of basic equipment operation
   b. Interfaces, interlocks and interaction with other equipment and systems
   c. Initial maintenance provide by contactor
2. General site operating procedures
   a. Instructions for changes in major system operating schedules
   b. Instructions for changes in major system holiday & weekend schedules
3. Basic troubleshooting
   a. Cite any recommended troubleshooting procedures specific to the major systems and equipment installed in the building.
   b. Manual operation procedures
   c. Standby/Backup operation procedures
   d. Bypass operation procedures
   e. Major system power fail resets and restarts
   f. Trend log listing
4. Recommended maintenance events log
   a. HVAC air filter replacement schedule & log
   b. Building control system sensor calibration schedule & log
5. Operation & Maintenance Manuals - Location or delivery information

D. *Major Systems*

1. HVAC systems & controls
    a. Air conditioning equipment (chillers, cooling towers, pumps, heat exchanges, thermal energy storage tanks, etc)
    b. Heating equipment (boilers, pumps, tanks, heat exchanges, etc.)
    c. Air distribution equipment (fans, terminal units, accessories, etc.)
    d. Ventilation equipment (Fans, accessories, and controls)
    e. Building automation system (workstation, servers, panels, variable frequency drives, local control devices, sensors, actuators, thermostats, etc.)
2. Indoor lighting systems & controls
    a. Lighting control panels
    b. Occupancy sensors
    c. Daylight harvesting systems
3. Renewable energy systems
    a. Photovoltaic panels & inverters
    b. Wind powered electrical generators & inverters
4. Landscape irrigation systems
    a. Water distribution diagrams
    b. Control system
5. Water reuse systems
    a. Reclaimed water system for indoor use
    b. Reclaimed water for irrigation use

E. *Site equipment inventory and maintenance notes*

1. Spare parts inventory
2. Frequently required parts and supplies
3. Special equipment required to operate or maintain systems
4. Special tools required to operate or maintain systems

F. *A copy of all special inspection verifications required by the enforcing agency of this code*

G. *Other resources and documentation*

While not required, an Issues Log could be a useful tool to keep track of the status of equipment repairs and it should be maintained by the facilities indefinitely. The log, in conjunction with an equipment inventory, can be used to track and manage issues associated with specific pieces of equipment or systems over time. An Issues Log is a formal and ongoing record of problems or concerns discovered within a facility and the recommended resolution of those problems and concerns. This living document could be created by the Cx team and maintained throughout the course of the investigation and implementation phase of a Cx project. The Issues Log should list the following categories, at a minimum:

1. Issue item number
2. Building name or number
3. Floor
4. Location or room number
5. Equipment tag
6. Observation method
7. Issues description
8. Recommended resolution
9. Resolution responsibility
10. Action taken
11. Date of action taken
12. Resolution status
13. Verified by
14. Verification date

12.8.3 Enforcement

At their discretion, the building official confirms demonstrated compliance during *Field Inspection* by a receipt of a copy of the Systems Manual.

12.9 Systems Operations Training

§120.8(h)2

The training of the appropriate maintenance staff for each equipment type or system shall be documented in the commissioning report. Training materials shall include the following:

1. System and equipment overview (i.e. what is the equipment, its function, and with what other systems or equipment does it interface).
2. Review and demonstration of operation, servicing, and preventive maintenance.
3. Review of the information in the Systems Manual.
4. Review of the record drawings on the systems and equipment.

12.9.1 Compliance Method

The written training program includes the following:

- Learning goals and objectives for each session.
- Training agenda, topics, and length of instruction for each session.
- Instructor information and qualifications.
- Location of training sessions (onsite, off-site, manufacturer's or vendor's facility).
- Attendance forms.
- Training materials.

- Description on how the training will be archived for future use that includes:

A. *Systems/equipment overview*

1. Review OPR and BOD related to the major systems and equipment
2. Describe system type and configuration
3. Explain operation of all major systems and equipment and how it interfaces with other systems and equipment
4. Describe operation of critical devices, controls and accessories
5. Review location of the major systems and equipment
6. Describe operation of control system for each system, location of critical control elements, and procedures to properly operate control system
7. Review recommendations for implementation to reduce energy and water use

B. *Review and demonstration of servicing/preventive maintenance*

1. Explain location or delivery contact of the Operation & Maintenance manuals
2. Review of all manufacturer's recommended maintenance activities to maintain warranty
3. Review and demonstrate frequent maintenance activities (air filter replacement, lubrication, fan belt inspection and/or replacement, condenser water treatment, etc.), and suggested schedule
4. Review and demonstrate typical servicing procedures and techniques (electrical current, pressure, and flow readings, calibration procedures, point trending, power fail restart procedures, etc.)
5. Locate, observe and identify major equipment, systems, accessories and controls
6. Review emergency shut-offs and procedures

C. *Review the Systems Manual*

1. Describe use of Systems Manual
2. Review elements of Systems Manual
3. Explain how to update and add revisions to Systems Manual

D. *Review record drawings on the systems/equipment*

1. Explain location or delivery contact of the record drawings
2. Review record drawings, revisions, and changes to original design drawings
3. Review equipment schedules and compare with actual installed systems

12.9.2 Enforcement

At their discretion, the building official confirms demonstrated compliance during *Field Inspection* by:

1. In the event of appropriate maintenance staff is made available to receive training for each equipment type and/or system installed in the building, receipt of a copy of the written training program and completed attendance forms.

2. In the event of appropriate maintenance staff is unavailable to receive training for each equipment type and/or system installed in the building, receipt of a copy of the training program provided to the owner or owner's representative.

12.10 Commissioning Report

§120.8(i)

A complete report of commissioning process activities undertaken through the design, construction and reporting recommendations for post-construction phases of the building project shall be completed and provided to the owner or representative.

12.10.1 Intent

The Commissioning Report documents the commissioning process and test results. The report includes confirmation from the commissioning coordinator verifying that commissioned systems meet the conditions of the OPR, BOD, and Contract Documents.

12.10.2 Compliance Method

The components of the Commissioning Report include the following and are defined as follows:

A. Executive summary of process and results of commissioning program – including observations, conclusions and any outstanding items.

B. History of any system deficiencies and how resolved
   1. Include outstanding deficiencies and plans for resolution
   2. Include plans for seasonal testing scheduled for a later date

C. System performance test results and evaluations

D. Summary of training process completed and scheduled

E. Attach commissioning process documents
   1. Commissioning Plan
   2. OPR
   3. BOD
   4. Executed installation checklists
   5. Executed Functional Performance Test (FPT) compliance documents
   6. Recommendations for end-of-warranty review activities

12.10.3 Enforcement

At their discretion, the building official confirms demonstrated compliance during *Field Inspection* by a receipt of a copy of the Commissioning Report.

Table of Contents

13. Acceptance Test Requirements

13.1 New Acceptance Test Requirements for 2016

A. Building Envelope, §110.6:

- No changes.

B. Mechanical Acceptance Tests, §120.5:

- Thermal Energy Storage (TES) Systems (NRCA-MCH-15-A)
  - Incorporates new acceptance criteria.
- Minor clarifications:
  - Outdoor Air (NRCA-MCH-02-A)
  - Supply Water Temperature Reset Controls (NRCA-MCH-09-A)
  - Hydronic System Variable Flow Controls (NRCA-MCH-10-A)
  - Fault Detection & Diagnostics for DX Units (NRAC-MCH-12-A)
  - Automatic Fault Detection & Diagnostic for Air Handling & Zone Terminal Units (NRCA-MCH-13-A)

C. Lighting Controls Acceptance Tests, §130.4:

- New Acceptance Test
  - Institutional Tuning of Lighting Controls (NRCA-LTI-05-A)
- Significant Alterations to Acceptance Tests
  - New sampling allowance for acceptance tests.
  - Changes to the lighting control occupancy sensor maximum time-out period.
  - Changes to the weighted area calculation procedure requirements.
- Minor clarifications:
  - Outdoor Lighting Acceptance Tests (NRCA-LTO-02-A)

D. Covered Process Spaces and Equipment, §120.6:

- New Acceptance Tests
  - Elevator Lighting and Ventilation Controls (NRCA-PRC-12-F)
  - Escalator and Moving Walkway Speed Control (NRCA-PRC-13-F)
- Changes to Acceptance Procedures
  - Commercial Kitchen Exhaust (NRCA-PRC-02-A)
  - Parking Garage Exhaust (NRCA-PRC-03-F)

13.2 Overview

From simple thermostats and manual light switches to complex building automation systems, controls are integral to building health, safety, comfort, and energy efficiency. However, building owners disable many building control and equipment components after occupancy due to lack of functionality from improper installation.

Acceptance test requirements specify targeted inspections and functional performance tests to demonstrate that the building components, equipment, systems, and interfaces conform to the *2016 Building Energy Efficiency Standards* (Energy Standards), Reference Nonresidential Appendix NA7, and applicable construction documents (plans and specifications). Furthermore, acceptance testing helps to ensure that the building meets its energy efficiency goals based on the original design in compliance with the energy standards and that the specified equipment or controls are functioning properly. This testing helps to eliminate issues found in the field. This conclusion was noted in a Public Interest Energy Research Program (PIER) report titled *Integrated Design of Small Commercial HVAC Systems, Element 4* that found a number of problems with package rooftop equipment. These problems include the following:

A. Economizers

Economizers reduce cooling energy use dramatically but often are inoperable. Economizers show a high rate of failure in the study. Of the units equipped with economizers, 64 percent were not operating correctly. Failure modes included dampers that were stuck or inoperable (38 percent), sensor or control failure (46 percent), and poor operation (16 percent). The average energy impact of inoperable economizers is about 37 percent of the annual cooling energy.

B. Cycling Fans

In 38 percent of the units tested, system fans cycled on and off with a call for heating or cooling. The supply of continuous fresh air during occupied hours relies on continuous operation of the HVAC unit supply fan.

C. Unoccupied Fan Operation

In 30 percent of the systems, fans ran continuously during unoccupied periods. While this practice improves space ventilation, a greater opportunity presents itself to save energy through thermostat setback and fan cycling when the space is unoccupied.

D. Simultaneous Heating and Cooling

Adjacent rooftop units controlled by independent thermostats provided simultaneous heating and cooling to a space in 8 percent of the units monitored in the study, largely due to occupant errors in the setup, thermostat misuse, or poor thermostat placement during construction.

E. No Outdoor Air

An inspection revealed that about 8 percent of the inspected units were not capable of supplying any outdoor air. In some cases, outdoor air intakes were not present or were sealed off at the unit. In other instances, outdoor air dampers were stuck shut, effectively preventing outdoor air intake.

13.2.1 General Requirements

Acceptance testing does not take the place of commissioning, or of test and balance procedures that may be required elsewhere in the Energy Standards, or that a building owner may incorporate voluntarily to assess his or her building. Instead, it serves as an adjunct process focusing only on demonstrating compliance with the Energy Standards and proper functionality as described by the approved building plans.

Acceptance testing is not required to be performed by a third party that is independent from the designer or the contractor. However, compliance with the duct sealing requirements specified in §140.4(l) must be verified by a certified, third-party HERS Rater or third party quality control program pursuant to the requirements in Nonresidential Appendix NA2.

Acceptance tests may be performed by one or more field technicians under the responsible charge of a licensed contractor or design professional responsible person eligible under Division 3 of the Business and Professions Code, in the applicable classification, to accept responsibility for the scope of work specified by the certificate of acceptance document. The responsible person must review the information on the certificate of acceptance document and sign it to certify compliance with the acceptance requirements.

Typically, individuals who participate in the acceptance testing/verification are contractors, engineers, or commissioning agents. The individuals who perform the field testing/verification and provide the information required for completion of the acceptance document (field technicians) are not required to be licensed contractors or licensed design professionals. Only the responsible person who signs the certificate of acceptance document must be licensed.

A certified acceptance test technician (ATT) is required to complete the lighting controls (NRCA-LTI-02-A), automatic daylighting (NRCA-LTI-03-A), demand responsive lighting controls (NRCA-LTI-03-A) and outdoor motion sensor and lighting shut-off controls (NRCA-LTO-02-A) acceptance tests and to sign the certificate of acceptance.

The acceptance tests related to mechanical systems are not required to be performed by a certified acceptance test technician. Although a certified acceptance test training provider has been approved by the Energy Commission, the industry certification threshold has not been surpassed. Once surpassed, then a certified acceptance test technician will be required to complete the associated mechanical acceptance tests and sign the certificate of acceptance.

The acceptance test procedures generally require the following:

- Review the bid documents to make sure that the building component (that is, equipment, sensors, devices and control sequences) are properly documented.
- Review the construction installation.
- Complete the required functional testing.
- Certify the acceptance test results on the certificate of acceptance.
- Submit the certificate to the enforcement agency prior to receiving a final occupancy permit.

13.2.2 Roles and Responsibilities

If more than one person is responsible for the acceptance testing, each person shall sign and submit the certificate of acceptance documentation applicable to the portion of the construction or installation for which he or she is responsible. Alternatively, the person with chief responsibility for the system design, construction, or installation shall sign and submit the certificate of acceptance documentation for the entire construction or installation.

The owner is responsible for designating the responsible parties for acceptance test work. Applicable roles and responsibilities related to acceptance testing should be clearly called out by the owner early in the process to ensure accurate pricing and bids.

A. Field Technician

The *field technician* is responsible for performing and documenting the results of the acceptance procedures on the certificate of acceptance documents. The field technician must sign the certificate of acceptance to certify that the information provided on the certificate of acceptance is true and correct. The field technician does not require a contractor’s, architect's or engineer's license but may require certification as an acceptance test technician.

- Given that the industry certification threshold for certified lighting ATTs has been satisfied, a certified ATT is required to perform the acceptance test referenced by §130.4 and to sign the certificate(s) of acceptance.
- When the industry certification threshold has been satisfied for mechanical ATTs, a certified ATT will then be required to perform the acceptance test referenced by §120.5 and sign the certificate(s) of acceptance.

The acceptance tests listed in §120.5 and §130.4 may require that the field technician be a certified ATT. Other acceptance tests, such as those found in §120.6, do not require that the field technician be a certified ATT.

B. Responsible Person

A certificate of acceptance must be signed by a responsible person who is licensed and eligible under Division 3 of the Business and Professions code to take responsibility for the scope of work specified by the certificate of acceptance. The responsible person can also perform the field testing and verification, and if this is the case, the responsible person must complete and sign both the field technician's signature block and the responsible person's signature block on the certificate of acceptance document. The *Responsible Person* assumes responsibility for the acceptance testing work performed by his Field Technician agent or employee. Aside from being licensed, the responsible person that conducts his or her own testing may also need to be a certified ATT if he or she is performing an acceptance test that requires a certified ATT.

C. Enforcement Agency

The certificate of acceptance must be submitted to the enforcement agency to receive the final certificate of occupancy. Enforcement agencies shall not release a *final* certificate of occupancy unless the submitted certificate of acceptance demonstrates that the specified systems and equipment have been shown to be performing in accordance with the applicable acceptance requirements.

The enforcement agency has the authority to require the field technician or responsible person to demonstrate competence to its satisfaction. When a certified ATT is required to complete an acceptance test, the enforcement agency must verify the technician certification status through the acceptance test technician certification provider (ATTCP) before issuing a final certificate of occupancy.

13.2.3 Acceptance Testing Process

The acceptance requirements require five major checkpoints to be conducted. They are:

1. Plan review.
2. Construction inspection.
3. Functional testing.
4. Signing of certification of acceptance.
5. Submission of certification of acceptance.

These are discussed in more detail below.

A. Plan Review

The responsible person must review the plans and specifications to ensure that they conform to the acceptance requirements, typically done prior to signing a certificate of compliance.

In reviewing the plans, the designer notes the appropriate certificate of compliance, all the respective acceptance tests that will be performed, as well as the parties responsible for performing the tests. An exhaustive list is required so that when the acceptance tests are bid, all parties are aware of the scope of acceptance testing on the project.

B. Construction Inspection

The construction inspection assures that installed equipment is capable of complying with the Energy Standards. Construction inspection also assures proper installation of equipment and current calibration.

The responsible person must perform a construction inspection prior to testing. Reviewing the acceptance requirements with the contractor before installation is very useful on several counts.

In some cases, performing tests immediately after installation is most economical, though this requires the complete installation of any associated systems and equipment necessary for proper system operation.

Awareness of the acceptance test requirements can allow the contractor to identify a design or construction practice that would not comply with the acceptance requirements prior to equipment installation.

Purchasing sensors and equipment with calibration certificates often reduces the amount of time required for site calibration, which can lower overall costs.

C. Functional Testing

A *field technician* assumes responsibility for performing the required acceptance requirements procedures. In some cases, the same field technician may not perform all the required acceptance tests for a project. However, for each acceptance test performed, the field technician who performs the test is responsible for identifying all performance deficiencies and, if necessary, repeating the test until the specified systems and equipment are performing in accordance with the acceptance requirements. The field technician who performs the testing signs the certificate of acceptance to certify the information recorded on the certificate is true and correct.

A responsible person ensures performance of the scope of work specified by the certificate of acceptance and reviews the test results provided by the field technician. The responsible person signs the certificate of acceptance to indicate his or her overall responsibility for the project.

The responsible person may also perform the field technician's responsibilities, and, if so, must also sign the field technician declaration on the certificate of acceptance. If the acceptance test requires a certified ATT and the responsible person performs the acceptance test, then he or she must be a certified ATT.

D. Certification of Acceptance

Acceptance test forms include a certificate of acceptance and worksheets to assist in field verification. Table 13-1 shows the certificate of acceptance documents and related references.

Table 13-1: Acceptance Documents

Component	Document Name	Energy Standards Reference	Reference Nonresidential Appendix NA7
Envelope	NRCA-ENV-02-F – Fenestration Acceptance	§10-103(a)4 & §10-111 & §110.6	NA7.4.1
Mechanical	NRCA-MCH-02-A – Outdoor Air Acceptance	§10-103(b)4 & §120.1(b)2 & §120.5(a)1	NA7.5.1.1 NA7.5.1.2
	NRCA-MCH-03-A – Constant Volume, Single Zone, Unitary Air Conditioner and Heat Pump Systems	§120.1(c)2 & §120.2 & §120.5(a)2	NA7.5.2
	NRCA-MCH-04-A – Air Distribution Systems Acceptance	§120.5(a)3 § 140.4(l)	NA7.5.3
	NRCA-MCH-05-A – Air Economizer Controls Acceptance	§120.5(a)4 & §140.4(e)	NA7.5.4
	NRCA-MCH-06-A – Demand Control Ventilation Systems Acceptance	§120.1(c)4 & §120.5(a)5	NA7.5.5
	NRCA-MCH-07-A – Supply Fan VFD Acceptance	§120.5(a)6 & §140.4(c)2B & §140.4(c)2C	NA7.5.6
	NRCA-MCH-08-A – Valve Leakage Test	§120.5(a)8, §140.4(k)1 §140.4(k)5, §140.4(k)6	NA7.5.7
	NRCA-MCH-09-A – Supply Water Temperature Reset Controls Acceptance	§120.5(a)9 & 140.4(k)4	NA7.5.8
	NRCA-MCH-10-A – Hydronic System Variable Flow Control Acceptance	§120.5(a)7, §140.4(k)1, §140.4(k)5, §140.4(k)6	NA7.5.9
	NRCA-MCH-11-A – Automatic Demand Shed Control Acceptance	§120.2(h), 120.5(a)10	NA7.5.10
	NRCA-MCH-12-A – Fault Detection & Diagnostics (FDD) for Packaged Direct Expansion Units	§120.2(i), §120.5(a)11	NA7.5.11
	NRCA-MCH-13-A – Automatic Fault Detection & Diagnostics (FDD) for Air Handling Units & Zone Terminal Units Acceptance	§120.5(a)12	NA7.5.12

Mechanical	NRCA-MCH-14-A – Distributed Energy Storage DX AC Systems Acceptance	§120.5(a)13	NA7.5.13
	NRCA-MCH-15-A – Thermal Energy Storage (TES) System Acceptance	§120.5(a)14	NA7.5.14
	NRCA-MCH-16-A – Supply Air Temperature Reset Controls Acceptance	§140.4(f), 120.5(a)15	NA7.5.15
	NRCA-MCH-17-A – Condenser Water Supply Temperature Reset Controls Acceptance	Not required per Energy Standards. However, this test is required if this control strategy is implemented.	NA7.5.16
	NRCA-MCH-18-A – Energy Management Control System Acceptance	§110.2(e), §120.2(h), §120.5(a)17, §130.4(b), §130.5(f), §150.0(k)	--------
Indoor Lighting	NRCA-LTI-02-A Lighting Controls	§110.9(b), §130.1(c)	NA7.6.2
	NRCA-LTI-03-A Automatic Daylighting Controls	§130.1(d)	NA7.6.1
	NRCA-LTI-04-A Demand Responsive Lighting Controls	§130.1(e)	NA7.6.3
	NRCA-LTI-05-A Institutional Tuning Power Adjustment Factor	§140.6(a)2J	NA7.7.6.2
Outdoor Lighting	NRCA-LTO-02-A – Outdoor Lighting Acceptance Tests	§110.9(b), §130.2(a & c)	NA7.8
Process	NRCA-PRC-01-F – Compressed Air System Acceptance	§120.6(e)	NA7.13
	NRCA-PRC-02-F – Commercial Kitchen Exhaust	§140.9(b)	NA7.11
	NRCA-PRC-03-F – Parking Garage Exhaust	§120.6(c)	NA7.12
	NRCA-PRC-04-F – Refrigerated Warehouse – Evaporator Fan Motor Controls Acceptance	§120.6(a)3	NA7.10.2
	NRCA-PRC-05-F – Refrigerated Warehouse – Evaporative Condenser Controls Acceptance	§120.6(a)4	NA7.10.3.1
	NRCA-PRC-06-F – Refrigerated Warehouse – Air-Cooled Condenser Controls Acceptance	§120.6(a)4	NA7.10.3.2
	NRCA-PRC-07-F – Refrigerated Warehouse – Compressor Variable Speed Acceptance	§120.6(a)5	NA7.10.4
	NRCA-PRC-08-F – Refrigerated Warehouse – Electric Resistance Underslab Heating System Acceptance	§120.6(a)2	NA7.10.1
	NRCA-PRC-12-F – Elevator Lighting and Ventilation Controls	§120.6(f)5	NA7.14
	NRCA-PRC-13-F – Escalator and Moving Walkways Speed Control	§120.6(g)2	NA7.15

E. Submission of Certification of Acceptance

The completed and signed certificate of acceptance must be submitted to the local enforcement agency in accordance with the local laws, ordinances, regulations, or customs. There is no general requirement for a certificate of acceptance to be submitted to any other regulatory agency or to an ATTCP, though specific contractual agreements may require such submissions. For example, in many cases ATTCP will require that certified acceptance test technicians electronically submit all completed certificates of acceptance as a condition of maintaining their certification status.

13.2.4 Envelope and Mechanical Acceptance Testing Overview

The administrative requirements contained in the Energy Standards (§10-103(b)) require the envelope and mechanical plans and specifications to contain:

- Completed acceptance testing documents for mechanical systems and equipment shown in Table 13-1; submission of record drawings to the building owners within 90 days of receiving a final occupancy permit.
- Submission of operating and maintenance information to the building owner.
- Installation certificates for mechanical equipment (for example, factory-installed economizers).

13.2.4.1 Envelope and Mechanical Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and climatic condition. While the steps for conducting each test and the acceptance criteria remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues that occur when applying acceptance tests on-site.

A. General Issues − Envelope

Important aspects to the fenestration acceptance requirements are:

- Verification of thermal performance (U-factor, SHGC, and VT) for each specified fenestration product to ensure that it matches the fenestration certificate, building plans, energy compliance documentation, and the purchase order or receipt.
- When installed fenestration thermal performance is equal or better than the specified or listed on the energy documentation, then no further recompliance is required.
- When installed fenestration is less than the energy documentation, then recompliance is required. Installation of less efficient fenestration can increase the cooling load of the building and adversely affect the overall energy use of the building.
- When using the performance approach, the weighted average thermal performance per orientation is applicable if it is equal or better than the specified values as noted above; otherwise, recompliance is required.

B. General Issues – Mechanical Combining Tests to Reduce Testing Costs

Many of the acceptance tests overlap in terms of activities. For example, both Reference Nonresidential Appendix NA7.5.1.1 Ventilation Systems for Variable Air and Constant Volume Systems Acceptance and NA7.5.6 Supply Fan Variable Flow Controls (FVC) Acceptance require zone controls be overridden to force the system into full design flow and low flow conditions. Since the bulk of the time for either test is driving the zone controls (for example, variable air volume [VAV] boxes) into a set position, one may combine these two tests: performing the superset of activities with the boxes at both design and part-load conditions. There are several places where combining tests will save time. These opportunities are summarized below and described again in the test descriptions.

Tests requiring override of zone controls:

- NA7.5.1.1 Ventilation Systems for Variable Air Volume Systems Acceptance
- NA7.5.6 Supply Fan Variable Flow Controls Acceptance

Tests requiring override of the OSA damper:

- NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance (or NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance)
- NA7.5.4 Air Economizer Controls Acceptance
- NA7.5.5 Demand Controlled Ventilation Systems Acceptance
- NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion Units

Tests requiring a change in the unit mode of operation:

- NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance
- NA7.5.4 Air Economizer Controls Acceptance

Tests requiring dead head of the circulation pump and overriding control valves:

- NA7.5.7 Valve Leakage Tests
- NA7.5.9 Hydronic System Variable Flow Controls Acceptance.

C. Internal Control Delays

Be aware of the potential for delays programmed into many control sequences. Delays prevent the system from instability. With delays between 5 to 30 minutes, the acceptance testing can be prolonged considerably.

Examples include the normal time that a damper uses to stroke (typically several minutes end to end) and antirecycle timers on refrigerant compressors (typically 5 to 15 minutes).

1. Initial Conditions

Each test instructs the contractor to return the systems to normal operating condition based on the initial schedules, set points, and control parameters. These initial settings shall be recorded prior to initiating testing.

2. Obtain Correct Control Sequences Before Testing

Before testing begins, be familiar with the control sequences. Otherwise, the contractor will not be able to customize the test to the particular systems or verify that the systems work as intended. In many cases, the testing will be performed in conjunction with the controls contractor. In addition, many of these tests can be performed as part of the equipment/system start-up process.

The equipment operations and maintenance (O&M) manual usually documents the internal electronic controls.

With pneumatic controls, the control drawings are the best resource to ascertain how the system controls function.

With DDC controls, review the existing control programming loaded in the controllers. An important note is that the actual control logic is often different from the sequences on the design plans and specifications due to a number of reasons including:

- Poorly written or incomplete sequences on the design drawings.
- Standard practices by the installing EMCS contractor.
- Issues that arose in the field during control system start-up and commissioning.

Functional testing based on incorrect sequences will not necessarily yield a valid result.

3. Estimated Time to Complete

To give the full picture to contractors, the test summaries below (“At-A-Glance”) include estimates of the time to complete construction observation, as well as functional testing on each system. These estimates are made for a specific test on a specific system and need to be combined to estimate the total time for completion on all systems associated with the entire building. Use these estimates with caution; times will vary depending on several factors, including the complexity of the controls, the number of control zones, the number of similar tests, and other issues. Expect delays during the first test. Subsequent tests take less time as the tester becomes more experienced and familiar with the test.

4. Sensor Calibration

A variety of sensors control many facets of heating, ventilating, and air conditioning systems. Confirming each sensor measures the respective parameter accurately is crucial to proper system operation and energy performance. For example, if a supply fan variable frequency drive is controlled based on duct static pressure, then an accurate pressure sensor is understandably imperative.

The requirement found in a few test procedures for sensor calibration can be met by either having a calibration certificate provided with the sensor from the manufacturer or through field verification. A calibration certificate from the manufacturer verifies testing of a particular sensor per a traceable standard (typically National Institute of Standards and Technology [NIST]) and confirms the sensor measures accurately. Common practice assumes a factory-calibrated sensor accurate and needs no further testing. Field verification generally requires checking the measured value from the sensor installed in the system against a calibrated instrument. Typically most sensors can be checked at a single operating point if the expected measurement range does not vary significantly. Any adjustments needed to make the field-installed sensor correspond to the value measured by the calibrated instrument can be made at either the transmitter itself or within the control system database.

The following sensors require checking for calibration:

- Pressure sensors used in variable flow applications (that is, supply fan or pump variable frequency drive is controlled to maintain a specific pressure set point). The following test procedure(s) apply: NA7.5.6 Supply Fan Variable Flow Controls and NA7.5.9 Hydronic System Variable Flow Controls.
- Temperature sensors used to control field-installed economizers and supply water temperature reset. The following test procedure(s) apply: NA7.5.4 Air Economizer Controls Acceptance and NA7.5.8 Supply Water Temperature Reset Controls.

- Carbon dioxide sensors used to implement a demand-controlled ventilation control strategy. The following test procedure(s) apply: NA7.5.5 Demand-Controlled Ventilation Systems Acceptance.

D. VAV Control Systems

There are many ways to control minimum ventilation in a VAV system, including, but not limited to:

- Supply/return flow tracking.
- Direct outdoor air flow measurement.
- Constant differential pressure across dedicated ventilation air damper.
- Constant mixed air plenum pressure.

The term "system" refers to whatever type of control strategy employed to control minimum ventilation air flow. The following test procedure(s) apply: NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance. Overall, the system must be able to control flow to within 10 percent of the design outdoor air ventilation value.

E. Air and Water Measurements

Before granting an occupancy permit for a new building or space, or a new space conditioning system serving a building or space, balance the system in accordance with the procedures defined by the Testing Adjusting and Balancing Bureau (TABB) National Standards (2003); the National Environmental Balancing Bureau (NEBB) Procedural Standards (1983); or Associated Air Balance Council (AABC) National Standards (1989).

F. Factory Air Economizer Certification Procedure

§120.5(a)4 requires air economizer acceptance testing in accordance with NA7.5.4, Air Economizer Controls. This test assures economizers work per the intent of the Energy Standards §140.4(e) Economizers. NA7.5.4, Air Economizer Controls describes the requirements for the acceptance test, as well as provides a detailed test description.

Air economizers installed by the HVAC system manufacturer and certified to the California Energy Commission as being factory installed, calibrated, and tested are exempted from the Air Economizer Controls acceptance test as described in the Nonresidential Reference Appendix NA7.5.4. The following sections describe the requirements of a "factory installed and calibrated economizer" certification and how to apply for Energy Commission approval of a certification program.

Inspection:

- Verify minimum outside air damper position can be adjusted. Verify outside and return air dampers modulate as necessary to achieve the desired position.
- Verify outside air dampers completely close when the unit is off.
- Verify outside air dampers move freely without binding.
- Provide a 5-year manufacturer warranty of economizer assembly.
- Provide an economizer specification sheet proving capability of at least 60,000 actuations
- Provide a product specification sheet proving compliance with Air Movement and Control Association (AMCA) Standard 500 damper leakage at 10 cfm/sf at 1.0 in.

w.g. Provide a product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third-party reviewer under AMCA Publication 511 may also be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable). (See figure below)

Figure 13-1: AMCA 511 Certification Product Labels

Good, Class 2 = 10 cfm/sf max   Better, Class 1 = 4 cfm/sf max   Best, Class 1A = 3 cfm/sf max

Class 2, Class 1, & Class 1A Are All Acceptable

- Verify system has return fan speed control, relief dampers, or dedicated exhaust fans to prevent building over pressurization in full economizer model
- Verify calibration of outdoor air, return air, mixed air, and supply air sensors to known references within the following measurement tolerances:
  - Dry bulb and wet bulb temperatures accurate to ± 2°F over the range of 40°F to 80°F
  - Enthalpy accurate to ± 3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb
  - Relative humidity (RH) accurate to ± 5 percent over the range of 20 percent to 80 percent RH
- Verify the economizer instruction material provides the sensor performance curve. In addition, confirm the sensor output value measured during sensor calibration is plotted on the performance curve.
- Verify whether the high limit set point is fixed dry-bulb or fixed enthalpy + fixed dry-bulb; in either case, the control shall have an adjustable set point.
- Verify the location of sensors used for the high limit control to prevent false readings, for example, properly shielded from direct sunlight
- Verify that the high-limit shutoff set point is set to these default limit settings per Table 140.4-B, as referenced in §140.4(e)3:

No climate zones allow fixed enthalpy, differential enthalpy, and electronic enthalpy.

1. Functional Testing

Factory-installed and calibrated economizer certification shall document that the following conditions are met:

- During a call for heating, outside air dampers close to minimum ventilation position and return air dampers open.
- Demonstrate proper integration between economizer and compressor using the steps in Table 13-2.
- Demonstrate economizer high-limit control and dead band using the process in Table 13-3.

Table 13-2: Steps to Demonstrate Proper Integration

Step	Description	Purpose
1	Simulate OAT to 45°F and RAT to 75°F	-------
2	Generate call for cooling and increase OAT such that economizer damper modulates to position between minimum and 50 percent open with no mechanical cooling.	Test partial economizing at low OAT.
3	Verify economizer position is correct (between minimum and 50 percent) and stable with no hunting, compressor is not enabled, and heating is disabled. Record the OAT and economizer damper position.	------
4	Increase the OAT such that economizer damper modulates to any position within 50 percent to 100 percent open with no mechanical cooling.	Test partial economizing.
5	Verify economizer modulates open to a larger degree, is stable with no hunting, the return air damper modulates more closed, and the compressor is not enabled. Record the OAT and economizer damper position.	-------
6	Increase the OAT such that the compressor turns on and the economizer damper modulates more closed.	Test partial economizing and compressor integration.
7	Verify the compressor is enabled. Record the OAT at high limit and the economizer damper position.	
8	Verify the compressor turns off and the economizer damper modulates to 100 percent open.	Test full economizing.
9	Record the compressor run time (minutes)	------
10	Repeat Steps 7-8 when the compressor turns on again. Also verify the economizer damper modulates to close.	Test partial economizing and compressor integration.
11	Record the compressor off time between cycles (minutes)	-------
12	Slowly increase the OAT such that mechanical cooling is enabled and the economizer damper modulates to minimum position	Test minimum ventilation and compressor integration.
13	Verify economizer and return air damper positions are correct and stable with no hunting, compressor is enabled, and heating is disabled.	-------

Table 13-3: Steps to Demonstrate High-Limit Control and Dead band

Step	Description	Purpose
1	Simulate RAT to 80°F; OAT to 72°F	
2	Generate a call for cooling	
3	Verify that economizer is at minimum position	Test minimum ventilation above the high limit setpoint.
4	Incrementally lower the OAT	
5	Verify that economizer stays at minimum position until ambient air conditions are less than high limit setpoint then opens to 100 percent	Test the high limit setpoint from above.
6	Incrementally raise the OAT	Test the dead band.
7	Verify that economizer stays at maximum position until ambient air conditions are higher than high limit setpoint then closes to minimum position	Test the high limit setpoint from below.
8	Test passes if both conditions are met: i.) economizer controller will utilize a dead band between economizer enable/disable operation of no greater than 2°F and ii.) high limit control meets the requirements of Table 140.4-C as referenced in §140.4(e)3	

2. *Documents to Accompany Factory-Installed and Calibrated Economizer Certificate*

- Installation instructions. For systems with cooling capacities greater than 54,000 Btu/hr, instructions shall include methods to assure economizer control is integrated and is cooling, even when economizer cannot serve the entire cooling load.
- Sensor performance curve for high-limit shutoff sensors and instructions for measuring sensor output. Performance curve shall also contain test points during calibration plotted on the curve. Curve details shall show measurement resolution in increments of 1°F and 1 Btu/lb.
- Economizer specification sheet proving capability of at least 60,000 actuations.
- Provide a product specification sheet proving compliance with AMCA Standard 500 damper leakage at 10 cfm/sf at 1.0 in. w.g. A product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third party under AMCA Publication 511 can be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable).

3. *Application for Factory-Installed and Calibrated Economizer Certification*

Manufacturers who wish to label their economizers as factory-installed and calibrated must provide the following information to the California Energy Commission:

- Brief description of test method, including:
  - Method of placing equipment in heating and cooling mode.
  - Method of calibrating high limit sensor.
  - Method of testing control and damper.
- Model numbers of products to be certified.
- Sample of factory-installed and calibrated economizer documentation that would accompany each qualifying economizer.

- Name and contact information of lead staff in charge of certification

  Send the application materials to:

  Building Standards Development Office

  California Energy Commission

  1516 Ninth St., MS 37

  Sacramento, CA 95814

4. Sample Certificate of Factory-Installed and Calibrated Economizers

“This document certifies that this economizer has been factory installed and calibrated according to the requirements of the California Energy Commission. As a result, this economizer is exempted from the functional testing requirements (but not the construction inspection requirements) as described in Appendix NA7.5.4 Air Economizer Controls’ and on the MECH-5 acceptance testing document.”

Date of economizer testing:	Model Number:
Supervisor:	Serial Number:
Technician:	Rated Cooling Capacity:
Economizer fully integrated? YES NO	

Table 13-4: Type of High-Limit Control and Setpoint (Check Appropriate Control Strategy)

Device Type	Control Type & Setpoint	Climate Zones	Required High Limit (Economizer Off When):	
			Equation	Description
Fixed Dry Bulb	□	1, 3, 5, 11-16	T_{OA} > 75°F	Outdoor air temperature exceeds 75°F
	□	2, 4, 10	T_{OA} > 73°F	Outdoor air temperature exceeds 73°F
	□	6, 8, 9	T_{OA} > 71°F	Outdoor air temperature exceeds 71°F
	□	7	T_{OA} > 69°F	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	□	1, 3, 5, 11-16	$T_{OA} > T_{RA}$	Outdoor air temperature exceeds return air temperature
	□	2, 4, 10	$T_{OA} > T_{RA}$ – 2°F	Outdoor air temperature exceeds return air temperature minus 2°F
	□	6, 8, 9	$T_{OA} > T_{RA}$ – 4°F	Outdoor air temperature exceeds return air temperature minus 4°F
	□	7	$T_{OA} > T_{RA}$ – 6°F	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy + Fixed Drybulb	□	All	h_{OA} > 28 Btu/lb or T_{OA} > 75°F	Outdoor air enthalpy exceeds 28 Btu/lb of dry air or Outdoor air temperature exceeds 75°F

Note to installer: Economizer high-limit setpoint must be reset when needed based upon climate zone and/or device type.

Outside Air Calibration

a. Outside air conditions during calibration test from reference measurement: T_{OA} = _______ h_{OA} = _______
b. Outside air sensor output during calibration test: T_{OA} = _______ h_{OA} = _______ Units (V, mA etc) ______
c. Sensor measured value from sensor performance curve: T_{OA} = _______ h_{OA} = _______
d. Are sensor measurements within 2°F or 3 Btu/lb of reference measurement?

   (Yes, No, N/A) T_{OA} = _______ h_{OA} = _______

   - ☐ Sensor output plotted on sensor performance curve
   - ☐ Sensors used for the high limit control are properly shielded from direct sunlight

e. Return air calibration (for differential dry bulb controls only)
f. Return air temperature during calibration test from reference measurement: T_{return} = _______
g. Return air sensor output during calibration test: Units (V, mV, etc) _______
h. Sensor measured value from sensor performance curve T_{return} = _______
i. Are sensor measurements within 2°F of reference measurement?

   (Yes, No, N/A) T_{OA} = _______

☐ Sensor output plotted on sensor performance curve

Functional Tests Under Simulated Temperature Conditions

- During a call for heating, outside air dampers are closed to a minimum outside air setting and air dampers are opened.
- During a call for full cooling and ambient conditions below the high-limit shutoff set point, before mechanical cooling is enabled, the outside air dampers must be 100 percent open and the return dampers fully closed.
- For systems with cooling capacities greater than 54,000 Btu/h, during a call for full cooling, if the ambient conditions are below the high limit shutoff set point and economizer cannot provide full cooling, then mechanical cooling is modulated to maximize economizer cooling, N/A system cooling capacity ≤ 54,000 Btu/h
- During a call for cooling, if the measured ambient air condition is greater than the high-limit shutoff set point, the outside air dampers are closed to a minimum outside air damper position and the return air dampers are opened.
- Minimum outside air can be adjusted.
- The outside air dampers are closed when the unit is off.
- The outside air dampers move freely without binding.

Accompanying Documents

- Installation instructions.
- For systems with cooling capacities greater than 54,000 Btu/hr, instructions shall include methods to assure economizer control is integrated and is cooling even when

economizer cannot serve the entire cooling load. N/A system cooling capacity ≤ 54,000 Btu/h.

- Economizer specification sheet proving capability of at least 60,000 actuations.
- Provide a product specification sheet proving compliance with AMCA Standard 500 damper leakage at 10 cfm/sf at 1.0 in. w.g. A product specification sheet showing the manufacturer's results after following the testing procedures of AMCA Standard 500 or AMCA certification by a third party under AMCA Publication 511 can be used to satisfy this requirement (Class 1A, 1, and 2 are acceptable)
- Performance curve for high-limit shutoff sensors and instructions for measuring sensor output.

The (**Manufacturing Company Name**) certifies that all the information on this certificate for factory installed and calibrated economizers is true and that this economizer complies with all of the California Energy Commission requirements for factory-installed and calibrated economizers.

13.2.5 Lighting Acceptance Testing Overview

Acceptance requirements can effectively improve code compliance and help determine whether lighting equipment meets operational goals and if efficiency and effectiveness need to increase.

The administrative requirements contained in the Energy Standards (§10-103(b)) require:

- Completed certificate of compliance, installation, verification and acceptance documents for lighting controls, automatic daylighting controls, demand responsive lighting controls, and outdoor motion sensors and lighting shutoff controls.
- Record drawings are provided to the building owners within 90 days of receiving a final occupancy permit.
- Operating and maintenance information be provided to the building owner.
- Completed installation certificates for daylighting controls, occupant sensing devices, and automatic shut-off controls.

13.2.5.1 Lighting Acceptance Test Issues

Acceptance testing must be tailored for each specific design, job site, and/or climatic condition. While the steps for conducting each test remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues that occur when the acceptance tests are applied to a project.

A. Internal Control Delays

Be aware of the potential for delays programmed into many control sequences. Delays prevent the system from instability. With delays between 5 to 30 minutes, the acceptance testing can be prolonged considerably.

B. Initial Conditions

Each test instructs the contractor to return the systems to normal operating condition based on the initial schedules, set points, and control parameters. These should be recorded before initiating testing.

C. Obtain Correct Control Sequences Before Testing

Before testing begins, the contractor must be aware*:*

- How the control sequence are programmed.
- That written control sequences often do not include enough detail to test the system (or they are found to be incorrect).
- How to operate the control system.

D. Estimated Time to Complete

To give the full picture to contractors, the at-a-glance includes the time to complete construction observation as well as functional testing. In addition, the At-A-Glance indicates the time shown is per system (not per building).

13.2.6 Process Acceptance Testing Overview

§10-103(b)

The administrative requirements contained in the Energy Standards require the refrigerated warehouse plans to contain:

- Applicable refrigerated warehouse compliance documents: NRCC-PRC-06-E, which includes the required acceptance tests, and documents NRCC-PRC-07-E and NRCC-PRC-08-E, as applicable.
- A note that specifies that the record drawings ("as-built" drawings) are provided to the building owners within 90 days of receiving a final occupancy permit.

Furthermore, the administrative requirements contained in the Energy Standards require:

- Installation certificates for refrigeration warehouses: NRCI-PRC-01-E.
- Refrigerated warehouse acceptance testing documents, NRCA-PRC-04-A, NRCA-PRC-05-A, NRCA-PRC-06-A, NRCA-PRC-07-A and NRCA-PRC-08-A.
- Operating and maintenance information in the building after occupancy.

13.2.6.1 **Process Acceptance Test Issues**

Acceptance testing must be tailored for each specific design, job site, and/or climatic conditions. While the steps for conducting each test and the acceptance criteria remain consistent, the application of the tests to a particular site may vary. The following section discusses some of the known issues when performing the acceptance tests.

A. Cooling Loads

Some acceptance tests require an accurate determination of an adequate cooling load. For performing the acceptance test, the system cooling load may be artificially increased (such as by lowering the space temperature set point).

B. Initial Conditions

Each acceptance test includes a final instruction stating that any schedules, set points, and/or control parameters changed during the acceptance test shall be restored to pretest values. Record these initial settings before performing the acceptance test.

C. Internal Control Features

The field technician should be aware that many control functions include internal control features such as start-up and shutdown delays, fail-safes, control dead bands, and automatic overrides. These features protect system equipment and increase system stability. These features are necessary for the safe and efficient operation of the refrigeration system and disregarded when determining if a component passes or fails an acceptance test.

Before doing any acceptance testing, the field technician shall fully understand the control logic for each component under test. Close coordination and communication with the controls engineer, contractor, or component vendor may be necessary.

D. Estimated Time to Complete

The “at-a-glance” summaries include estimates of the time to complete construction inspection, as well as functional testing for each system component. These estimates are made for a test on a single component; actual time to complete the tests will vary depending on the complexity of the controls and the refrigeration system, the number of control systems, and other factors. Expect delays during the first test.

E. Sensor Calibration

In refrigerated warehouses, sensors used for refrigeration system control include numerous field-installed sensors, such as evaporator zone temperatures, suction and discharge pressure transducers, and outdoor temperature and humidity sensors. Sensors may also be factory-installed on equipment such as a screw compressor package. To ensure efficient system operation, as well as meet the construction inspection requirements for the acceptance tests, all sensors used for operational control of the system must have current calibration.

Sensors used for information or other purposes that do not relate to maintaining pressures, temperatures, or routine equipment sequencing and operational control are not subject to these calibration requirements.

For field-installed sensors, on-site calibration must be completed, even if the sensor was provided with a calibration certificate. For field-installed sensors, there are multiple potential sources of error in the readings between the sensor and the operator interface. Errors may include, but are not limited to, sensor error, transmitter error, conversion error, thermal drift, or electrical noise. To provide accurate values to the control system, calibrate from end-to-end (in other words, sensor to the operator interface).

The instruments used to calibrate the field-installed sensors must be highly accurate to prevent bias errors. This calibrating instrument, also called the calibration “standard,” must be calibrated at least every two years using a NIST traceable reference. The refrigerated warehouse refrigeration system acceptance tests **require calibrating instrument** measurement tolerances as follows:

- Temperature: ±0.7°F between -30°F to 200°F
- Pressure: ±2.5 psi between 0 and 500 psig
- Relative humidity (RH): ±1 percent between 5 percent and 90 percent RH

The calibration includes checking the sensor reading (as read from the operators interface) versus the calibration instrument reading. The control system values shall be adjusted according to the control system procedures, which may include zero and span values or single offset values for calibration, so that the reading from the operator readout is within an acceptable deviation from the calibrating instrument reading. To ensure consistency with control system documentation and proper implementation of sensor function and signal conversion (for example, proper ranges and engineering units), perform calibration at more than one condition (such as temperature or pressure). Measurements taken for calibration values should be tested for repeatability in the event of a controller or computer power reset.

For factory-installed sensors on an equipment package that is used for system control, the package manufacturer may certify the sensor as calibrated using a NIST-traceable reference or using the preceding field calibration.

For refrigerated warehouses, the calibration requires documentation to be provided to the field technician completing the acceptance test and the building owner for documentation and use in ongoing system maintenance. Calibration documentation includes records showing the calibration date, instruments used in calibration, and any offsets or other calibration values adjusting sensor readings in the control system. This process requires both field-installed sensors and factory-installed sensors on equipment packages.

13.3 NA7.4.1 Fenestration Acceptance

At-A-Glance

NA7.4.1 Fenestration Acceptance
Use Document NRCA-ENV-02-F
Purpose of the Test
Envelope components require an NFRC or Energy Commission label certificate, including site-built fenestration. The label certificate matches the building plans and energy compliance documentation. This certificate of acceptance summarizes the results of the acceptance test, as specified in the Reference Nonresidential Appendix, NA7.4. Additional related references are in §10-103(a)4, §10-111, §116(a)5 of the Energy Standards.
Instrumentation
No instrumentation recommended.
Test Conditions
Not applicable.
Estimated Time to Complete
Not applicable.
Acceptance Criteria
Products will be either NFRC-rated or not rated. For NFRC-rated products, record and cross reference the rating. For unrated products, record and attach the NRCC-ENV-05-E document and cross reference against the building plans.
Potential Issues and Cautions
Important aspects to the fenestration acceptance requirements are the following: • Verify that thermal performance (U-factor, SHGC, and VT) of each specified fenestration product matches the fenestration certificate, building plans, and energy compliance documentation, and that each product matches purchase order or receipt.

- If the to-be-installed fenestration thermal performance is equal to or better than the specified or listed on the energy documentation, then no further recompliance is required.
- If the to-be-installed fenestration is less than the energy documentation, then recompliance is required. Installing less efficient fenestration can increase the cooling load of the building and change the overall energy use of the building.
- If using the performance approach, then the weighted average thermal performance per orientation can be used as long it's equal to or better than the specified values as noted above; otherwise, recompliance is required.

A. Construction Inspection

Review the building plans and any completed NRCC-ENV-05-E documents; confirm that all products are represented.

B. Functional Testing

For NFRC-rated products:

- Record the NFRC label certificate ID.
- If receipts or orders are available and they identify the NFRC ID number, then cross reference against the NFRC label certificate to match ID numbers.
- Cross reference the efficiencies listed on the NFRC label certificate of NRCC-ENV-05-E– to ensure they match the building plans window schedule of efficiencies.

For nonrated fenestration, attach a copy of the NRCC-ENV-05-E to the NRCA-ENV-02-F.

13.4 NA7.5.1 Outdoor Air: Variable Air and Constant Volume Systems

At-A-Glance

NA7.5.1 Variable Air Volume Systems Outdoor Air Acceptance
Use Document NRCA-MCH-02-A
Purpose of the Test
This test ensures the provision of adequate outdoor air ventilation through the variable air volume air handling unit at two representative operating conditions. The test consists of measuring outdoor air values at maximum flow and at or near minimum flow. The test verifies the introduction of a minimum volume of outdoor air, in accordance with §120.1(b)2, into the air handling unit and is within 10 percent of the required volume when the system is in occupied mode at these two conditions of supply airflow. Perform this test in conjunction with NA7.5.6 (NRCA-MCH-07-A) Supply Fan Variable Flow Controls Acceptance test procedures to reduce the overall system testing time as both tests use the same two conditions of airflow for their measurements. Related acceptance tests for these systems include: • NA7.5.4 Air Economizer Controls. • NA7.5.5 Demand Control Ventilation (DCV) Systems (if applicable). • NA7.5.6 Supply Fan Variable Flow Controls

Instrumentation

Performance of this test will require measuring outdoor air flow. When the system includes an airflow monitoring system (AFMS) on the outdoor air, then it may be used for the measurements if it has a calibration certificate or is field-calibrated. The instrumentation needed to perform the task may include, but is not limited to:

- An airflow measurement probe (for example, hot-wire anemometer or velocity pressure probe), or
- A watch or some equivalent device to measure time in minutes

Test Conditions

The test needs an override of the normal control operations. The control system of the air handling unit and zone controls must be complete, including:

- Supply fan capacity control (typically a variable speed drive).
- Air economizer control.
- Minimum outdoor air damper control.
- Zone airflow control (including zone thermostats and VAV boxes).

Installed systems shall be ready for system operation, including:

- Duct work
- VAV boxes.
- Control sensors (temperature, flow, pressure, and so forth).
- Electrical power to air handling unit and control system components.
- Completion of air handling unit start-up procedures, per manufacturer's recommendations.

Document the initial conditions before executing system overrides or manipulation of the set points and schedules. At the end of the test, return all systems to normal.

Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.

Estimated Time to Complete

Construction inspection: 0.5 hours to 2 hours, depending on complexity and difficulty in calibrating the "system" controlling outdoor air flow.

Functional testing: 1 to 3 hours, depending on the type of zone control and the number of zones.

Acceptance Criteria

Field- or factory-calibrated sensor controlling outdoor air flow with documentation attached.

Measured outdoor airflow reading is within 10 percent of the total value found on the Energy Standards Mechanical Plan Check document NRCC-MCH-03-E, under the following conditions:

- Minimum system airflow or 30 percent of total design flow
- Design supply airflow

Potential Issues and Cautions
Use caution when performing test during winter months in cold climates. Since outdoor airflow must remain constant as supply fan flow is reduced, total supply flow can approach 100 percent outdoor air. Be sure that all freeze protection and heating coil controls are functioning before performing test. Coordinate test procedures with the controls contractor who may assist with manipulation of the BAS to achieve the desired operating conditions. Ensure disabling of economizer and demand controlled ventilation controls before performing the test.

A. Test Application

- Newly constructed and additions/alterations: Applies only to new variable air volume (VAV) systems
- Constant air volume systems outdoor air acceptance
- Newly constructed and additions/alterations: Applies only to new constant air volume (CAV) systems

B. Construction Inspection

1. Reference the supporting documentation as needed. Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.
2. Indicate method and equipment used to measure airflow during the functional test (for example, hot-wire anemometer) on the acceptance document. Note calibration date; calibration date must be within one year.
3. Check the system type (VAV or CAV) on the acceptance document. (The following instructions apply only to VAV systems.)
4. Check that the sensors used to control outside air (OSA) flow is either factory- or field-calibrated. Attach the calibration certificate or field calibration results to the acceptance test document NRCA-MCH-02-A.
5. Check that a fixed minimum damper set point is not controlling OSA. The field technician shall review the operation sequences to ensure the system performs dynamic control of minimum outdoor air and reviews the installation to confirm all of the devices of that sequence are present.
6. Indicate the dynamic control method used to control OSA in the system. There are several means to dynamically control minimum OSA for VAV systems, and many ways for the designer to specify an active ventilation air control “system” intended to maintain a constant outdoor air flow rate as supply fan flow rate decreases.

   For example, an installed flow station measures outdoor air flow rate and modulates the outdoor air dampers accordingly. Or perhaps dampers are modulated to maintain a constant differential pressure across a dedicated outdoor air damper assembly. The sensors, equipment, and control strategy necessary to achieve the desired control shall be calibrated as a “system,” regardless of the control method of the outdoor airflow.

7. Indicate the method used to deliver outside air to the unit (for example, duct, return air plenum). For systems using return air plenums to distribute outside air to a zonal heating or cooling unit, confirm that outside air supply connects either:
   - Within 5 feet of the unit.
   - Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.
8. Confirm the system program includes a preoccupancy purge for the 1-hour period immediately before normal occupancy of the building per §120.1(c)2. This confirmation is most easily accomplished by scheduling the unit to start one hour before actual occupancy. The purge amount must be the lesser of the minimum outdoor air rate or three complete building air changes (ACH).

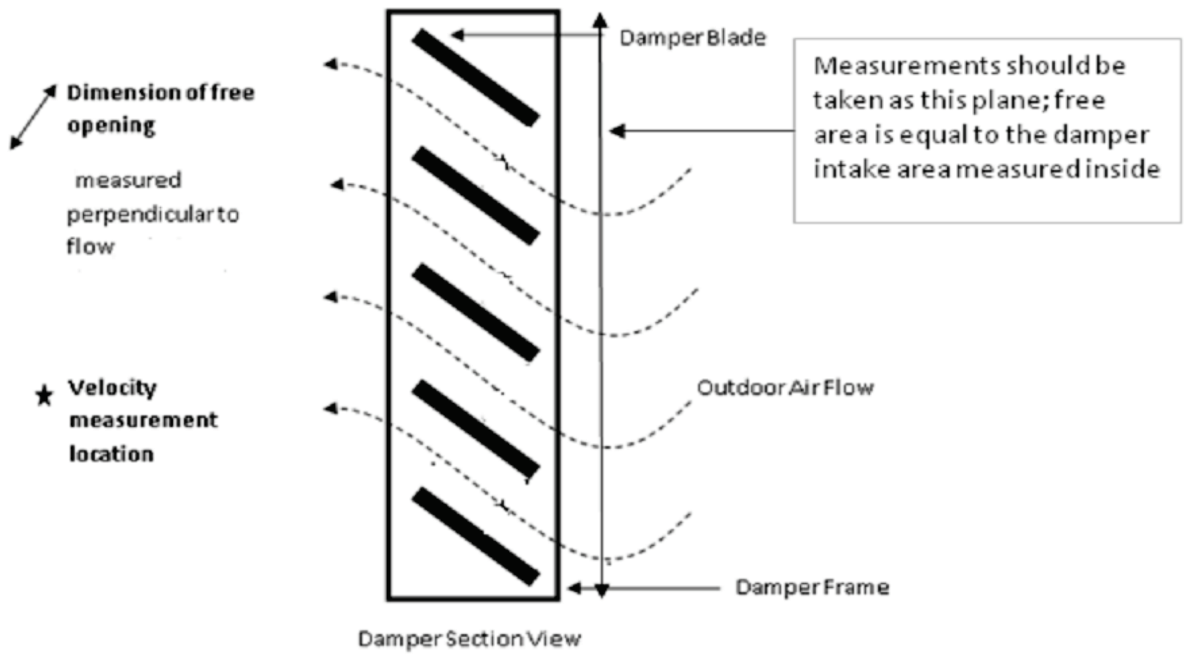
C. Functional Testing

Air handling systems with a dedicated fan providing ventilation air to the unit are exempt from measuring ventilation airflow at minimum and maximum supply airflow conditions. An independent ventilation air fan will deliver a constant minimum outdoor air volume to the air handling unit regardless of the speed of the supply fan. Therefore, the only verification needed for this system type would be to measure the actual CFM delivered by the dedicated ventilation air fan.

Follow the best practice guidelines below to increase accuracy of outdoor air flow measurements:

- Traverse measurements taken in supply, return or outdoor air ducts shall be located in an area of steady, laminar flow. If possible, take measurements at least six to eight duct diameters away from turbulence, air intakes, bends, or restrictions.
- When using face velocity measurements to calculate outdoor air flow, take particular care to accurately measure free area intake dimensions.
- When taking velocity measurements at the plane of the intake between damper blades where flow is restricted (that is, to achieve faster flows), free area shall be measured as the actual open space between dampers and should not include frames or damper blades. See Figure 13-2 below for illustration of free opening measurements.

Figure 13-2: Location for measurement of air flow through dampers



- Hot wire anemometers are more appropriate than velocity pressure probes for measuring low-speed flows (that is, less than 250 feet per minute). When measuring flow with a hot wire anemometer, make sure to position the measurement device perpendicular to the flow direction.
- Take multiple measurements and average results to minimize effects of fluctuations in system operation and environmental conditions (such as wind).

Your body can obstruct air flow and affect measurements. To increase measurement accuracy, position your body away from the intake and airflow.

Step 1: Disable demand control ventilation, if applicable.

Step 2: Verify unit is not in economizer mode. Disable the air economizer, if applicable.

For systems with an air economizer, disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than supply airflow variations. Disabling the economizer is necessary only if the system is in cooling mode and outdoor air temperature is below the economizer high-limit set point. The economizer can be disabled in several ways, depending on the control strategy used to modulate the outdoor air dampers:

- Use the high-limit switch by reducing the set point (return air value or outdoor air value if a comparative or changeover strategy, respectively, is used) below the current OSA dry-bulb or enthalpy measurement.
- Disable the economizer damper control loop through software if it is a DDC system.

Step 3: Modify VAV boxes to achieve full design airflow.

The intent is to measure outdoor air flow when the system is operating at or near the design airflow condition, or maximum airflow at full cooling. This point is provided along with the minimum operating point to test the minimum OSA control at either end of the control range. There are a number of ways to achieve design airflow including:

- Override all space temperature cooling set points to a low temperature (for example, 60°F cooling) that will force the VAV boxes into full cooling (may be accomplished by a global command or it may have to be done per box).
- Command all VAV boxes to design flow position (may be accomplished by a global command or it may have to be done per box).
- Set the VAV box minimum flow set point to be the same as maximum flow set point (may be accomplished by a global command or it may have to be done per box).

Verify and Document:

- Document the supply airflow at full cooling on the acceptance document.
- Document VFD speed; VFDs should be at or near 60Hz.
- Document the measured outdoor air reading. Document the required outdoor airflow as found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow rate.
- Outdoor air flow can be measured directly, or indirectly, in a variety of ways. Acceptable methods for measuring outdoor air flow include, but are not limited to the following techniques:
    - Read the outdoor air flow value measured by an air flow monitoring station, if one is installed.
    - Traverse across the outdoor air duct to measure duct velocity, measure duct size, and calculate flow.
    - Measure face velocity at various points across outdoor air intake, measure intake damper size, and calculate flow.
    - Traverse across the supply and return ducts to calculate flow (outdoor airflow can be estimated as the difference between the supply and return airflow rates).
- Document time for OSA damper to stabilize after the VAV boxes open on the acceptance document. Confirm that dampers stabilize within 5 minutes. The intent is to ensure the proportional-integral-derivitative (PID)[1] control loops are tuned properly.

[1] A proportional-integral-derivative controller (PID controller) is a control mechanism commonly used in industrial control systems. A PID controller continuously calculates the difference between a measured process variable and a desired setpoint. In this case, the variable and setpoint are in relation to the VAV damper stability control.

Step 4: Drive all VAV boxes to either the minimum airflow, full heating airflow, or 30 percent of total design airflow.

The intent is to measure outdoor air flow when the system is operating at or near a minimum flow condition (for example, full heating). This point is provided along with the design point to test the minimum OSA control at either end of the control range. If the system has an airflow monitoring station (AFMS), it will test the accuracy of that AFMS at the lowest velocity, namely the least accurate point.

There are several ways to force the VAV boxes to a minimum position depending on the building automation system capabilities and control strategies used, for example:

- Override all space temperature set points to a wide range (e.g. 60°F heating and 90°F cooling) that will force the VAV boxes into the dead band (may be accomplished by a global command or it may have to be done per box).
- Command all VAV boxes to minimum flow position (may be accomplished by a global command or it may have to be done per box).
- Set maximum flow set point to be the same as minimum flow set point (may be accomplished by a global command or it may have to be done per box).

An alternative method is to manually adjust the VFD until the system airflow is at the desired condition. If the VAV boxes are in control they will open up as you are doing this, so you need to provide some time (about 5 minutes) to allow the system to settle. Although this is acceptable for testing OSA, this would not meet the requirements of NA7.5.6 Supply Fan Variable Flow Controls for testing the stability of the pressure control loop. These two tests should be done concurrently to minimize cost.

Verify and Document:

- Document the supply airflow on the acceptance document.
- Document VFD speed.
- Document the measured outdoor air reading. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow rate found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. The methods provided earlier for conducting field airflow measurements also apply here.
- Document time for OSA damper to stabilize after the VAV boxes open on the acceptance document. Confirm that dampers stabilize within 5 minutes. The intent is to ensure the PID control loops are tuned properly.

Step 5: Return system back to normal operating condition.

Ensure all schedules, set points, operating conditions, and control parameters are placed back at the initial conditions. Release any overrides on the economizer or demand ventilation controls.

13.5 NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance

At-A-Glance

NA7.5.1.2 Constant Volume Systems Outdoor Air Acceptance

Use Document NRCA-MCH-02-A

Purpose of the Test

This test ensures the constant volume air handling unit provides adequate outdoor air ventilation to the spaces served under all operating conditions.

Systems requiring demand ventilation controls per §120.1(c)3 must conform to §120.1(c)4E regarding the minimum ventilation rate when the system is in occupied mode.

Related acceptance tests for these systems include the following:

- NA7.5.2 Constant-Volume, Single-Zone, Unitary Air Conditioners and Heat Pump Systems
- NA7.5.4 Air Economizer Controls (if applicable)
- NA7.5.5 Demand-Controlled Ventilation Systems Acceptance (if applicable)

Instrumentation

Performance of this test will require measuring outdoor air flow. If the system was installed with an airflow monitoring station (AFMS) on the outdoor air, then it can be used for the measurements if it has a calibration certificate or is field-calibrated. The instrumentation needed to perform the task may include, but is not limited to:

- A means to measure airflow (typically either a velocity pressure probe or hot wire anemometer).
- A watch or some equivalent instrument to measure time in minutes

Test Conditions

To perform the test, override the control system of the air handling unit. The control system of the air handling unit must be complete.

All systems must be installed and ready for system operation, including:

- Air economizer controls.
- Duct work.
- Control sensors (temperature, flow, thermostats, and so forth).
- Electrical power to air handling unit and control system components.
- Completion of air handling unit start-up procedures, per manufacturer's recommendations.
- Documentation of the initial conditions before overrides or manipulation of the set points and schedules. All systems must be returned to normal at the end of the test.

Note: Systems requiring demand ventilation controls per §120.1(c)3 must conform to §120.1(c)4E regarding the minimum ventilation rate (refer to NA7.5.5 Demand Controlled Ventilation Systems Acceptance Test).

Estimated Time to Complete
Construction inspection: 0.5 hours **Functional testing**: 1 hour (depending on difficulty in measuring outdoor air flow)
Acceptance Criteria
System demonstrates a means of maintaining the minimum outdoor air damper position. Minimum damper position is marked on the outdoor air damper Measured outdoor air flow is within 10 percent of the total value found on the Energy Standards mechanical plan check document NRCC-MCH-03-E Column M.
Potential Issues and Cautions
Do not attempt to set the minimum damper position and perform the acceptance test at the same time. The acceptance test verifies the outdoor airflow of the system after calibration and system set-up is complete. Testing costs can be reduced by conducting the acceptance test immediately after set-up is concluded.

A. Test Application

- Newly constructed and additions/alterations: Applies only to new variable air volume (VAV) systems
- Constant air volume systems outdoor air acceptance
- Newly constructed and additions/alterations: Applies only to new constant air volume (CAV) systems

B. Construction Inspection

1. Reference the supporting documentation as needed. Reference NRCC-MCH-03-E or the mechanical equipment schedules to determine the total required outdoor airflow for the system.
2. Indicate method and equipment used to measure airflow during the functional test (for example, hot-wire anemometer) on the acceptance document. Note calibration date; calibration date must be within one year.
3. Check the system type (VAV or CAV) on the acceptance document (the following instructions apply only to CAV systems).
4. Check that the system is designed to provide a fixed minimum OSA when the unit is on and has a means of maintaining a minimum outdoor air damper position. Minimum position is marked on the outdoor air damper. The intent is that if the damper position is moved for any reason, it can be returned to the proper position to maintain design minimum outdoor air flow requirements.
   - Packaged HVAC systems without an economizer will most likely have a fixed outdoor air damper that can be adjusted manually.
   - Small packaged HVAC systems (< 20 tons) with an economizer will most likely have a controller/actuator that will control the outside and return air dampers (for example, a Honeywell W7459A economizer control package). The economizer control package is responsible for maintaining a minimum ventilation damper position as necessary and will most likely receive operation signals from either a thermostat or through a connection to a central DDC system.

- Large packaged HVAC systems (≥ 20 tons) will most likely have either a stand-alone economizer controller/actuator package (for example, a Honeywell W7459A) or a control package similar to a built-up system (that is, outside and return air dampers controlled by a DDC signal). The stand-alone economizer package may receive operation signals from a thermostat, an internal DDC controller, or a central DDC system. The "built-up" style economizer will most likely be controlled by an internal DDC controller or a central DDC system. Some large package systems may also have a dedicated outdoor air damper/actuator, independent of the economizer control strategy.
- Built-up HVAC system can control the outside and return dampers through a single actuator and damper linkages or through independent actuators and control signals. The control signals will most likely come from a central DDC system. Some built-up systems may also have a dedicated outdoor air damper/actuator, independent of the economizer control strategy.

5. Indicate the method being used to deliver outside air to the unit (for example, duct, return air plenum). For systems where return air plenum is used to distribute outside air to a zonal heating or cooling unit, confirm that outside air supply is connected either:
   - Within 5 feet of the unit.
   - Within 15 feet of the unit, with the air directed substantially toward the unit, and with a discharge velocity of at least 500 feet per minute.
6. Confirm that preoccupancy purge has been programmed into the system for the 1-hour period immediately before the building is normally occupied per §120.1(c)2. Confirmation is most easily accomplished by scheduling the unit to start one hour prior to actual occupancy. The purge amount must be the lesser of the minimum outdoor air rate or three complete building air changes (ACH).

C. Functional Testing

- Follow the best practice guidelines below to increase accuracy of outdoor air flow measurements. Traverse measurements taken in supply, return, or outdoor air ducts should be located in an area of steady, laminar flow. Where possible, take measurements at least six duct diameters away from turbulence, air intakes, bends, or restrictions.
- When using face velocity measurements to calculate outdoor air flow, care should be taken to accurately measure free area dimensions of intake.
- When velocity measurements are taken at the plane of the intake between damper blades where flow is restricted (to achieve faster flows), free area should be measured as the actual open space between dampers and should not include frames or damper blades. See Figure 13-2 for illustration of free opening measurements.
- Hot wire anemometers are more appropriate than velocity pressure probes for measuring low-speed flows (that is, less than 250 feet per minute). When measuring flow with a hot wire anemometer, make sure to position the measurement device perpendicular to flow direction.
- Take multiple measurements and average results to minimize effects of fluctuations in system operation and environmental conditions (in other words, wind).

Your body can obstruct air flow and effect measurements. Position your body away from the intake and flow of air.

Step 1: Disable demand control ventilation, when applicable.

Step 2: Disable the air economizer when applicable and test at full supply airflow

When the system has an outdoor air economizer, force the economizer to the minimum position and stop outside air damper modulation.

For systems with an air economizer, disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than supply airflow variations. Disabling the economizer is necessary only if the system is in cooling mode and outdoor air temperature is below the economizer high limit setpoint. The economizer can be disabled in several ways, depending on the control strategy used to modulate the outdoor air dampers:

1. Use the high-limit switch by reducing the setpoint (return air value or outdoor air value if a comparative or changeover strategy, respectively, is used) below the current OSA dry-bulb or enthalpy measurement
2. Disable the economizer damper control loop through software if it is a DDC system.

Verify and Document

- Document the measured outdoor air reading. Document the required outdoor airflow rate found on mechanical plan check document NRCC-MCH-03-E Column M, or mechanical equipment schedules. In the “Testing Calculation and Results” section of the acceptance document, confirm that measured outdoor air flow is within 10 percent of design outdoor air flow

Outdoor air flow can be measured directly, or indirectly, in a variety of ways. Acceptable methods for measuring outdoor air flow include, but are not limited to, the following techniques:

1. Read the outdoor air flow value measured by an air flow monitoring station if one is installed.
2. Traverse across the outdoor air duct to measure duct velocity, measure duct size, and calculate flow.
3. Measure face velocity at various points across outdoor air intake, measure intake damper size, and calculate flow.
4. Traverse across the supply and return ducts to calculate flow. (Outdoor airflow can be estimated as the difference between the supply and return airflow rates.)

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at the initial conditions. Release any overrides on the economizer or demand ventilation controls.

13.6 NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance

NA7.5.2 Constant Volume, Single-Zone, Unitary Air Conditioner and Heat Pumps Systems Acceptance
Use Document NRCA-MCH-03-A
Purpose of the Test
This test verifies the components of a constant volume, single-zone, unitary air conditioner and heat pump system function correctly, including: thermostat installation and programming, supply fan, heating, cooling, and damper operation.
Testing of the economizer, outdoor air ventilation, and demand-controlled ventilation are located in the following sections of the Reference Appendices: • NA7.5.1.2 Constant Volume System Outdoor Air Acceptance • NA7.5.4 Air Economizer Controls (if applicable) • NA7.5.5 Demand Control Ventilation (DCV) Systems (if applicable)
Instrumentation
Temperature meter, amp meter
Test Conditions
Unit and thermostat installation and programming must be complete. HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the setpoints and schedules. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 1 hour (depending on familiarity with thermostat programming) **Equipment test**: 1 to 2 hours

Acceptance Criteria
The following are verified through inspection: • Thermostat is located within the space conditioning zone that is served by the respective HVAC system. • Thermostat meets the temperature adjustment and dead band requirements of §120.2(b). • Occupied, unoccupied, and holiday schedules have been programmed per the schedule of the facility. • Preoccupancy purge has been programmed to meet the requirements of §120.1(c)2. The following modes of operation function correctly: • **Occupied heating mode operation**: The supply fan operates continuously, all heating stages operate, cooling is not enabled, and the outdoor air damper is at minimum position. • **Occupied operation with no heating or cooling load**: The supply fan operates continuously, heating or cooling is not enabled, and the outdoor air damper is at minimum position. • **Occupied cooling mode operation**: The supply fan operates continuously, all cooling stages operate, heating is not enabled, and outside damper is at minimum position. • **Unoccupied operation with no heating or cooling load**: The supply fan shuts off, heating or cooling is not enabled, and the outdoor air damper is closed. • **Unoccupied operation with heating load**: The supply cycles ON, heating is enabled, cooling is not enabled, and the outdoor air damper is either closed or at minimum position. • **Unoccupied cooling mode operation**: The supply cycles ON, cooling is enabled, heating is not enabled, and the outdoor air damper is at minimum position. • **Manual override mode**: System reverts to occupied mode, the supply fan turns ON for duration of override, heating or cooling is enabled as necessary, and the outdoor air damper opens to minimum position.

Potential Issues and Cautions
Ensure that the supply fan runs continuously in occupied mode and cycles appropriately in unoccupied mode. Cycling refers to the supply fan running only when heating or cooling is enabled. When testing the manual override, adjust the length of the override period to minimize test time. Be sure to reset the override period back to the correct length of time. Tip: Overall test time may be reduced (especially for rooftop HVAC units controlled by thermostats) if two people perform the test − one to manipulate the thermostat while someone else verifies operation at the packaged unit. The Energy Standards do not mandate the actual differential between occupied and unoccupied setpoints, only that the system must be adjustable down to 55°F for heating and up to 85°F for cooling and that the thermostat can be set for a 5°F dead band. Setback control is only required for climates where the winter median of extremes is less than or equal to 32°F. Setup control is only required for climates where the 0.5 percent summer design dry-bulb temperature is greater than or equal to 100°F.

A. Test Application

Newly Constructed and Additions/Alterations: Applies only to new constant-volume, single-zone, unitary units with direct expansion (DX) cooling. These units may be cooling only or heating and cooling.

The following acceptance test procedures are applicable to systems controlled by thermostats, internal DDC, or central DDC systems. Most of the tests can be performed through simple manipulation of the thermostat or the DDC system controlling each packaged HVAC unit. Specific details and examples of how to perform each test are provided below.

B. Construction Inspection

Prior to functional testing, verify and document the following:

1. Thermostat, or temperature sensor, is within the zone that the respective HVAC system serves.
2. Thermostat is wired to the HVAC unit correctly. This can be inferred from the acceptance tests.
3. In particular, ensure that multiple stage terminals (that is, first and second stage wires) on the thermostat, both cooling and heating stages, are wired to the corresponding circuits at the HVAC unit.
4. Verify that no factory-installed or field-installed jumpers exist across the first and second stage cooling terminals at the unit. (This will ensure that only the economizer can be enabled as the first stage of cooling.)
5. For heat pumps only, verify the “O” terminal on the thermostat is wired to the reversing valve at the unit.
6. For heat pumps only, verify thermostat dip switch or programmable software is set to heat pump.

7. Thermostat meets the temperature adjustment and dead band requirements of §120.2(b): The thermostat shall allow a heating setpoint of 55°F or lower and a cooling setpoint of 85°F or higher. The dead band shall be at least 5°F, where heating and cooling is shut off. On the acceptance document MECH-04A, note the minimum heating setpoint, maximum cooling setpoint, and dead band.
8. Occupied, unoccupied, and holiday schedules have been programmed per the schedule of the facility.

Preoccupancy purge has been programmed to meet the requirements of §120.1(c)2. This is typically accomplished by scheduling the unit to start one hour prior to actual occupancy. Check the method used to determine preoccupancy purge:

- The lesser of 15 cfm per person, or the conditioned floor area times the ventilation rate from the Energy Standards Table 120.1-A,

OR

- Three complete building air changes (ACH).

C. Functional Testing

The following procedures are applicable to systems controlled by a programmable thermostat, internal DDC (packaged systems only), or central DDC system.

As you complete each step, check the appropriate operating mode boxes on the acceptance document.

Step 1: Disable economizer control and demand-controlled ventilation systems (if applicable) to prevent unexpected interactions.

The economizer can be disabled by temporarily adjusting the high-limit setpoint. The demand-controlled ventilation system can be disabled by setting the CO_2 setpoint well below current zone CO_2 concentration.

Step 2: Simulate a heating demand during occupied condition.

- Either set the “occupied” time schedule to include actual time or adjust the time to be within the “occupied” time schedule.
- Set heating setpoint above actual space temperature.

Verify and Document

- Supply fan operates continually during occupied condition.
- Ensure all available heating stages operate; the heater stages on. This may require raising the heating setpoint even further so that multiple heating stages can become enabled. For example, many programmable thermostats and DDC control algorithms use time delays and deviations from setpoint to enable multiple heating stages. Setting the heating setpoint very high should prevent the first stage of heat from meeting setpoint and allow the system adequate time to enable the second or third stages.
- No cooling is provided by the unit.
- Outdoor air damper is open to minimum ventilation position (Note: Outdoor ventilation air requirements will be tested under section NA7.5.1.2 Constant Volume System Outdoor Air Acceptance).

Step 3: Simulate operation in the dead band (no-load condition) during occupied condition.

- Set "occupied" time schedule to include actual time or adjust time to be within the "occupied" time schedule (whichever is easier).
- Adjust heating and cooling setpoints so that actual space temperature is between the two values.

Verify and Document

- Supply fan operates continually during occupied condition.
- Confirm heating and cooling is not provided by the unit.
- Outdoor air damper is open to minimum ventilation position.

Step 4: Simulate a cooling demand during occupied condition.

- Set "occupied" time schedule to include actual time or adjust time to be within the "occupied" time schedule (whichever is easier).
- Set cooling setpoint below actual space temperature.

Verify and Document

- Supply fan operates continually during occupied condition.
- Ensure all available cooling stages operate; the compressor stages on. This may require lowering the cooling setpoint even further so that multiple cooling stages can become enabled. For example, many programmable thermostats and DDC control algorithms use time delays and deviation from setpoint to enable multiple cooling stages. Setting the cooling setpoint very low should prevent the first stage of cooling from meeting set point and allow the system adequate time to enable the second stage.
- No heating is provided by the unit.
- Outdoor air damper is open to minimum ventilation position.

Step 5: Simulate operation in the dead band (no-load condition) during unoccupied condition.

- Set "unoccupied" time schedule to include actual time or adjust time to be within the "unoccupied" time schedule (whichever is easier).
- Ensure actual space temperature is in between unoccupied heating and cooling setpoints. Adjust each setpoint as necessary to achieve desired control.

Verify and Document

- Supply fan shuts off during unoccupied condition.
- Unit does not provide heating or cooling.
- Outdoor air damper is fully closed.

Step 6: Simulate heating demand during unoccupied condition.

- Set "unoccupied" time schedule to include actual time or adjust time to be within the "unoccupied" time schedule (whichever is easier).

- Set heating setpoint above actual space temperature.

Verify and Document

- Supply fan cycles on with call for heating.
- Heating is provided by the unit; heater stages on.
- No cooling is provided by the unit.
- Outdoor air damper is either fully closed or at minimum position

Step 7: Simulate cooling demand during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).
- Set cooling setpoint above actual space temperature.

Verify and Document

- Supply fan cycles on with call for cooling.
- No heating is provided by the unit.
- Cooling is provided by the unit.
- Outdoor air damper is either fully closed or at minimum position.

Step 8: Simulate manual override during unoccupied condition.

- Set “unoccupied” time schedule to include actual time or adjust time to be within the “unoccupied” time schedule (whichever is easier).
- Engage the manual override, which may entail pushing an override button, triggering an occupant sensor, or enabling some other form of override control.

Verify and Document

- System reverts back to an “occupied” condition. For a DDC control system, verify the “active” heating and cooling setpoints correspond to those programmed for the occupied condition. For a programmable thermostat, the thermostat may display that it is in the “occupied” mode.
- System reverts back to an “unoccupied” condition when manual override period expires. It may be necessary to adjust the length of the override period to minimize test time.
- Check that the supply fan operates continually during occupied condition.
- Check that outside air damper is open to minimum ventilation position.

Step 9: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, overrides, and control parameters are placed back at the initial conditions. Confirm testing results on the certificate of acceptance document NRCA-MCH-03-A.

13.7 NA7.5.3 Air Distribution Systems Acceptance

At-A-Glance

NA7.5.3 Air Distribution Systems Acceptance
Use Document NRCA-MCH-04-A
Purpose of the Test
This test verifies all duct work associated with all nonexempt constant volume, single-zone, HVAC units (in other words, air conditioners, heat pumps, and furnaces) meet the material, installation, and insulation R-values per §120.4(a) and leakage requirements outlined either in §140.4(l) for new duct systems or §141.0(b)2D for existing duct systems. As detailed in the Energy Standards, this test is required only for single-zone units serving less than 5,000 ft² of floor area where 25 percent or more of the duct surface area is in one of the following spaces: • Outdoors. • In a space directly under a roof where the U-factor of the roof is greater than the U-factor of the ceiling. • In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces. • In an unconditioned crawlspace. • In other unconditioned spaces. Within these criteria, this test applies to both new duct systems and existing duct systems that are either being extended per §141.0(b)2D or the space conditioning system is altered by the installation or replacement of space conditioning equipment per §141.0(b)2E, including replacement of the air handler, outdoor condensing unit of a split-system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger. Existing duct systems do not have to be tested if they are insulated or sealed with asbestos.
Instrumentation
Performance of this test will require measuring duct leakage. Equipment used: Fan flowmeter (a fan with a calibrated orifice used to pressurize the ducts) accuracy within 3 percent of measured flow. To view a list of the current certified equipment go to: http://www.energy.ca.gov/title24/equipment_cert/ama_fas/index.html Digital manometer (pressure meter) accuracy within 0.2 pascals. Duct leakage tests must be verified by a third-party HERS Rater who has been certified by a HERS Provider that has been approved by the California Energy Commission.

Test Conditions
For newly constructed buildings, all ductwork must be accessible for visual inspection before ceiling installation. All ductwork and grilles should be in place before performing the fan flow test to ensure the system depicts normal operating configuration. Hence, testing must occur after visual inspection and installation of the diffusers. HVAC system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours, depending on duct access for visual inspections and availability of construction material documentation (that is, cut sheets and so forth) **Equipment Test**: 3 to 6 hours, depending on how long it takes to seal all supply diffusers and return grills.
Acceptance Criteria
Flexible ducts are not compressed or constricted in any way. Duct connections meet the requirements of §120.4 (new ducts only). Joints and seams are properly sealed according to requirements of §120.4 (new ducts only). Duct R-values meet the minimum requirements of §120.4(a) (new ducts only). Insulation is protected from damage and suitable for outdoor usage per §120.4(f) (new ducts only). The leakage fraction for new HVAC ducts does not exceed 6 percent per §140.4(l), where the leakage fraction is calculated by dividing total measured leakage flow rate by the total fan system flow rate. The leakage fraction for existing HVAC ducts does not exceed either 15 percent or overall system leakage is reduced by a 60 percent per §141.0(b)2D. The leakage fraction is calculated by either dividing total measured leakage flow rate by the total fan system flow rate *or* by comparing "pre-modification" and "post-modification" measured system leakage values. Obtain HERS Rater field verification as described in Reference Nonresidential Appendix NA1.
Potential Issues and Cautions
If this test is to be applied to existing duct systems that are having alterations made to the ducts or the HVAC equipment attached to the ducts, test the system leakage before making the alterations. Ensure all the supply and return diffusers/grills are sealed tightly, all access panels are in place, and duct ends are sealed tightly before leakage testing. After the test, remember to remove all blockages from the supply and return ducts (that is, where the supply and return ducts at the HVAC unit were blanked off).Seal any holes drilled in the supply and return ducts for the static pressure probes. Since a certified California HERS Rater must also verify duct leakage performance, it may be prudent to coordinate this test with the HERS Rater so that the HERS Rater can witness/verify the test simultaneously.

A. Test Application

This test applies to both new duct systems and to existing duct systems, which are either being extended per §141.0(b)2D, or the space conditioning system is altered by the installation or replacement of space conditioning equipment per §141.0(b)2E, including replacement of the air handler; outdoor condensing unit of a split-system air conditioner or heat pump, cooling or heating coil, or the furnace heat exchanger. Existing duct systems do not have to be tested if they are insulated or sealed with asbestos.

The duct work of these small single-zone systems with ducts in unconditioned spaces must meet the duct leakage requirements of §140.4(l) for new ducts or §141.0(b)2D for existing ducts. New duct systems or the extension of existing ducts must meet the requirements of §120.4, including construction materials, installation, and insulation R-values. Existing ducts are not required to be brought up to current standards in terms of insulation or requirements for joint seams and fasteners.

B. Construction Inspection

1. Review the drawings and construction to verify that the following items are specified in the construction set and installed in the field. (A comprehensive review of each duct is not required.)
   - Drawbands are either stainless steel worm-drive hose clamps or UV-resistant nylon duct ties. Verify compliance by reviewing material cut sheets and visual inspection.
   - Flexible ducts are not constricted in any way. For example, ensure the flex duct is not compressed against immovable objects, squeezed through openings, or contorted into extreme configurations (such as 180° angles). Do not bend flexible ducts so that the bend radius at the centerline is less than one duct diameter. A constricted flex duct can increase system static pressure as well as compromise insulation values. Verify compliance through visual inspection.
   - Joints and seams are not sealed with a cloth-backed rubber adhesive tape unless used in combination with mastic and drawbands. Verify compliance through visual inspection.
   - Duct insulation R-value shall comply with §120.4(a), §120.4(c), and §120.4(d) and can be verified by reviewing material cut sheets and through visual inspection.
   - Insulation is protected from damage or is suitable for outdoor usage, per §120.4(f). Verify compliance by reviewing material cut sheets and through visual inspection.

Duct inspection and leakage tests shall be performed before access to ductwork and associated connections are blocked by permanently installed construction material. The intent is to ensure construction modifications can be made, if necessary, before access to the ductwork is restricted.

C. Functional Testing

Refer to the *Scope of the Requirements* section above to determine when this test is required. When required, the test will often be conducted by the installer and verified by a HERS Rater using the procedures outlined in Reference Nonresidential Appendix NA2 and documented on compliance document, NRCA-MCH-04-A.

As described in Reference Nonresidential Appendix NA2.1.4.1, total fan flow, also known as *nominal air handler airflow*, shall be 400 cfm/ton for cooling or heating/cooling equipment where a ton of cooling capacity is equal to 12 kBtu/h of cooling capacity. For heating-only equipment, total fan flow is 21.7 CFM per kBtuh rated output capacity. The cooling and heating capacity of equipment can be found on the product nameplate.

For new duct systems, the installer blocks all of the supply and return registers or diffusers. Then, the installer pressurizes the ducts with a fan flowmeter to a positive 25 Pa (0.1 inches of water) and record the leakage airflow measured by the fan flowmeter. This measured leakage is divided by the total fan flow to generate the leakage percentage value. When this leakage percentage is less than or equal to 6 percent, the system passes. Otherwise, the installer should locate and seal any leaks until the system conforms to the maximum 6 percent leakage requirement. Leaks are more detectable while positive pressure is in the ducts.

For existing duct systems needing additional ducts added, undergoing major repairs, or having equipment replaced that connects to the ducts, the leakage rate of the existing duct system shall be tested first before proceeding with any alterations. This leakage amount is the **pretest** leakage value. Next, proceed with the test method described above for new duct systems to measure the **final test** leakage rate, with the only exception that the maximum leakage allowed is increased to 15 percent.

If, after all accessible leaks are sealed, the leakage percentage is still above 15 percent, the installer has two options:

- If the final test leakage is 60 percent lower than the pretest leakage rate and a visual inspection finds no accessible leaks, crushed ducts, animal infestation, rusted ducts, and so forth, this will be sufficient to pass this requirement.
- If the system meets neither the 15 percent leakage percentage nor was it possible to reduce the pretested leakage value by 60 percent, then the system must pass a visual inspection by a HERS Rater. Unlike the other methods of compliance, this method cannot be sampled – every system must be inspected by the HERS Rater.

After completing the air distribution system acceptance test, the installer shall affix a sticker to the air handler access door describing whether the system met the prescriptive leakage requirements (6 percent leakage for new systems and 15 percent for existing systems) or if the system failed to meet this standard but all accessible leaks were sealed. The installer is responsible for supplying the stickers that may have their company logo on them. However, the preceding information must be on the sticker in 14 point font or larger.

D. Document Management

After conducting the air distribution system acceptance test, the installer or the permit applicant must arrange to have a HERS Rater perform the required third-party verification. Copies of the *Construction Inspection* and the *Air Distribution System Leakage Diagnostic* sections of the NRCA-MCH-04-A should be sent to the HERS Provider, HERS Rater; the builder (general contractor or construction manager), and the building owner at occupancy. A copy must also be posted at the construction site and made available for all applicable inspections by the enforcement agency.

The HERS Rater must perform field verification and diagnostic testing, document the results on a certificate of field verification and diagnostic testing, and send copies of the certificate of field verification and diagnostic testing to the builder (general contractor or construction manager) and the building owner at occupancy. A copy must also be posted at the construction site and made available for all applicable inspections by the enforcement agency. If the test complies by virtue of the tested leakage (6 percent for new ducts and 15 percent for existing duct) or by virtue of a 60 percent leakage reduction after the system was repaired or altered, the building permit applicant may choose for the HERS field verification to be completed for the permitted space conditioning unit alone or as part of a designated sample group of up to seven space conditioning units for which the same installing company has completed work that requires field verification and diagnostic testing for compliance. If the sampling method is chosen, the HERS Rater must randomly select one system from the group for verification. For existing duct systems that fail both the 15 percent leakage rate and the 60 percent reduction in leakage, the HERS Rater must validate all of these systems (100 percent sampling) by visual inspection. Refer to Nonresidential Appendix NA1.5 for additional information about sampling.

E. Reference Material From Reference Nonresidential Appendix NA2

Below are excerpts of air distribution system acceptance testing requirements from Reference Nonresidential Appendix NA2.1 − Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems.

NA2.1.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

NA2.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (that is, sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

NA2.1.2.2 Duct Leakage Measurements

Duct leakage air flows during duct leakage testing shall be measured with digital gauges that have an accuracy of ± 3 percent or better.

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified NA2. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

NA2.1.3.1 Apparatus for Duct Pressurization and Leakage Flow Measurement

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in NA2.1.2.

NA2.1.4.1 Nominal Air Handler Airflow

The nominal air handler airflow used to determine the target leakage rate for compliance for an air conditioner or heat pump shall be 400 cfm per rated ton of cooling capacity. Nominal air handler airflow for heating-only system furnaces shall be based on 21.7 cfm per kBtu/hr of rated heating output capacity.

NA2.1.4.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Table 13-5 shows the leakage criteria and test procedures that may be used to demonstrate compliance.

Table 13-5: Duct Leakage Tests

Case	User and Application	Leakage Compliance Criteria (percent of Nominal Air Handler Airflow)	Procedure(s)
Sealed and tested new duct systems	Installer Testing HERS Rater Testing	6%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15%	NA2.1.4.2.1
Sealed and tested altered existing duct systems	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100 percent Verification	NA2.1.4.2.2 NA2.1.4.2.3 NA2.1.4.2.4

NA2.1.4.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing the entire duct system to +25 Pa with respect to outside with all ceiling diffusers/grilles and HVAC equipment installed. When existing ducts are to be altered, this test shall be performed before and after duct sealing. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums, and all the connectors, transition pieces, duct boots and registers are installed. The entire system shall be included in the test.
2. For newly installed or altered ducts, verify that cloth-backed rubber adhesive duct tape has not been used.
3. Seal all the supply and return registers, except for one return register or the system fan access. Verify that all outdoor air dampers and/or economizers are sealed prior to pressurizing the system.
4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
5. Install a static pressure probe at a supply.
6. Adjust the fan flowmeter to produce a + 25 Pa (0.1 in water) pressure at the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the flow through the flowmeter ($Q_{total,25}$).This is the total duct leakage flow at 25 Pa.
8. Divide the leakage flow by the total fan flow determined by the procedure in Section NA2.1.4.1 and convert to a percentage. If the leakage flow percentage is less than the criteria from Table 13-5, the system passes.

Duct systems that have passed this total leakage test will be sampled by a HERS Rater to show compliance.

NA2.1.4.2.2 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass the leakage test NA2.1.4.2.1, this test will show if all accessible leaks are sealed. The following procedure shall be used:

1. At a minimum, complete the procedure in NA2.1.4.2.1 to measure the leakage before commencing duct sealing.
2. Seal all accessible ducts.
3. After sealing is complete, use the same procedure to measure the leakage after duct sealing.
4. Complete the smoke test[2] as specified in NA2.1.4.2.3
5. Complete the visual inspection as specified in NA2.1.4.2.4.

All duct systems that could not pass either the total leakage test or the leakage reduction test must be verified by a HERS Rater to demonstrate compliance. This is a sampling rate of 100 percent.

NA2.1.4.2.3 Smoke-Test of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the smoke test will confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 PA (0.1 inches water) relative to duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if one of the following conditions is met.
   - No visible smoke exits the accessible portions of the duct system.
   - Smoke only emanates from the furnace cabinet that is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

NA2.1.4.2.4 Visual Inspection of Accessible Duct Sealing

For altered existing duct systems that fail to be sealed to 15 percent of total fan flow, this inspection will confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Visually inspect to verify that the following locations have been sealed:
   - Connections to plenums and other connections to the forced air unit.
   - Refrigerant line and other penetrations into the forced air unit.
   - Air handler door panel (do not use permanent sealing material, metal tape is acceptable).
   - Register boots sealed to surrounding material.

[2] For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. See Nonresidential Appendices NA2.1.4.2 for duct leakage test procedures and requirements.

- Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

2. Visually inspect to verify that portions of the duct system that are excessively damaged have been replaced. Ducts that are considered to be excessively damaged are:
   - Flex ducts with the vapor barrier split or cracked with a total linear split or crack length greater than 12 inches.
   - Crushed ducts where cross-sectional area is reduced by 30 percent or more.
   - Metal ducts with rust or corrosion resulting in leaks greater than 2 inches in any dimension.
   - Ducts that have been subject to animal infestation resulting in leaks greater than 2 inches in any dimension.

13.8 NA7.5.4 Air Economizer Controls Acceptance

At-A-Glance

NA7.5.4 Air Economizer Controls Acceptance
Use Document NRCA-MCH-05-A
Purpose of the Test
Functionally Testing an air economizer cycle verifies that an HVAC system uses outdoor air to satisfy space-cooling loads. There are two types of economizer controls: stand-alone packages and DDC controls. The stand-alone packages are commonly associated with small unitary rooftop HVAC equipment. DDC controls are typically associated with built-up or large packaged air handling systems. Cooling fan systems > 54,000 Btu/hr must have an economizer. Air economizers must be able to provide 100 percent of the design supply air with outside air; water economizers must be able to provide 100 percent of the design cooling load at 50°F dry-bulb and 45°F wet-bulb. The in-field economizer functional tests do not have to be conducted for units that are factory-installed and certified operational by the manufacturer to the Energy Commission's economizer quality control requirements. A copy of the manufacturer's certificate must be attached to the NRCA-MCH-05-A. Regardless of whether the economizer is field- or factory-installed, complete the construction inspection, including the compliance with high temperature lockout temperature setpoints.
Instrumentation
Instrumentation to perform the test includes: • Hand-held temperature probe (must be calibrated within the past year). • Device capable of calculating enthalpy (must be calibrated within the past year) • 1.2 kOhm resistor (when specified by the manufacturer). • 620 Ohm resistor (when specified by the manufacturer).

Test Conditions
Equipment installation is complete (including HVAC unit, duct work, sensors, control system, thermostats). Non-DDC DX systems are required to have a two-stage thermostat. The HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. For those units having DDC controls, it may be necessary to use the building automation system (BAS) to override or temporarily modify the variable(s) to achieve the desired control. BAS programming for the economizer, cooling valve control, and related safeties must be complete. For built-up systems all interlocks and safeties must be operable − for example, freeze protection, limit switches, static pressure cut-out, and so on. Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test. Before conducting the test, demand control ventilation systems must be disabled, if applicable.
Estimated Time to Complete
Construction Inspection: 0.5 to 1 hours (depending on familiarity with the controls) **Functional Testing**: 0.5 to 2 hours (depending on familiarity with the controls and issues that arise during testing)
Acceptance Criteria
If the economizer is factory installed and certified, a valid factory certificate is required for acceptance. No additional equipment tests are necessary. Air economizer lockout setpoint complies with Energy Standards Table 140.4-B per §140.4(e)3. This table is reproduced in Table 13-6 located below. Outside sensor location accurately reads true outdoor air temperature and is not affected by exhaust air or other heat sources. All sensors are located appropriately to achieve the desired control. During economizer mode, the outdoor air damper modulates open to a maximum position, and the return air damper modulates 100 percent closed. The outdoor air damper is 100 percent open before mechanical cooling is enabled and remains at 100 percent open while mechanical cooling is enabled (economizer integration when used for compliance with §140.4(e)2B). The economizer is capable of providing partial cooling even when additional mechanical cooling is required to meet the load. For unit controls, the outdoor air damper may not begin to close until the leaving air temperature is below 45°F. When the economizer is disabled, the outdoor air damper closes to a minimum position, the return damper modulates 100 percent open, and mechanical cooling remains enabled. If the unit has heating capability, the outdoor air damper remains at minimum position when heating is enabled. When the unit is turned off or otherwise disabled, the outdoor air damper closes.

Potential Issues and Cautions
If conditions are below freezing when test is performed, coil(s) may freeze when operating at 100 percent outdoor air. Outdoor air and relief dampers should be closed when the system is in unoccupied and warm-up modes, preventing problems with unconditioned air entering the building during unoccupied hours. If the damper interlocks fail and the outdoor air damper does not open before the return damper closes, damage to the air handling unit or associated duct work may occur. Air economizers with poor mixing can have excessively stratified air streams that can cause comfort problems or freeze stat trips[3]. Mixing problems are more likely to occur as the VAV system reduces flow, leading to reduced velocities in the mixing box and through the dampers. Check for exterior doors standing open and other signs of building over pressurization when all units are on full economizer cooling (100 percent OSA).

A. Test Application

Newly Constructed and Additions/Alterations: All new equipment with air economizer controls must comply. Units with economizers that are installed at the factory and certified with the Energy Commission do not require functional testing but do require construction inspection.

There are basically two types of economizer controls:

1. Stand-alone packages (for example, Honeywell W7459A, Trane Precedent or Voyager, Carrier Durablade, which are most common). These are most commonly associated with rooftop packaged HVAC equipment.
2. DDC controls. These are typically associated with built-up or large packaged air handling systems

Test procedures for both economizer control types have been developed, and a brief description of each control strategy is provided below.

The typical economizer control will have the following components:

- A controller (stand-alone or DDC)
- An actuator that will drive both outside and return air dampers (sometimes separate actuators in built-up systems)
- An outdoor air sensor
- A return air sensor where differential high-limit controls are used
- A mixed/discharge air temperature sensor to which the economizer is controlled.

[3] A freezestat protects water coils in rooftop HVAC units from freezing. When a freezestat trips it opens the a hot water valve (either to full or partial) to remove the danger of damage from freezing water within the system. Typically freezestats must be rest by hand. Poorly functioning air economizers can cause freezestats to falsely trip or some cases may actually cause freezing conditions.

The sensor types used to measure outside and return air include dry-bulb temperature sensors, enthalpy sensors, and electronic enthalpy sensors (a combination of dry-bulb and enthalpy). §140.4(e)4E requires that outdoor air, return air, mixed air, and supply air sensors be calibrated to within specific accuracies, as follows:

- Dry-bulb and wet-bulb temperatures accurate to ±2°F over the range of 40°F to 80°F.
- Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
- Relative humidity (RH) accurate to ±5 percent over the range of 20 percent to 80 percent RH.

In general, a first-stage call for cooling from the zone thermostat will enable the economizer controller, which will either allow the outdoor air damper to open fully if outdoor air conditions are suitable or enable the compressor. When the zone thermostat calls for a second stage of cooling, the compressor is enabled to provide mechanical cooling.

The three strategies available for economizer control are:

1. Fixed dry-bulb.
2. Fixed enthalpy + fixed dry-bulb.
3. Differential dry-bulb.

The fixed dry-bulb and fixed enthalpy + fixed dry-bulb strategies both compare outdoor air conditions to a “fixed” setpoint to determine if the economizer can be enabled. On the other hand, the differential dry-bulb strategy compares outdoor air and return air conditions to enable the economizer when outdoor air conditions are more favorable.

The economizer is considered integrated if the economizer can operate simultaneously with the compressor or chilled water coil. If the controls disable the economizer when the compressor (or chilled water coil) is on, it is considered non-integrated. Where economizers are required by the Energy Standards, they must have integrated controls.

B. Construction Inspection

Air economizer high limit setpoint complies with Energy Standards Table 140.4-B (Table 13-6) per §140.4(e)3. For DDC control systems, the high limit setpoint should be a control parameter in the sequence of operations that can be verified for compliance. For stand-alone packages, the high limit setpoint is determined by settings on the controller (for example, A, B, C, D settings on the Honeywell W7459A controller or dip switches on a Trane control package). Consult with manufacturer’s literature to determine the appropriate A, B, C, D or dip switch settings.

Unit controls must have the mechanical capacity controls interlocked with the economizer controls, such that the economizer is at 100 percent open position when mechanical cooling is on and does not begin to close until the leaving air temperature is less than 45°F.

A *snap disk* is a temperature sensitive relay with a fixed temperature setpoint, and thus a type of fixed dry-bulb control. The snap disk closes the economizer circuit when the air temperature is below setpoint and opens the circuit when the air temperature exceeds setpoint. The Energy Standards specify if the high-limit control is a fixed dry-bulb, it must have an adjustable setpoint. Thus, a snap disk is not an acceptable high limit control device because it does not provide an adjustable setpoint.

1. Check that the air economizer outside (lockout) sensor location is adequate to achieve the desired control and prevent false readings. Outdoor air sensors should be located away from building exhausts and other heat sources like air-cooled condensers and cooling towers; should be open to the air but not exposed to direct sunlight (unless it is provided with a radiation shield); and could be located either directly in the air stream or remote from the unit (for example mounted on a north-facing wall).
2. Check that economizer reliability features are present per §140.4(e)4. This includes the following:
   - Verify the economizer has a 5-year warranty of the assembly.
   - Provide a product specification sheet proving economizer assembly capability of at least 60,000 actuations.
   - Provide a product specification sheet proving economizer damper sections are certified by AMCA 511 for a maximum damper leakage rate of 10 cfm/sf at 1.0 in. w.g. (Class 1A, 1, and 2 are acceptable.)
   - If the high limit setpoint is fixed dry-bulb or fixed enthalpy + fixed dry-bulb, then the control shall have an adjustable setpoint.
   - Outdoor air, return air, mixed air, and supply air sensors shall be calibrated as follows:
     - Dry-bulb and wet-bulb temperatures accurate to ±2°F over the range of 40°F to 80°F.
     - Enthalpy accurate to ±3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
     - Relative humidity (RH) accurate to ±5 percent over the range of 20 percent to 80 percent RH.
   - Check that the sensor performance curve(s) is provided by the factory with economizer instruction materials, and that sensor output values measured during sensor calibration are plotted on the performance curve(s).
   - Sensors used for high limit control shall be located to prevent false readings, including, but not limited to, being properly shielded from direct sunlight.
   - For unitary systems 65,000 Btu/hr or less, verify that a two-stage thermostat is used, and that the system is wired so that the economizer is the first stage of cooling and the compressor is the second stage.
   - Check that all systems have some method of relief to prevent over pressurization of the building when in full economizing mode (100 percent outdoor air). Most packaged HVAC units with stand-alone economizer controls will typically have barometric dampers to exhaust the return air when the return dampers are fully closed and the unit is in economizer mode. Built-up and larger packaged air handling units may control return fans, relief dampers, or dedicated relief fans to maintain building pressurization when the unit is in economizer mode.
   - For systems with DDC controls, check that lockout sensor(s) are either factory calibrated or field calibrated. For systems with non-DDC controls, check that manufacturer’s startup and testing procedures have been applied.

Table 13-6: Air Economizer High Limit Shut off Control Requirements

Device Type [a]	Climate Zones	Required High Limit (Economizer Off When): Equation [b]	Description
Fixed Dry Bulb	1, 3, 5, 11-16	$T_{OA} > 75°F$	Outdoor air temperature exceeds 75°F
	2, 4, 10	$T_{OA} > 73°F$	Outdoor air temperature exceeds 73°F
	6, 8, 9	$T_{OA} > 71°F$	Outdoor air temperature exceeds 71°F
	7	$T_{OA} > 69°F$	Outdoor air temperature exceeds 69°F
Differential Dry Bulb	1, 3, 5, 11-16	$T_{OA} > T_{RA}°F$	Outdoor air temperature exceeds return air temperature
	2, 4, 10	$T_{OA} > T_{RA}-2°F$	Outdoor air temperature exceeds return air temperature minus 2°F
	6, 8, 9	$T_{OA} > T_{RA}-4°F$	Outdoor air temperature exceeds return air temperature minus 4°F
	7	$T_{OA} > T_{RA}-6°F$	Outdoor air temperature exceeds return air temperature minus 6°F
Fixed Enthalpy[c] + Fixed Drybulb	All	$h_{OA} > 28$ Btu/lb [c] or $T_{OA} > 75°F$	Outdoor air enthalpy exceeds 28 Btu/lb of dry air [c] or Outdoor air temperature exceeds 75°F

a Only the high limit control devices listed are allowed to be used and at the setpoints listed. Others, such as dew point, fixed enthalpy, electronic enthalpy, and differential enthalpy controls, may not be used in any climate zone for compliance with §140.4(e)1 unless approval for use is provided by the Energy Commission Executive Director.

b Devices with selectable (rather than adjustable) setpoints shall be capable of being set to within 2°F and 2 Btu/lb of the setpoint listed.

c At altitudes substantially different than sea level, the fixed enthalpy limit value shall be set to the enthalpy value at 75°F and 50 percent relative humidity. As an example, at approximately 6,000 foot elevation, the fixed enthalpy limit is about 30.7 Btu/lb.

Energy Standards Table 140.4-B

C. Functional Testing

Since the test procedures vary significantly between stand-alone packages and DDC controls, the procedures for each system type are provided. In addition, there can be significant differences in test procedures among various stand-alone packages. Contact your equipment supplier to see if they have equipment and test protocols that will allow you to easily field test their economizer to NA7.5.4 Air Economizer Controls for filling out document NRCA-MCH-05-A. While it would not be feasible to cover every variation, three of the most common stand-alone packages are discussed below. The common feature of these procedures is that they all exercise the economizer function either by enabling an on-board diagnostic function or by "fooling" the control by inserting resistors that simulate mild weather conditions while the system is in cooling mode.

a. **Stand-Alone Package − Trane Voyager and Precedent Series**

Both of these control packages have internal test sequences that can be used to verify proper system operation. Each operating mode is enabled by providing a momentary (2-second) jump across the test terminals.

Step 1: Disable demand control ventilation (DCV) system modes, if applicable for the unit.

Step 2: Use internal test sequences to enable operating modes.

Refer to manufacturer's literature for detailed description of procedures, including the basic steps are outlined below:

- 1st jumper – supply fan is enabled
- 2nd jumper – economizer mode is enabled
- 3rd jumper – compressor is enabled
- 4th jumper – heating stage is enabled

Verify and Document

- Verify the outdoor air damper opens completely and the return damper closes completely during economizer mode (Step 2 on the acceptance document NRCA-MCH-05-A).
- Verify that the outside air damper remains 100 percent open while using mechanical cooling when the demand cannot be met by outside air alone and the system is still below the lockout point.
- Outdoor air damper is at minimum position when the supply fan is enabled (Step 3 on the acceptance document NCRA-MCH-05-A).
- Outdoor air damper is at minimum position when the compressor is enabled and economizing is disabled (Step 3 on the acceptance document NRCA-MCH-05-A).
- Outdoor air damper is at minimum position when heating is enabled and economizing is enabled (Step 4 on the acceptance document NRCA-MCH-05-A).
- Verify the mixed/discharge cut-out sensor wire is landed on the SA terminal on the OEM board. If the sensor wire is not landed on the SA terminal, the economizer will not operate.

Step 3: **Turn off the unit.**

- Turn the unit *off* at the disconnect. This is Step 5 on the acceptance document NRCA-MCH-05-A.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 4: Return system to normal operation.

After restoring power, the unit returns to normal operation. This is Step 6 on the acceptance document NRCA-MCH-05-A.

Verify and Document

- Final economizer changeover dip-switch settings comply with Energy Standards Table 140.4-B per §140.4(e)3.

b. **Honeywell Controllers**

There are many Honeywell controllers available. The most common controller is the W7459A series with checkout, which may be used on other models. (Always refer to manufacturer's literature for additional information.) All Honeywell controllers have a 620 Ohm resistor across the SR and + terminals on the adjustment pot with "A, B, C, D" settings. For a fixed changeover strategy, the position of the adjustment pot with respect to the A, B, C, D settings will determine the economizer lockout setpoint. For a differential changeover strategy, the controller should be on the "D" setting. The controllers typically come from the factory with the adjustment pot at the "D" setting. This setting does not mean the use of a differential control strategy. The easiest way to verify a differential changeover strategy is to look at the SR and + terminals on the controller. When standard sensor wires are connected to the terminals, the controller uses a differential control strategy. When there is a 620 Ohm resistor jumpered across these terminals, then the controller uses a fixed control strategy.

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable for the unit.

Step 2: Simulate a cooling load and enable the economizer.

The simplest way to determine if the controller is functioning is to:

- Turn the unit *off* at the disconnect.
- Install a 1.2 kOhm resistor across the S_O and + terminals on the controller. (This is the outdoor air temperature sensor.)
- Install a 620 Ohm resistor across the S_R and + terminals on the controller. (This resistor is already installed for a fixed control strategy and must be installed only if there is a return air sensor.)
- Turn the economizer setpoint adjustment pot all the way to the "A" setting.
- Install a jumper across the R and Y1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers open fully. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Return air dampers close completely. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Compressor runs when cooling load becomes too high for economizing to meet alone. The outdoor air dampers should remain 100 percent open at this point.

Step 3: Simulate a cooling load and disable the economizer.

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Turn the economizer setpoint adjustment pot all the way to the “D” setting.
- Leave jumper across the R and Y1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers close to minimum position. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Return air dampers open completely. Adjust linkages, if necessary, to ensure dampers are at the desired position.
- Compressor operates.

Step 4: If the unit is equipped with heating, simulate a heating load with the economizer enabled.

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Turn the economizer setpoint adjustment pot all the way to the “A” setting.
- Remove the jumper across the R and Y1 terminals at the unit terminal strip, and place the jumper across the R and W1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Outdoor air dampers remain at minimum position.
- Heating is enabled.
- Compressor does not operate.

Step 5: Turn off unit.

- Turn the unit *off* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 6: Return system back to normal operating condition.

- Remove all jumpers and reconnect all wires.
- Turn the unit *on* at the disconnect.

Verify and Document

- Final economizer changeover setting (A, B, C, D) complies with Energy Standards Table 140.4-B per §140.4(e)3. Consult with manufacturer's literature to determine the appropriate A, B, C, D setting for **both** fixed dry-bulb **and** enthalpy control strategies. The controller must be set on "D" for all differential control strategies.

c. **Carrier Durablade**

Most Carrier HVAC units use the "Durablade" economizer control package, which uses a single damper "blade" that slides on a worm gear across both the outside and return air streams. Blade position is determined by end switches that will cut power to the drive motor when desired damper position is reached. Typically the economizer will be controlled by either a fixed dry-bulb or fixed enthalpy control strategy. Enthalpy control typically uses a customized Honeywell controller, and the checkout procedures outlined above can be used to determine economizer functionality. The following test procedures should be followed for a fixed dry-bulb strategy.

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable to the unit.

Step 2: Simulate a cooling load and enable the economizer.

The simplest way to determine if the economizer is functioning is to:

- Turn the unit *off* at the disconnect.
- Install a jumper across the outdoor air temperature thermostat.
- Install a jumper across the R and Y1 terminals at the unit terminal strip.
- Disconnect the wire from the Y2 terminal at the unit terminal strip. (This will prevent the second stage of cooling from being enabled during the test.)
- Turn the unit back *on* at the disconnect.

Verify and Document

- Damper blade slides completely across the return air duct, and mixed air plenum is open to the outdoor air intake. Adjust end switches as necessary to achieve the desired position.
- Compressor does not run.

Step 3: Simulate a cooling load and disable the economizer.

- Turn the unit *off* at the disconnect
- Remove the jumper and disconnect the outdoor air sensor completely from the circuit
- Leave Y2 disconnected
- Turn the unit back *on* at the disconnect

Verify and Document

- Damper blade returns to minimum outdoor air position. Adjust end switches as necessary to achieve the desired position
- Compressor operates

Step 4: If the unit is equipped with heating, simulate a heating load with the economizer disabled.

Continuing from above:

- Turn the unit *off* at the disconnect.
- Leave the 1.2 kOhm resistor across the S_O and + terminals and 620 Ohm resistor across the S_R and + terminals in place.
- Leave the economizer setpoint adjustment pot at the “D” setting.
- Remove the jumper across the R and Y1 terminals at the unit terminal strip, and place the jumper across the R and W1 terminals at the unit terminal strip.
- Turn the unit back *on* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Return air damper opens.

Step 5: Turn off unit

- Turn the unit *off* at the disconnect.

Verify and Document

- Economizer dampers close completely.
- Heating and cooling do not operate.

Step 6: Return system back to normal operating condition

- Remove all jumpers and reconnect all wires
- Turn the unit back *on* at the disconnect

Verify and Document

- Final economizer changeover setting complies with Energy Standards Table 140.4-B per §140.4(e)3

d. **DDC Controls**

Step 1: Disable demand controlled ventilation (DCV) system modes, if applicable.

For DDC systems, this may include overriding the readings from the CO_2 sensor(s) or temporarily disabling the sensor(s).

Step 2: Simulate a cooling load and enable the economizer.

Simulating a cooling load and enabling the economizer can be accomplished by:

- Commanding the discharge air temperature set point to be lower than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, raising the economizer lockout set point to be above current outdoor air conditions (if this is not the case already) to enable the economizer.

- For a differential dry-bulb control strategy, raise the return air conditions to be above current outdoor air conditions (if this is not the case already) to enable the economizer.

Verify and Document

- Verify outdoor air damper modulates open to a maximum position.
- Verify return air damper modulates closed and is 100 percent closed when the outdoor air dampers are 100 percent open. Return dampers should close tight to minimize leakage.
- Verify outdoor air damper is 100 percent open before mechanical cooling is enabled, which implies that cooling coil valves in chilled water systems should not modulate or compressors in DX systems should not start until the unit is in 100 percent economizer mode. Depending on the speed of the PID loop, mechanical cooling could be commanded on before the outdoor air dampers actually stroke fully open. When this situation occurs, the system has not failed the test. One remedy is to watch the output of the PID loop and verify that the command sent to the outdoor air damper reaches 100 percent before a command is sent to the mechanical cooling devices.
- Although space pressurization requirements are not part of the current Energy Standards, most systems employ some form of control strategy to maintain space pressure during economizer mode. Control strategies can include, but are not limited to, 1) return fan speed control, 2) dedicated relief fans, or 3) relief damper controls. Observe that the space served by the air handling unit being tested does not appear to experience any pressurization problems (in other words, perimeter doors pushed open or excessive airflow between zones served by different units).

Step 3: Simulate a cooling load and disable the economizer.

- Keep the discharge air temperature setpoint lower than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, lower the economizer lockout setpoint to be below current outdoor air conditions (if this is not the case already) to disable the economizer.
- For a differential dry-bulb or enthalpy control strategy; lower the return air conditions to be below current outdoor air conditions (if this is not the case already) to disable the economizer.

Verify and Document

- Outdoor air damper closes to a minimum position.
- Return air damper opens to normal operating position when the system is not in economizer mode.
- Mechanical cooling remains enabled to satisfy discharge air temperature setpoint.

Step 4: If the system has heating, simulate a heating demand and enable the economizer.

- Command the discharge air temperature setpoint to be higher than current discharge conditions.
- For a fixed dry-bulb or enthalpy control strategy, raise the economizer lockout setpoint to be above current outdoor air conditions (if this is not the case already) to keep the economizer enabled.

- For a differential dry-bulb control strategy, raise the return air conditions to be above current outdoor air conditions (if this is not the case already) to keep the economizer enabled.

Verify and Document

- Outdoor air dampers remain at a minimum position.
- Return air dampers remain open.
- Heating is enabled to satisfy discharge air temperature setpoint.
- Mechanical cooling is disabled.

Step 5: Turn off all systems.

Switch the system into unoccupied mode.

Verify and Document

- Outdoor air dampers close completely.
- Heating and cooling do not operate.

Step 6: Return system back to normal operating condition.

- Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.9 NA7.5.5 Demand Control Ventilation (DCV) Systems Acceptance

At-A-Glance

NA7.5.5 Demand Control Ventilation (DCV) Systems Acceptance
Use Document NRCA-MCH-06-A
Purpose of the Test
The purpose of the test is to verify that systems required to employ demand controlled ventilation (refer to §120.1(c)3) can vary outside ventilation flow rates based on maintaining interior carbon dioxide (CO_2) concentration setpoints. Demand Controlled ventilation refers to an HVAC system's ability to reduce outdoor air ventilation flow below design values when the space served is at less than design occupancy.CO_2 is a good indicator of occupancy load and is the basis used for modulating ventilation flow rates.
Instrumentation
To perform the test, it may be necessary to vary and possibly measure (if calibration is necessary) ambient CO_2 levels. The instrumentation needed to perform the task may include, but is not limited to: • Hand-held reference CO_2 probe calibrated to ±10 ppm • Manufacturer's calibration kit • Calibrated CO_2/air mixtures

Test Conditions
Equipment installation is complete (including HVAC unit, duct work, sensors, and control system). HVAC system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. Building automation system (BAS) programming (if applicable) for the air handler and demand Controlled ventilation strategy must be complete. To perform the test, it may be necessary to use BAS to override or temporarily modify the CO_2 sensor reading. Air Economizer is disabled so that it will not interfere with outdoor air damper operation during test. Document the initial conditions before overrides or manipulation of the settings. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 1 hours (depending on CO_2 sensor calibration) **Functional testing**: 1 to 2 hours (depending on how ambient CO_2 concentration levels are manipulated, system response time to variations in CO_2)
Acceptance Criteria
Each CO_2 sensor is factory calibrated (with calibration certificate) or field calibrated. Each CO_2 sensor is wired correctly to the controls to ensure proper control of the outdoor air damper. Each CO_2 sensor is located correctly within the space 3 to 6 ft above the floor. Interior CO_2 concentration setpoint is ≤600 ppm plus outdoor air CO_2 value if dynamically measured or ≤1000 ppm if no OSA sensor is provided. A minimum OSA setting is provided whenever the system is in Occupied mode per §120.1(c)4E regardless of space CO_2 readings. A maximum OSA damper position for DCV control can be established per the *Exception* to §120.1(c)4C, regardless of space CO_2 readings. The outdoor air damper modulates open when the CO_2 concentration within the space exceeds setpoint, The outdoor air damper modulates closed (toward minimum position) when the CO_2 concentration within the space is below setpoint.
Potential Issues and Cautions
Lock out the economizer control during the test. Outdoor air damper may not modulate correctly if the economizer control strategy is controlling damper operation. Overall test time may be reduced (especially for rooftop HVAC units) if two people perform the test - one to vary the CO_2 concentration while someone else verifies operation of the outdoor air dampers. During the testing of the DCV controls, the outside damper will modulate open. Care should be taken to prevent freezing of coils when testing with cold temperatures outside.

A. Test Application

Newly Constructed and Additions/Alterations: All new DCV controls installed on new or existing HVAC systems must be tested.

Single-zone systems. The intent was to limit the demand Controlled ventilation requirement to systems that primarily serve spaces with variable occupancy. However, it is possible that a facility may have a majority of spaces with fixed occupancy and only a few variable occupancy zones that meet the requirement, but still must implement demand Controlled ventilation for those variable occupancy zones. Single-zone HVAC systems can include, but are not limited to: 1) constant volume packaged units with stand-alone economizer controllers (e.g., Honeywell W7340 Logic Module); or 2) constant volume systems with individual dampers/actuators and either stand-alone or centralized DDC control.

The Energy Standards require that only HVAC systems with the following characteristics must employ demand Controlled ventilation:

- The HVAC system must have an economizer. The reason for this requirement is that the system must have the ability to modulate outdoor air flow.
- Spaces served with specific use types or have the following occupancy densities, as described in the California Building Code (CBC) Chapter 10, must utilize DCV control:
  - Assembly areas, concentrated use (without fixed seating)
  - Auction rooms
  - Assembly areas, less concentrated use
  - Occupancy density of 40 ft^2 per person or less

  Occupancy density is calculated using CBC Section 1004.1.1 CBC for spaces without fixed seating and CBC Section 1004.7 for spaces with fixed seating. However, classrooms are exempt from the demand Controlled ventilation requirement.

The Energy Standards state that the system will maintain a minimum ventilation flow rate no less than the value calculated per §120.1(c)4E.

B. Construction Inspection

The CO_2 sensor is located within the control zone(s) between 3 feet and 6 feet above the floor or at the anticipated level of the occupant's heads. This is the critical range for measuring CO_2 since most occupants will be typically either sitting or standing within the space.

CO_2 sensor is either factory calibrated or field calibrated. A calibration certificate from the manufacturer will satisfy this requirement. In order to perform a field calibration check, follow the calibration procedures provided by the manufacturer. Some sensor manufacturers may require using equipment-specific calibration kits (kits may include trace gas samples and other hand-held devices) whereas others may be calibrated simply by using a pre-calibrated hand-held CO_2 measuring device and making proper adjustments through the sensor or ventilation controller.

Interior CO_2 concentration setpoint is ≤ 600 ppm plus outdoor air CO_2 value if outside concentration is measured dynamically. Otherwise, setpoint is ≤ 1000 ppm. Outdoor air CO_2 concentration can be determined by three methods:

1. Assume a value of 400 ppm without any direct measurement.
2. Measure outside concentration dynamically to continually adjust interior concentration setpoint.
3. Measure outside concentration one time during system checkout and use this value continually to determine inside concentration setpoint.

C. Functional Testing

Step 1: Disable the economizer.

Disabling the economizer will prevent the outdoor air damper from modulating during the test due to atmospheric conditions rather than CO_2 variations. The economizer can be disabled in a number of ways depending on the control strategy used to modulate the outdoor air dampers; however the simplest method would be to change the economizer changeover setpoint below current atmospheric conditions. The changeover setpoint is the value that will lock out the economizer, example control strategies include:

- Outdoor air dry-bulb temperature or enthalpy
- Comparison between outside and return air temperature or enthalpy

Step 2: Simulate a high space occupancy.

The intent of this test is to ensure the outdoor air damper modulates open when the CO_2 concentration within the space exceeds setpoint. Simulating a high space occupancy can be accomplished by, but not limited to: 1) commanding the setpoint value to be slightly below current concentration level; or 2) exposing the sensor to a known concentration of source gas (i.e. canister of CO_2 gas with a concentration greater than setpoint). In all cases you should endeavor to simulate a condition just slightly above the current CO_2 setpoint. Regardless of the method used to simulate an excessive CO2 load, ensure the condition persists long enough for the HVAC system to respond.

Verify and Document

Ensure the outdoor air damper modulates open.

If the CO_2 setpoint is lowered just below current concentration levels, the outdoor air damper will modulate open and the increased outdoor air should bring interior concentrations down to meet and maintain the new setpoint. If a known concentration of CO_2 gas was used to simulate an elevated concentration, then the outdoor air damper may modulate fully open since the “measured” concentration will not be influenced by the increase in outdoor air (Note that §121.0(c)4C states that outdoor ventilation rate is not required to exceed design minimum value calculated in §121(b)2, regardless of CO_2 concentration. Therefore, the outdoor air damper may only open to a position that provides the design minimum flow rate). If an unknown concentration was used to simulate a high load, then the outdoor air damper could modulate open and closed since the “measured” concentration may vary considerably throughout the test.

Step 3: Simulate a low occupant density.

The intent of this test is to ensure the outdoor air damper modulates towards minimum position when the CO2 concentration within the space is below setpoint. Eventually the outdoor air damper should close to a position that provides minimum ventilation flow rate per §121(c)4E, regardless of how far the measured interior concentration is below setpoint. Simulating a low occupant density can be accomplished by, but not limited to:

1. Commanding the setpoint value to be significantly higher than current concentration level;
2. Exposing the sensor to a known concentration of source gas (i.e. canister of CO2 gas with a concentration less than setpoint);
3. Open doors and windows to reduce CO2 concentration in the space. In each case you want the CO2 reading to be well below the setpoint.

Regardless of the method used to simulate a low occupant density, ensure the condition persists long enough for the HVAC system to respond.

Verify and Document

Ensure the outdoor air damper modulates towards minimum position. If setpoint is raised just above current concentration levels, the outdoor air damper will modulate closed and the reduced outdoor air should bring interior concentrations up to meet and maintain the new setpoint. If necessary, continue to adjust the setpoint upward until the outdoor air damper closes to a minimum position. If a known concentration of CO_2 gas was used to simulate a lowered concentration, then the outdoor air damper will most likely modulate to minimum position since the “measured” concentration will not be influenced by the decrease in outdoor air.

Step 4: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.10 NA7.5.6 Supply Fan Variable Flow Controls Acceptance

At-A-Glance

NA7.5.6 Supply Fan Variable Flow Controls
Use Document NRCA-MCH-07-A
Purpose of the Test
The purpose of the test is to ensure that the supply fan in a variable air volume application modulates to meet system airflow demand. In most applications, the individual variable air valve (VAV) boxes serving each space will modulate the amount of air delivered to the space based on heating and cooling requirements. As a result, the total supply airflow provided by the central air handling unit must also vary to maintain sufficient airflow through each VAV box. Airflow is typically controlled using a variable frequency drive (VFD) to modulate supply fan speed and vary system airflow. The most common strategy for controlling the VFD is to measure and maintain static pressure within the duct. Related acceptance tests for these systems include the following: • NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • Differential pressure gauge (must be calibrated within the past year) • Pitot tube • Drill

Test Conditions
If applicable, supply air temperature reset should be disabled during testing to prevent any unwanted interaction. All systems and components must be installed and ready for system operation, including: • Duct work • VAV boxes • Static pressure sensor(s) (note multiple sensors with separate control loops are often used on large systems with multiple branches) • Electrical power to air handling unit • Air handling unit start-up procedures are complete, per manufacturer's recommendations BAS programming for the operation of the air handling unit and VAV boxes must be complete, including but not limited to: • Supply fan motor control, either VFD or ECM motor control • VAV box control (including zone temperature sensors and maximum/minimum flow rates) • Before testing, ensure all schedules, setpoints, operating conditions, and control parameters are documented. All systems must be returned to normal at the end of the test. • This test can and should be performed in conjunction with NA7.5.1.1 Variable Air Volume Systems Outdoor Air Acceptance test procedures.
Estimated Time to Complete
Construction inspection: 0.5 to 1.5 hours (depending on sensor calibration and minimum VFD speed verification) **Functional testing**: 1 to 2 hours (depending on how total fan power at design airflow is determined and system control stability)
Acceptance Criteria
Static pressure sensor(s) is field calibrated to within 10 percent of reference sensor, with differential pressure gauge and pitot tube. For systems without DDC controls to the zone level the pressure sensor setpoint is less than 1/3 of the supply fan design static pressure. For systems with DDC controls with VAV boxes reporting to the central control panel, the pressure setpoint is reset by zone demand (box damper position or a trim and respond algorithm or other method that dynamically reduces duct static pressure setpoint as low as possible while maintaining adequate pressure at the VAV box zone(s) of greatest demand). At full flow: • Supply fan maintains discharge static pressure within ± 10 percent of the current operating control static pressure setpoint • Supply fan control stabilizes within 5 minute period.

At minimum flow (at least 30 percent of total design flow): • Supply fan controls modulate to decrease capacity. • Current operating setpoint has decreased (for systems with DDC to the zone level) • Supply fan maintains discharge static pressure within ± 10 percent of the current operating setpoint.
Potential Issues and Cautions
Ensure that all disabled reset sequences are enabled upon completion of this test. Coordinate test procedures with the controls contractor since they may be needed to assist with manipulation of the BAS to achieve the desired operating conditions.

A. Test Application

Newly Constructed and Additions/Alterations: All new VAV fan controls installed on new or existing systems must be tested.

B. Construction Inspection

Instrumentation used to perform the test may include a calibrated differential pressure gauge, a pitot tube, and a drill. Note the date of calibration for the differential pressure gauge on the NRCA-MCH-07-A Document; calibration must be within the past year.

1. Check that the static pressure sensor location, setpoint, and reset control meet the requirements of §140.4(c)2, as follows:
   - Location: For a multi-zone system with a static pressure sensor located downstream of major duct splits, multiple sensors must be installed in each major branch while controlling fan capacity controlled to satisfy the sensor furthest below its setpoint.
   - Setpoint: Setpoint of must be no greater than one-third of the total design fan static pressure. Note the design total static pressure and the setpoint in I.W.C. on the NRCA-MCH-07-A document.
   - Setpoint Reset Control: For systems with direct digital control of individual zone boxes reporting to the central control panel, static pressure set points shall be reset based on the zone requiring the most pressure; i.e., the set point is reset lower until one zone damper is nearly wide open.
2. Verify that the supply fan includes a means to modulate airflow such as a variable speed drive.
3. Discharge static pressure sensor(s) shall be field calibrated. Performing a field calibration check requires measuring static pressure as close to the existing sensor as possible using a calibrated hand-held measuring device and comparing the field measured value to the value measured by the BAS. When the value measured by the BAS is within 10 percent of the field-measured value, the sensor is calibrated. Attach supporting documentation to the NRCA-MCH-07-A document.

C. Functional Testing

Supply air temperature reset should be disabled during testing to prevent any unwanted interaction.

Step 1: Drive all VAV boxes to achieve full design airflow.

- The intent is to verify proper supply fan operation at or near full flow condition. This typically occurs when all of the VAV boxes are operating at maximum cooling flow rate. There are a variety of ways to force the VAV boxes to a maximum cooling position depending on the building automation system capabilities and control strategies used, for example:
- Command all VAV boxes to maximum flow position (may be accomplished by a global command or it may have to be done per individual box or zone thermostat).
- Space temperature setpoint can be lowered below current space conditions to force the VAV box into maximum cooling (may be accomplished by a global command or it may have to be done per individual box or zone thermostat).

For this test, you cannot simply adjust the fan VFD to a maximum speed since the purpose of the test is to show the stability of the pressure control loop that automatically controls the fan speed. The fan speed must be set to AUTO.

Verify and Document

- Record system full design airflow in cfm (e.g. from design documents).
- Check that supply fan speed modulates to increase capacity. For VFD, record fan motor frequency (Hz).
- For multi-zone systems, check that supply fan maintains discharge static pressure setpoint within ±10 percent of the current operating set point. Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- When tests depart from NA7.5.1 (document NRCA-MCH-02-A), check if another method was used for verifying VFD operation (besides commanding to maximum flow and cooling).
- Verify system operation and supply fan control stabilizes within 5 minutes. The intent is to ensure the PID control loops are tuned properly to prevent the system from hunting excessively.

Step 2: Drive all VAV boxes to a low airflow condition.

The intent is to verify proper supply fan operation when the system is at or near minimum flow conditions. There are a variety of ways to force the VAV boxes to a minimum position depending on the building automation system capabilities and control strategies used, for example:

- Command all VAV boxes to minimum flow position (using global command or per individual box).
- Set maximum flow setpoint to be the same as minimum flow setpoint (using a global command or per individual box).
- Space temperature setpoint can be raised above current space conditions to force the VAV box into minimum cooling or heating mode (using a global command, per individual box, or per zone thermostat).

Again, you cannot simply override the VFD as doing so negates the purpose of the test.

Verify and Document

- Supply fan speed decreases to meet flow conditions. For VFD, record fan VFD frequency (Hz).
- For systems with DDC to the zone level, check that current operating static pressure setpoint has decreased.
- For multi-zone systems, check that supply fan maintains discharge static pressure setpoint within ± 10 percent of the current operating set point. Verification can be accomplished by simply reading the value measured by calibrated pressure sensor and comparing it to setpoint.
- System operation and supply fan control stabilizes within 5 minutes. The intent is to ensure the PID control loops are tuned properly preventing the system from excessive hunting.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions.

13.11 NA7.5.7 Valve Leakage Acceptance

At-A-Glance

NA7.5.7 Valve Leakage Acceptance
Use Document NRCA-MCH-08-A
Purpose of the Test
This test ensures that control valves serving variable flow systems are designed to withstand the pump pressure over the full range of operation. Valves with insufficient actuators will lift under certain conditions causing water to leak and loss of flow control. This test applies to the variable flow systems covered by §140.4(k)1 Chilled and hot-water variable flow systems, §140.4(k)2 Chiller isolation valves, §140.4(k)3 Boiler isolation valves, and §140.4(k)5 Water-cooled air conditioner and hydronic heat pump systems. Related acceptance tests for these systems include the following: • NA7.5.9 Hydronic System Variable Flow Controls Acceptance Testing time will be greatly reduced if these acceptance tests are done simultaneously.
Instrumentation
Performance of this test will require measuring differential pressure across pumps. The instrumentation needed to perform the task may include, but is not limited to either a: • Differential pressure gauge or • Handheld hydronic manometer For accurate comparison with the pump curves, measure using the taps on the pump casing. Taps on the inlet and discharge piping to the pumps will not correlate to the pump curves.

Test Conditions
The whole hydronic system must be complete – all coils, control valves, and pumps installed; all piping is pressure tested, flushed, cleaned, filled with water; BAS controls, if applicable. All equipment start-up procedures are complete, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction inspection: 0.5 to 2 hours (depending on availability of construction documentation and complexity of the system.) **Functional testing**: 30 minutes to 3 hours (depending on the complexity of the system and the number of valves)
Acceptance Criteria
Provisions have been made for variable flow: System has no flow when all coils are closed and the pump is turned on.
Potential Issues and Cautions
The Acceptance Agent will likely need access to the EMCS during testing Running a pump in a "dead head" condition (no flow) for more than 5 minutes can damage the pump seals or motor. Care must be taken to set up the test so that the pump only needs to run for 5 minutes or less. If balance valves are used for isolation of three-way valves or pumps, their initial position must be noted prior to using them for shut off of flow so that they can be returned to their initial position at the end of the test.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to chilled and hot water systems that are designed for variable flow. It also applies to new boilers and chillers where there is more than one boiler or chiller in the plant and the primary pumps are connected to a common header.

This test is required for the variable flow systems covered by §140.4(k)1 Chilled and hot-water variable flow systems, §140.4(k)2 Chiller isolation valves, §140.4(k)3 Boiler isolation valves, and §140.4(k)5 Water-cooled air conditioner and hydronic heat pump systems.

B. Construction Inspection

- Collect the pump curve data I and note the impeller size. The curve data establishes the conditions for which the pump operates. Beware pumps may ship with a different impeller than indicated on the plate of the pump.
- Ensure installation of all valve and piping arrangements per the design drawings in order to achieve the proper control. Doing so verifies each heat exchanger or coil has its own two-way control valve and flow measuring devices, where applicable.
- Confirm measuring devices are located adequately to achieve the most accurate results measurements (i.e. sufficient straight-line piping before and after the meter).

- Confirm piping arrangements are correct (for example: three-way valves may be located at one or more of the coils to achieve required system minimum flow rates).

C. Functional Testing

Step 1: Dead head One Pump.

The intent of this test is to establish a baseline pump pressure. Close off the system using either manual isolation or balance valves at the inlet or bypass of all three way valves. When using a balance valve, mark its initial position so that it may be reset after the test.

Verify and Document

Isolate one circulation pump and ensure all chillers (or boilers) are off. Close the isolation valve at the pumps discharge. Turn the pump on for no more than 5 minutes. Measure and note the pressure across the pump at this “dead head” condition. When the system is piped primary/secondary make sure there is a secondary pump. At the end of the measurement, turn off the pump and re-open the discharge valve.

Step 2: Close control valves.

The intent of this test is to ensure that all two-way valves and actuators can modulate fully closed. With the chillers (or boilers) off, start the same pump used in Step 1 and drive all HX or coil control valves closed. There are a variety of ways to close the control valves; examples of which include: resetting control setpoints so that valves respond accordingly; commanding the valves directly using the DDC control system (i.e., building automation system); or applying a fixed amount of air pressure to an actuator or valve in the case of a pneumatic control system. Again, ensure the pump operates for no more than 5 minutes in this dead head condition.

Verify and Document

Ensure each control valve closes completely under normal operating pressure. The intent is to confirm the actuator-valve torque requirements are adequate to shut the valve under normal operating system pressure. Verify complete closure by measuring the pressure across the operating pump. If the pressure is more than 5 percent less than the previous test, then one or more valves have not fully closed. Fix any leaks and retest.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, isolation and balance valves, operating conditions, and control parameters are returned to their initial conditions.

13.12 NA7.5.8 Supply Water Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.8 Supply Water Temperature Reset Controls Acceptance
Use Document NRCA-MCH-09-A
Purpose of the Test
This test ensures that both the chilled water and hot water supply temperatures are automatically reset based on either building loads or outdoor air temperature, as indicated in the control sequences. Many HVAC systems are served by central chilled and heating hot water plants. The supply water operating temperatures must meet peak loads when the system is operating at design conditions. As the loads vary, the supply water temperatures can be adjusted to satisfy the new operating conditions. Typically the chilled water supply temperature can be raised as the cooling load decreases, and heating hot water supply temperature can be lowered as the heating load decreases. This requirement only applies to chilled and hot water systems that are not designed for variable flow and that have a design capacity greater than or equal to 500 kBtuh (thousand BTU's per hour) , according to §140.4(k)4.
Instrumentation
Performance of this test will require measuring water temperatures as well as possibly air temperatures. The instrumentation needed to perform the task may include, but is not limited to: • Hand-held temperature probes for ice water or drywell bath. Devices must be calibrated within the last year.
Test Conditions
To perform the test, use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, boilers, air handling units, and pumps must include but may not be limited to: • Supply water temperature control, • Equipment start-stop control, • Installed and calibrated control sensors, and • Tuned control loops. All systems must be installed and ready for system operation, including: • Chillers, boilers, pumps, air handling units, valves, and piping; • Control sensors (temperature, humidity, flow, pressure, etc.) Verify all piping is pressure tested, flushed, cleaned, and filled with water. Confirm electric power supply to all equipment. Verify start-up procedures for all pieces of equipment are complete, per manufacturer's recommendations Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.

Estimated Time to Complete
Construction inspection: 0.5 to 1 hours (depending on availability of construction documentation (i.e. plumbing drawings, material cut sheets, specifications, etc.) as well as sensor calibration.) **Functional testing**: 1 to 2 hours (depending on familiarity with BAS, method employed to vary operating parameters, and time interval between control command and system response)
Acceptance Criteria
Supply water temperature sensors are field calibrated, to within one percent of calibrated reference sensor, with supporting documentation attached to MECH-09A document. Sensor performance complies with specifications. Supply water reset works according to control schedule, and actual water temperature is within 2 percent of control setpoint.
Potential Problems and Cautions
If the hot water temperature reset tests when there is minimal heating load, make sure to test the low end of the reset first (coldest hot water supply temperature).If the hottest supply water temperature is tested first, it may be difficult to dissipate the heat in the hot water loop without artificially creating a heating load. Waiting for a small heating load to dissipate the heat in the loop could add significant time to the test procedure. Where humidity control is required, chilled water supply water reset is not recommended.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to chilled or hot water systems that have a supply temperature reset control strategy programmed into the building automation system.

The most common control variables used to reset supply water temperature setpoint include are provided below:

- **Coil valve position.** A central energy management system is used to monitor cooling coil and/or heating coil valve positions to determine when the supply water temperature can be reset. The following example highlights a common heating hot water control strategy, in which all heating coil valve positions (central heating and re-heat coils) are monitored to determine current valve position. When all heating valves are less than 94 percent open, the hot water supply temperature lowers incrementally until one valve opens to 94 percent and maintains the setpoint. When any valve opens more than 98 percent, the hot water supply temperature incrementally raises and maintains until one valve drops back down to 94 percent open. A similar control strategy can be used to reset the chilled water supply temperature. The designer determines the chilled and hot water temperature setpoint values, which should be provided in the design narrative, specifications, or control drawings.
- **Outdoor air temperature.** Another very common control strategy is to reset supply water temperature based on outdoor air temperature. Depending on the building type, internal loads and design conditions, the designer may develop a relationship between the chilled and hot water supply temperatures necessary to satisfy building loads at various outdoor air temperatures. For example, hot water temperature may be reset linearly between 90°F and 140°F when the outdoor air temperature is below

35°F and above 50°F, respectively. The design values should be available from, the design narrative, specifications or control drawings.

- **Humidity control.** For special applications like hospitals, museums, semiconductor fabrication and laboratories, the cooling coil control may be based on maintaining a constant relative humidity within the space for not only comfort but also indoor air quality and moisture control (i.e. mold issues). Therefore, the temperature of the chilled water delivered to the coil should be sufficient to remove moisture from the supply air stream and the chilled water temperature can be reset upwards as the latent load decreases. The designer determines actual chilled water temperature setpoint reset schedules and provides them within the design narrative, specifications or control drawings.

B. Construction Inspection

Temperature sensors must be either factory calibrated or field calibrated by a Controls contractor, or other appropriate person. Depending on the control strategy used to reset supply water temperature, sensors can include, but are not limited to: supply water temperature sensors and outdoor air temperature sensors (when used for reset).

Field calibration requires using either a secondary temperature reference or placing the sensor in a known temperature environment (typically either an ice water or a calibrated dry-well bath). When field calibrating temperature sensors, perform a “through system” calibration, which compares the reference reading to the reading at either the EMCS front end or inside the controller (e.g. it includes any signal degradation due to wiring and transducer error). Hydronic system temperature sensors must calibrate to within one percent of the calibrated reference sensor, ice water or drywell bath.

Provide supporting calibration documentation and attach to the MECH-09A document.

C. Functional Testing

Step 1: Change reset control variable to its maximum value.

Manually change the control variable in order to reset supply water temperature. Check the method used to override the control variable on the NRCA-MCH-09-A document. These overrides include:

- For a valve position control strategy, command at least one coil valve to 100 percent open.
- Adjust discharge air temperature or zone temperature setpoints to drive a valve into a 100 percent open condition. For an outdoor air temperature control strategy, override actual outdoor air sensor to exceed maximum water temperature boundary value. For example, if the control strategy calls for 42°F chilled water when outdoor air temperature is above 70°F, command the sensor to read 72°F. For a humidity control sequence, command the humidity setpoint to be 5 percent below actual humidity conditions.

Verify and Document

- Chilled and/or heating hot water supply temperature setpoint is reset to the appropriate value determined by the designer per the control strategy.
- Actual supply water temperature changes to within 2 percent of the control setpoint.

Step 2: Change reset variable to its minimum value.

Manually change the control variable in order to reset supply water temperature. For a valve position control strategy, command all coil valves to only be partially open. Continuing with one of the examples above, if supply water temperature is reset when a valve is less than 94 percent open, command all valves to be 90 percent open. An alternate method would be to adjust discharge air temperature or zone temperature setpoints to drive a valve into a partially open condition. For an outdoor air temperature control strategy, override actual outdoor air sensor to exceed minimum water temperature boundary value. For example, if the control strategy calls for 90°F heating water when outdoor air temperature is above 50°F, command the sensor to read 52°F.

Verify and Document

- Verify chilled and/or heating hot water supply temperature setpoint is reset to the appropriate value determined by the designer per the control strategy.
- Verify actual supply water temperature changes to within 2 percent of the control setpoint.

Step 3: Test automatic control of reset control variable to automatic control.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back to automatic control.

Verify and Document

- Verify chilled and/or heating hot water supply set-point is reset to the appropriate value.
- Verify actual supply temperature changes to meet the setpoint. This process may take a few minutes for the water temperature to change depending on system conditions and equipment operation.
- Verify that the supply temperature is within 2 percent of the control setpoint.

13.13 NA7.5.9 Hydronic System Variable Flow Control Acceptance

At-A-Glance

NA7.5.9 Hydronic System Variable Flow Control Acceptance
Use Document NRCA-MCH-10-A
Purpose of the Test
All hydronic variable flow chilled water and water-loop heat pump systems with total circulating pump power larger than 5 hp shall vary system flow rate by modulating pump speed using either a variable frequency drive (VFD) or equivalent according to §140.4(k)6. Pump speed and flow must be controlled as a function of differential pressure, and pump motor demand must be no more than 30 percent design wattage at 50 percent design flow. As the loads within the building fluctuate, control valves should modulate the amount of water passing through each coil and add or remove the desired amount of energy from the air stream to satisfy the load. In the case of water-loop heat pumps, each two-way control valve associated with a heat pump closes when not operating The purpose of the test is to ensure that, as each control valve modulates, the pump variable frequency drive (VFD) responds accordingly to meet system water flow requirements. Note that this is not required on heating hot water systems with variable flow designs or for condensing water serving only water cooled chillers. The related acceptance tests for this systems is: • NA7.5.7 Valve Leakage Test (if applicable)
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • Differential pressure gauge (hydronic manometer)
Test Conditions
To perform the test, use the control system to manipulate system operation to achieve the desired control. At a minimum, control system programming for the operation of the central equipment, control valves, and pumps must include, but not be limited to: • Equipment start-stop control, • Installed and calibrated control sensors, and • Tuned control loops. All systems must be installed and ready for system operation, including: • Heat pumps, cooling towers, boilers, pumps, control valves, piping, etc. • Control sensors (temperature, flow, pressure, etc.) Verify all piping is pressure tested, flushed, cleaned, and filled with water. Verify electrical power supply to all equipment. Confirm start-up procedures for all pieces of equipment are complete, per manufacturer’s recommendations. Document the initial conditions before overrides or manipulation of the BAS. Return all systems to their initial condition after test.

Estimated Time to Complete
Construction inspection: 0.5 to 1 hour (depending on availability of construction documentation – i.e. plumbing drawings, material cut sheets, specifications, etc – as well as sensor calibration) **Functional testing**: 2 to 4 hours (depending on familiarity with BAS, method employed to vary operating parameters, verification method for system flow and VFD power)
Acceptance Criteria
Differential pressure sensor(s) are field calibrated. For systems without DDC to individual coils, pressure sensor(s) are located at or near the most remote HX or control valve, or the HX requiring the greatest differential pressure. For systems with DDC to individual coils, the pressure sensor(s) has no location restriction, but are reset according to the valve requiring the greatest pressure and shall be no less than 80 percent open. System controls to the setpoint stably.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with adjusting system operation and overriding controls.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any water system that has been designed for variable flow, where the pumps are controlled by variable frequency drives (i.e. chilled and hot water systems, water-loop heat pump and air-conditioning systems).

§140.4(k)6 permits two general variable flow control strategies: (1) supply pressure reset by coil demand for systems with DDC controls to the coil level and (2) fixed pressure setpoint control.

Verify the minimum VFD speed setpoint. When the minimum speed is below 6Hz (10 percent) the pump motor may overheat. However, if the minimum speed is set too high, the system will not adjust down, preventing the full energy savings of the VFD. To achieve the highest energy savings, the minimum speed should be between 6Hz and 10Hz for variable flow systems. Note that this minimum speed may be provided either in the EMCS or at the VSD, but not both as a possible cumulative minimum is not desirable.

B. Construction Inspection

The static pressure location, setpoint, and reset control must meet the requirements of the §140.4(k)6B:

- For systems without DDC, pressure setpoint control is fixed and pressure sensor(s) are located at or near the most remote HX or control valve, or the HX requiring the greatest differential pressure.
- For systems with DDC to individual coils, the pressure sensor(s) locations are not restricted, but the sensors are reset according to the valve requiring the greatest pressure and shall be no less than 80 percent open.

- For heating hot water systems or condenser water systems, variable flow is not required, and an Acceptance Test is not required.

The differential pressure sensor (when applicable) is factory or field calibrated by a Controls contractor or other qualified person. Field calibration requires measuring system pressure (or differential pressure), as close to the existing sensor as possible using a calibrated hand-held measuring device. All pressure sensors must be within 10 percent of the calibrated reference sensor. Supporting documentation must be attached to the Acceptance Document NRCA-MCH-10-A.

C. Functional Testing

This method is acceptable to verify VFD operation even though the control does has a flow meter. If while at minimum flow, VFD speed decreases and system pressure is not greater than at full flow, the system is compliant.

Step 1: Modulate control valves to reduce water flow to 50 percent of the design flow or less, but not lower than the pump minimum flow.

Modulating control valves by simply commanding each valve to a specific position or by adjusting temperature setpoints within the existing temperature range.

Verify and Document

- Current pump operating speed decreased (for systems with DDC to the zone level).
- Current operating setpoint has not increased (for all other systems that are not DDC).
- System pressure is within 5 percent of current operating setpoint. Record the measured system pressure at the control sensor. Record the system pressure setpoint.
- System operation stabilizes within 5 minutes after test procedures are initiated.

Step 2: Open control valves to increase water flow to a minimum of 90 percent design flow.

Open control valves so that they reach between 90 - 100 percent of design flow. Opening the control valves can be achieved in a variety of ways, such as resetting control setpoints so that the valves respond accordingly, or commanding the valves directly using the DDC control system.

Verify and Document

- Verify pump speed increases to 100 percent.
- Verify system pressure increases and is within 5 percent of current operating setpoint, Record the measured system pressure at the control sensor. Record the system pressure setpoint.
- Verify system pressure setpoint is greater than the setpoint recorded in Step 1.
- Verify system operation stabilizes within 5 minutes after test starts.

Step 3: Restore system to initial operating conditions.

13.14 NA7.5.10 Automatic Demand Shed Control Acceptance

At-A-Glance

NA7.5.10 Automatic Demand Shed Control Acceptance
Use Document NRCA-MCH-11-A
Purpose of the Test
All control systems with DDC to the zone level are required to enable centralized demand shed at non-critical control zones from either a single software or hardware point in the system §120.2(h). Field studies have shown that in typical commercial buildings resetting the zone temperatures up by 2°F to 4°F during on-peak times can reduce the peak electrical cooling demand by as much as 30 percent. This test ensures the central demand shed sequences have been properly programmed into the DDC system
Instrumentation
The instrumentation needed to perform the task may include, but is not limited to: • The front end computer to the DDC system
Test Conditions
To perform the test, use the control system to manipulate system. The entire HVAC installation and control system must be completed prior.
Estimated Time to Complete
Construction inspection: 0.5 hour to review the EMCS programming **Functional testing**: 0.5 to 1 hour (depending on familiarity with BAS)
Acceptance Criteria
The control system changes the setpoints of non-critical zones on activation of a single central hardware or software point. Then the system restores the initial setpoints when the point is released.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with the testing.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to construction inspection of the EMCS interface shed controls and testing.

B. Construction Inspection

- Inspect the EMCS interface enable activation of the central demand shed controls.

C. Functional Testing

Step 1: Engage the global demand shed system.

- This step can be done by either jumping the digital contact or simply overriding its condition in the EMCS front end. Wait 5-10 minutes to let the changes take effect.

Verify and Document

- The cooling setpoints in the non-critical spaces increase by the expected amount.
- The cooling setpoints in the critical spaces do not change.

Step 2: Disengage the global demand shed system.

- This step can be done by either removing the jumper from the digital contact or simply releasing the override of the point in the EMCS front end. Wait 5-10 minutes to let the changes take effect.

Verify and Document

- The cooling setpoints in the non-critical spaces return to their original setpoint.
- The cooling setpoints in the critical spaces do not change.

13.15 NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion (DX) Units Acceptance

At-A-Glance

NA7.5.11 Fault Detection and Diagnostics (FDD) for Packaged Direct-Expansion (DX) Units Acceptance
Use Document NRCA-MCH-12-A
Purpose of the Test
The purpose of this test is to verify proper fault detection and reporting for automated fault detection and diagnostics systems for packaged DX units. Automated FDD systems ensure proper equipment operation by identifying and diagnosing common equipment problems such as temperature sensor faults, low airflow or faulty economizer operation. FDD systems help to maintain equipment efficiency closer to rated conditions over the life of the equipment.
Instrumentation
The system test for refrigerant charge requires a calibrated refrigerant gauge with an accuracy of plus or minus 3 percent.
Test Conditions
Packaged unit and thermostat installation along with programming must be complete. HVAC system must be installed and ready for operation, including completion of all start-up procedures, per manufacturer’s recommendations. Prior to FDD verification, test the system operating modes. When the system includes a field-installed air economizer, test the economizer per NRCA-MCH-02-A.

Estimated Time to Complete
Construction inspection: 0.5 hour **Functional testing**: 1 to 2 hours FDD systems have the capability to report alarms to a remote server; accessible via a Web interface. It may be helpful to have two people conducting the test – one to perform testing on the unit and a second to verify reporting of the alarm to the remote interface.
Acceptance Criteria
The FDD system is able to detect a disconnected outside air temperature sensor and report the fault. The FDD system is able to detect excess outside air and report the fault. The FDD system is able to detect a stuck outdoor air economizer damper and report the fault. The saturated discharge and saturated suction temperatures must be measured within 5°F of a calibrated refrigerant gauge.
Potential Problems and Cautions
Compared to the pressure sensors, the temperature sensors can have a longer response time to reach a steady-state condition. Therefore, the FDD algorithms may have trouble working properly during transitional states – for example, when the fan or compressor first turns on. The tester should be aware of the potential for false alarms.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any FDD system installed on a packaged direct expansion (DX) unit.

B. Construction Inspection

Prior to functional testing, verify and document the following:

- Verify that the installed FDD has been certified to the Energy Commission and is listed on the Energy Commission's website (http://www.energy.ca.gov/title24/equipment_cert/).

C. Functional Testing

For each HVAC unit to be tested do the following:

1. Test for Air Temperature Sensor Failure/Fault

Step 1: Verify the FDD system indicates normal operation.

Step 2: Disconnect outside air temperature sensor from unit controller. Verify and document the following:

- FDD system reports a fault.

Step 3: Connect outside air temperature sensor to unit controller. Verify and document the following:

- FDD system indicates normal operation.

2. Test for Excessive Outside Air

Step 1: Coordinate this test with NA7.5.1 Outdoor Air

- After passing the tests described in NA7.5.1 Outdoor Air, verify FDD system indicates normal operation.

3. Test for Economizer Operation

Step 1: Interfere with normal unit operation to generate an Air Economizer Control failure by immobilizing the outdoor air economizer damper according to manufacturer's instructions.

- After Air Economizer Controls fails, verify FDD system reports a fault.

Step 2: Successfully complete and pass tests described in NA7.5.4 Air Economizer Controls

- Verify FDD system reports normal operation.

13.16 NA7.5.12 FDD for Air Handling Units and Zone Terminal Units Acceptance

At-A-Glance

NA7.5.12 Automatic Fault Detection Diagnostics (FDD) for Air Handling Units and Zone Terminal Units Acceptance
Use Document NRCA-MCH-13-A
Purpose of the Test
Fault detection and diagnostics can also be used to detect common faults with air handling units and zone terminal units. Many FDD tools are standalone software products that process trend data offline. Maintenance problems with built-up air handlers and variable air volume boxes are often not detected by energy management systems because the required data and analytical tools are not available. Performing the FDD analysis within the distributed unit controllers is more practical because of the large volume of data. The acceptance tests are designed to verify that the system detects common faults in air handling units and terminal units. FDD systems for air handling units and zone terminal units require DDC controls to the zone level. Successful completion of this test provides a compliance credit when using the performance approach. An FDD system that does not pass this test may still be installed, but no compliance credit will be given.
Instrumentation
FDD tests for air handling units and zone terminal units require no additional instrumentation for testing, since control algorithms are embedded in unit controllers.
Test Conditions
The air handling unit should be installed and the heating, cooling and economizer modes of operation tested. To perform the test, use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, boilers, air handling units, and pumps must be complete. All equipment startup procedures must have been completed per manufacturer's instructions. All control sensors must be installed and control loops tuned. Document the initial conditions before any overrides to the building automation system.

Estimated Time to Complete
Acceptance tests will take 1-2 hours for each air handler. Time for acceptance testing for terminal units depends on the number of boxes to be tested.
Acceptance Criteria
The system is able to detect common faults with air handling units, such as sensor failures, damper failures, actuator failures, or improper operating modes. The system is able to detect and report common faults with zone terminal units, such as damper failure, actuator failure, or a control tuning issue.
Potential Problems and Cautions
Difficulties could be encountered with manipulating the control system if not familiar with the programming language. Therefore, a controls contractor should be on-site to assist with the testing.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to any FDD system installed on an air handling unit or a zone terminal unit. A minimum of 5 percent of the terminal boxes (VAV box) shall be tested.

B. Functional Testing

Testing of each Air Handling Units with FDD controls shall include the following tests:

1. **Sensor drift/failure**: The threshold for a sensor drift fault should be given in percentage of full range, or in units for each type of sensor (temperature, differential pressure / airflow rate, etc.).

   Step 1: Disconnect outside air temperature sensor from unit controller.

   Step 2: Verify the FDD system reports a fault.

   Step 3: Connect OAT sensor to the unit controller.

   Step 4: Verify that FDD indicates normal system operation.

2. **Damper/actuator fault:** This fault reports a failed actuator, or a damper stuck in an open, closed, or fixed position.

   Step 1: From the control system workstation, command the mixing box dampers to full open (100 percent outdoor air), by lowering the supply air temperature setpoint.

   Step 2: Disconnect power to the actuator and verify that a fault is reported at the control workstation.

   Step 3: Reconnect power to the actuator and command the mixing box dampers to full open by maintaining the supply air temperature setpoint.

   Step 4: Verify that the control system does not report a fault.

   Step 5: From the control system workstation, command the mixing box dampers to a minimum position (0 percent outdoor air) by raising the supply air temperature setpoint.

   Step 6: Disconnect power to the actuator and verify that a fault is reported at the control workstation.

   Step 7: Reconnect power to the actuator and command the dampers closed.

Step 8: Verify that the control system does not report a fault during normal operation.

3. **Valve/actuator fault:** This test covers faults such as an actuator failure, a valve stuck in an open or closed position, and/or valve leaks.

   Step 1: From the control system workstation, command the heating coil valve to the full open position by temporarily setting the space heating setpoint higher than the current space temperature, if the system is not in heating mode.

   Step 2: Disconnect power to the actuator and verify that a fault is reported.

   Step 3: Reconnect power to the actuator and command the heating coil valve to full open.

   Step 4: Verify that the control system does not report a fault.

   Step 5: From the control system workstation, command the cooling coil valve to the full open position by temporarily setting the space cooling setpoint lower than the current space temperature, if the system is not in cooling mode.

   Step 6: Disconnect power to the actuator and verify that a fault is reported.

   Step 7: Reconnect power to the actuator and command the cooling coil valve to full open.

   Step 8: Verify that the control system does not report a fault.

The following tests are designed to capture faults when the system is running in an improper mode of operation such as simultaneous heating, mechanical cooling, and/or economizing. (For systems with integrated economizers, economizer and cooling operation can be simultaneously enabled.)

Step 1: From the control system workstation, override the heating coil valve and verify that the control workstation reports a fault.

Step 2: From the control system workstation, override the cooling coil valve and verify that the control workstation reports a fault.

Step 3: From the control system workstation, override the mixing box dampers and verify the control workstation reports a fault.

Testing shall be performed on one of each type of terminal unit (VAV box) in the project. A minimum of 5 percent of the terminal units shall be tested.

1. **Sensor drift/failure**:

   Step 1: Disconnect the tubing to the differential pressure sensor of the VAV box.

   Step 2: Verify the control system detects and reports the fault.

   Step 3: Reconnect the sensor and verify proper sensor operation.

   Step 4: Verify that the control system does not report a fault.

2. **Damper/actuator fault – damper stuck open:**

   Step 1: Command the damper to be fully open. Override the space temperature setpoint below the current space temperature to force the system into maximum cooling. Another option is to command the VAV box to the maximum position through the control workstation.

   Step 2: Disconnect the actuator to the damper.

Step 3: Adjust the cooling setpoint such that the room temperature is below the cooling setpoint to command the damper to the minimum position. Verify that the control system reports a fault.

Step 4: Reconnect the actuator and restore to normal operation.

3. **Damper/actuator fault – damper stuck closed:**

   Step 1: Set the damper to the minimum position.

   Step 2: Disconnect the actuator to the damper.

   Step 3: Set the cooling setpoint below the room temperature to simulate a call for cooling. Verify that the control system reports a fault.

   Step 4: Reconnect the actuator and restore all setpoints to their original values to resume normal operation.

4. **Valve/actuator fault (For systems with hydronic reheat):** This fault could be caused by actuator failure or a valve stuck in an open or closed position. This test is only applicable to systems with hydronic reheat.

   Step 1: Command the reheat coil valve to (full) open by setting the heating setpoint temperature above the space temperature setpoint. Wait for the controls to respond to the command to open the reheat coil valve.

   Step 2: Disconnect power to the actuator. Set the heating setpoint temperature to be lower than the current space temperature, to command the valve closed. Verify that the fault is reported at the control workstation.

   Step 3: Reconnect the actuator and restore all setpoints to their original values to resume normal operation.

5. **Feedback loop tuning fault:** This test is designed to capture a fault that might occur from excessive hunting or sluggish control.

   Step 1: Set the integral coefficient of the box controller (reset action) used for airflow control to a value 50 times the current value. Reduce the space temperature setpoint to be 3°F below the current space temperature to simulate a call for cooling.

   Step 2: Verify the damper cycles continuously over a period of several minutes. (The cycling period time depends on the type of controller used but is typically on the order of a few minutes.) Verify that the control system detects and reports the fault.

   Step 3: Reset the integral coefficient of the controller to its original value and reset the space setpoint to its original value to restore normal operation.

6. **Disconnected inlet duct**:

   Step 1: From the control system workstation, command the damper to a minimum position (full closed) by raising the space temperature setpoint.

   Step 2: Then disconnect power to the actuator and verify that a fault is reported at the control workstation.

   Step 3: Reset the space temperature setpoint back to its original value.

7. **Discharge air temperature sensor**:

   Step 1: Adjust zone setpoints to drive the box from dead band to full heating.

   Step 2: Verify the supply air temperature resets to the maximum setpoint while the airflow maintains at the dead band flow rate.

   Step 3: Verify that the airflow rate increases to the heating maximum flow rate to meet the heating load.

13.17 NA7.5.13 Distributed Energy Storage DX AC System Acceptance

At-A-Glance

NA7.5.13 Distributed Energy Storage DX AC Acceptance
Use Document NRCA-MCH-14-A
Purpose of the Test
This test verifies proper operation of distributed energy storage DX systems. Distributed energy systems reduce peak demand by operating during off peak hours and storing cooling, usually in the form of ice. During peak cooling hours the ice is melted to avoid compressor operation.
Instrumentation
Distributed energy storage acceptance tests require no additional instrumentation for testing.
Test Conditions
The DX equipment should be installed and operational. Perform pre-startup installation procedures as specified by the manufacturer. Verify that the building cooling is controlled by a standard indoor HVAC thermostat and not by factory installed controls. Verify that ice making is not controlled by the thermostat. The water tank should be filled to the proper level as specified by the manufacturer prior to the start of the test. Verify refrigerant piping connects and the system is charged with refrigerant.
Estimated Time to Complete
Construction Inspection: 0.5 hours **Acceptance Tests**: 2 hours
Acceptance Criteria
Verify nighttime ice making operation. Verify that tank discharges during on-peak cooling periods. Verify that the compressor does not run and the tank does not discharge when there is no cooling demand during on-peak periods. Verify that the system does not operate during a morning shoulder period when there is no cooling demand. Verify that the system operates in direct mode (with compressor running) during the morning shoulder time period.
Potential Problems and Cautions
These tests only apply to systems with storage capacity less than 100 ton-hours. Systems with storage above 100 ton-hours should be modeled using the thermal energy storage compliance option. Be sure the water tank is filled to the proper level indicated by the manufacturer prior to

the start of the tests. The tests require override of the system controller programming. Be sure to record the system settings prior to the start of the testing, and restore the system settings to their original values upon completion of the tests.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to constant and variable volume, direct expansion systems with distributed energy storage (DES/DXAC). This acceptance requirement is an addition to economizer and packaged equipment acceptance.

B. Construction Inspection

The distributed energy storage system third party submittal form should be verified, which contains the following information: testing laboratory, address, phone number, contact person, date tested, tracking number, model number, and manufacturer. The following performance information should be recorded and reported on the document NRCA-MCH-14-A:

- The water tank is filled to the proper level.
- The water tank is sitting on a foundation with adequate structural strength to support the weight of the filled vessel
- The water tank is insulated and the top cover is in place.
- The DES/DXAC is installed correctly (refrigerant piping, etc.).
- The correct model number is installed and configured.

C. Functional Testing

Step 1: Simulate cooling load during daytime period.

The intent of this test is to verify that during on-peak conditions the tank will discharge and the compressor will remain off.

- Set the time clock to on-peak hours (typically between 12 noon and 6 PM), or change the on-peak start time control parameter to be earlier than the current time. Set the space cooling setpoint to be below the current space temperature**.**

Verify and document

- Supply fan operates continually.
- If the system has ice storage, verify that the DES/DXAC runs in ice melt mode and that the compressor remains off. The supply fan operates continuously to provide cooling to the space. The refrigerant pump operates to circulate refrigerant to the evaporator coil(s).
- If the DES/DXAC system has no ice and there is a call for cooling, verify that the DES/DXAC system runs in direct cooling mode, with the compressor running. Verify that cooling is provided to the space.

Step 2: Simulate no cooling load during daytime conditions.

- This is done by setting the cooling setpoint above the current space temperature, and set the system time during the daytime period.

Verify and document

- Supply fan operates as per the facility thermostat or control system.
- The DES/DXAC and the condensing unit do not run.

Step 3: Simulate no cooling load during the morning shoulder time period (before noon).

- Set the space temperature setpoint to be above the current space temperature and set the system time clock to be between the hours of 6AM and noon.

Verify and document

- The DES/DXAC system remains idle.

Step 4: Simulate a cooling load during the morning shoulder time period (between 6 am and noon).

- Set the space setpoint below the current space temperature.

Verify and document

- Verify that the DES/DXAC system runs in direct cooling mode, with the compressor running.
- Verify that the tank does not discharge during this period.

Calibrating Controls

- Set the date and time back to the current date and time after completion of the acceptance tests, following manufacturer's instructions.

13.18 NA7.5.14 Thermal Energy Storage (TES) System Acceptance

At-A-Glance

NA7.5.14 Thermal Energy Storage (TES) System Acceptance
Use Document NRCA-MCH-15-A
Purpose of the Test
This test verifies proper operation of thermal energy storage (TES) systems. TES systems reduce energy consumption during peak demand periods by shifting energy consumption to nighttime. Operation of the thermal energy storage compressor during the night produces cooling energy, which is stored in the form of cooled fluid or ice in tanks. During peak cooling hours the thermal storage is used for cooling to prevent the need for chiller operation.
Benefits of the Test
The test will ensure that the TES system is able to charge the storage tank during off-peak hours and conversely discharge the storage tank during on peak hours. Since the chiller may operate more efficiently at night when ambient temperatures are lower, the system may save cooling energy in some climate zones.
Instrumentation
TES acceptance tests require no additional instrumentation for testing.

Test Conditions

The chiller, EMS, piping, and components should be installed and operational. The thermal storage tank should be without charge, or even partially charged (not fully charged), at the start of testing. The system should be configured with an on-peak cooling period (tank discharge) and an off-peak charging period. The cooling load can be met by storage if the tank has stored energy available or by compressor cooling if there is no stored energy available.

Estimated Time to Complete

Construction Inspection: 0.5 hours

Acceptance Tests: 2 hours

Acceptance Criteria

The TES system and the chilled water plant is controlled and monitored by an EMS.

Verify:

- The TES system stores energy in storage/charge mode.
- The storage charging stops when an end of charge signal is generated.
- The TES system starts discharging with the compressor(s) in discharge mode.
- The TES does not discharge and the cooling load is met by the compressor(s) in mechanical cooling only mode.
- The TES discharges with the chiller sharing the load during discharge and mechanical cooling mode.
- Storage does not discharge and all compressors are off during the off/storage-secure mode.
- When applicable, tanks can be charged while serving in active cooling mode during charge-plus cooling mode.

Potential Problems and Cautions

Potential damage to the chiller, pumps, storage tanks, etc., by improper manipulation of the control system.

Perform this test with the assistance of the controls vendor or facility operator.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to thermal energy storage systems used in conjunction with chilled water air conditioning systems.

B. Construction Inspection

Verify that the efficiency of the chiller meets or exceeds the requirements of §110.2.

Supporting documentation needed to perform the test includes:

- Construction documents (plans, drawings, equipment schedule, etc.)
- Approved submittals (for chillers, storage tanks, controls)
- Copy of manufacturers' product literature
- Copy of the Building Energy Efficiency Standards and Appendices

System Installation Information

The following information for both the chiller and the storage tank(s) shall be provided on the plans to document the key TES System parameters.

1. **Chiller(s)**
   - Manufacturer Brand and Model
   - Type (Centrifugal, Reciprocating, etc) and quantity
   - Heat rejection type (air, water, other)
   - Charge mode capacity (tons) at average fluid temperature
   - Discharge mode capacity (tons) at temperature
   - Discharge mode efficiency (kW/ton or EER) at design ambient temperature
   - Charge mode efficiency at nighttime design ambient temperature (kW/ton or EER)
   - Fluid type and percentage (nameplate)
2. **Storage**
   - Type (Ice-on-Coil Internal Melt, Ice-on-Coil External Melt, Encapsulated (e.g. ice balls), Ice Harvester, Ice Slurry, Other Phase Change Material (e.g. paraffin), Chilled Water, Brine (or chilled water with additives), Eutectic Salt, Clathrate Hydrate Slurry (CHS) Cryogenic, Other (specify)
   - Brand and Model
   - Number of Tanks
   - Height/width/depth, or height/diameter (if custom tanks)
   - Storage capacity per tank (ton-hours) at entering/leaving temperatures and hours discharged
   - Storage rate (tons) at flow rate (gpm) per tank
   - Minimum charging temperature based on chiller and tank selections
   - Discharge rate (tons) at entering/leaving temperatures and hours discharged

C. Functional Testing

Step 1: TES System Design Verification

The installing contractor(s) shall certify the following information, which verifies proper installation of the TES system components, consistent with system design expectations.

- Chiller(s) start-up procedure has been completed
- System fluid test and balance has been completed
- Air separation and purge has been completed
- Fluid (e.g. glycol) has been verified at the concentration and type indicated on the design documents
- The TES system has been fully charged at least once and charged duration noted
- The system has been partially discharged at least once and discharged duration noted
- The system is in partial charge state in preparation for Step 2
- Schedule of operation has been activated as designed

- Mode documentation describes the state of system components in each mode of operation

Step 2: TES System Controls and Operation Verification

The Acceptance Testing Technician shall verify the following information:

1. The TES system and the chilled water plant is controlled and monitored by an EMS.
2. The system has controls in place configured for the operator to manually select each mode of operation or use an EMS schedule to specify the mode of operation.
3. The scheduled operations listed below, not the times when the system will be in each mode of operation:
   - **Storage/charge mode.** Manually select storage mode. Verify that the TES system stores energy. If the TES operates on a schedule, note the times, what causes the TES to engage, and that the TES system enters energy storage mode.
   - **End of charge signal.** Simulated a full storage charge by changing the thermal storage manufacturer's recommended end of charge output sensor to the EMS. Verify that the storage charging stops.
   - **Discharge Mode.** Simulate a call for cooling. Manually select storage only discharge mode. Verify that the TES system starts discharging with the compressors off. Return to the off/secured mode. If the TES operates on a schedule, note times, what causes the TES to engage, and that the TES system starts discharging with the compressor(s) off.
   - **Mechanical cooling only mode.** Simulate a call for cooling. Manually select mechanical cooling only mode and verify that the storage does not discharge and the cooling load is met by the compressor(s) only. Return to the off/secured mode. If the TES operates on a schedule, not the times, what causes the TES to engage, and that the storage does not discharge and the cooling load is met by the compressor(s) only.
   - **Discharge and mechanical cooling mode.** Simulate a call for cooling. Manually select discharge and mechanical cooling mode. Verify that the TES system discharges with the chiller(s) sharing the load. Return to the off/secured mode. If the TES operates on a schedule, not the times, cause the TES to engage, and verify that the storage starts discharging with the compressor(s) sharing the load.
   - **Off/storage-secured mode**. Manually select the off/storage-secured mode. Verify that the storage does not discharge and all compressors are off. If the TES operates on a schedule, note the times, what causes the TES to engage, and that the storage does not discharge and all compressor(s) are off, regardless of the presence of calls for cooling.
   - **Charge plus cooling mode** If the provisions for this mode have been made by the system designer, verify that the tank(s) can be charged while serving an active cooling load, simulated by generating a call for cooling and entering the charge mode either manually or by time schedule. If the system disallows this mode of operation, verify that energy storage is disallowed or discontinued while an active cooling load is present.

13.19 NA7.5.15 Supply Air Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.15 Supply Air Temperature Reset Controls Acceptance

Use Document NRCA-MCH-16-A

Purpose of the Test

The purpose of the test is to ensure that the supply air temperature in a constant or variable air volume application serving multiple zones, according to §140.4(f), modulates to meet system heating and cooling loads.

Space conditioning systems must have zone level controls to avoid reheat, re-cool, and simultaneous cooling and heating (§140.4(d)); or, must have controls to reset supply air temperature (SAT) by at least 25 percent of the difference between the design supply-air temperature and the design room air temperature (§140.4(f)2).

Air distribution systems serving zones with constant loads shall be designed for the air flows resulting from the fully reset (e.g. lowest/highest) supply air temperature.

The requirements for SAT reset apply to both CAV and VAV systems. Exceptions include:

- Systems with specific humidity needs for exempt process loads (computer rooms or spaces serving only IT equipment are not exempt),
- Zones served by space conditioning systems in which at least 75 percent of the energy for reheating, or providing warm air in mixing systems, is provided from a site-recovered or site-solar energy source,
- Systems in which supply air temperature reset would increase overall building energy use, and.
- Systems with controls to prevent reheat, re-cool, and/or simultaneous cooling and heating

Supply air temperature may be reset in response to building loads, zone temperature, outside air temperature, or any other appropriate variable.

Instrumentation

The instrumentation needed to perform the task may include, but is not limited to:

- Hand-held temperature probe or temperature data logger, which was calibrated within the last year with date of calibration noted on the Acceptance Document MECH 16-A.

Test Conditions

Confirm all systems and components are installed and ready for system operation, including:

- Duct work
- Terminal boxes
- Heating and/or cooling coils
- Outside air dampers and controls
- Supply air temperature sensor(s)
- Electrical power to air handling unit

Air handling unit start-up procedures should be complete, per manufacturer's recommendations. If applicable, BAS programming for the operation of the air handling unit and terminal boxes should be complete, including but not limited to:

- Heating and cooling coil temperature control
- Terminal box control (including zone temperature sensors and reheat coils)
- Discharge air temperature sensor

Controls for economizer or outside air damper should be disabled during testing to prevent any unwanted interaction.

Before testing, ensure all schedules, set points, operating conditions, and control parameters are documented. All systems must be returned to normal at the end of the test.

Document current supply air temperature.

Estimated Time to Complete

Construction inspection: 0.5 to 1 hours (depending on sensor calibration)

Functional testing: 0.5 to 1 hours (depending on system control stability)

Acceptance Criteria

Construction Inspection Criteria: The temperature sensor(s) must be factory calibrated, field calibrated by a TAB technician, or field checked by test technician with a calibrated standard. Calibration certificate or other supporting documentation must be provided.

Functional Testing: For each system, the test criteria include:

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes. Supply air temperature and temperature setpoint must be documented in the acceptance form.

Potential Issues and Conditions

Coordinate test procedures with the controls contractor and building staff, if possible, since they may be needed to assist with manipulation of the BAS to achieve the desired operating conditions.

Check to make sure that chilled / hot water coils, if used, are not already fully open and calling for maximum cooling / heating. In this case, reverse Steps 1 and 2 and change the set point range as necessary to allow system to operate within acceptable bounds.

In general, take care to avoid demand peaks exceeding what would be encountered during the normal operation of the building.

Ensure that all disabled reset sequences are enabled upon completion of this test.

A. Test Application

Newly Constructed and Additions/Alterations: All new supply air temperature reset controls installed on new or existing systems must be tested.

Some of the most common control variables used to reset supply air temperature set point include, but are not limited to: outdoor air temperature; zone or return air temperature; zone box damper position; or number of zone boxes calling for heating or cooling. Examples of each control strategy are provided below:

- **Outdoor air temperature.** One control strategy is to reset supply air temperature based on outdoor air temperature. For example, cold deck or cooling mode temperature may reset linearly between 55°F and 65°F while the outdoor air temperature is between 50°F and 80°F, respectively.
- **Zone or return air temperature.** Another control strategy is to reset supply air temperature based on zone temperature or return air temperature. For example, supply air temperature may modulate to maintain a zone temperature dead band between 70°F and 76°F.
- **Zones calling for cooling or heating.** In a VAV system, the building automation system may reset the supply air temperature based either on the needs of the zone with the highest heating or cooling loads, or based on a certain percent response from the zone boxes for cooling or heating. For example, in a “trim and response” sequence, the air handler supply temperature may reset downwards by 0.5°F when the maximum system demand is above 100 percent, or reset upwards by 0.5°F when the maximum system demand is below 80 percent.

B. Construction Inspection

Reference the supporting documentation when needed.

1. Verify supply air temperature reset controls are installed per the requirements of the 2016 Energy Standards §140.4(f): Multi-zone systems shall include controls that automatically reset supply-air temperatures:
   - In response to representative building loads or to outdoor air temperature; and
   - By at least 25 percent of the difference between the design supply-air temperature and the design room air temperature.
2. If an exception is taken to these requirements, note the exception, in which case the test is not needed.
3. Document all system air temperature sensor(s) are factory or field calibrated. Attach a copy of the calibration certificate, TAB verification results, or field verification results including results from system air sensors and calibrated reference standards.
4. Document the current supply air temperature.

C. Functional Testing

1. Disable economizer controls and/or outside air damper during testing to prevent any unwanted interaction or effect on air temperature.
2. Check to make sure that chilled and hot water coils, if used, are not already fully open and calling for maximum cooling or heating. If this is the case, reverse Steps 1 and 2 in the test and/or change the set point range as necessary to conduct this test.
3. Document the reset control parameter (e.g. zone air temperature).

Step 1: During occupied mode, adjust the reset control parameter to decrease the supply air temperature (to the lower supply temperature limit).

Override reset control variable to decrease supply air temperature.

For example, temporarily replace outside temperature signal with a high fixed temperature value for outside air temperature, or temporarily override zone damper signals to imitate all zones calling for maximum cooling. For example, if the supply air is currently 65°F, and the control strategy calls for 60°F cool supply air when outdoor air temperature is above 70°F, override the sensor reading to 75°F.

When the reset control variable input cannot be modified, change the limit of the variable around the currently occurring value. For example, if the control strategy calls for 55°F cool supply air when outdoor air temperature is above 80°F, and the current outdoor air temperature is 75°F, adjust the maximum limit from 80°F to 70°F.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes.
- Document both supply air temperature setpoint and actual supply air temperature.

Step 2: During occupied mode, adjust the reset control parameter to increase the supply air temperature (to the upper supply temperature limit).

Override reset control variable to increase supply temperature.

When the reset control variable input cannot be modified, change the limit of the variable around the currently occurring value. For example, modify the reset schedule to create an outside air set point low limit above the current outside air temperature, or shift the entire set point range.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F.
- Supply air temperature stabilizes within 15 minutes.
- Document both supply air temperature setpoint and actual supply air temperature.

Step 3: Restore reset control parameter to automatic control.

Ensure all set points, operating conditions, and control parameters are placed back at their initial conditions. Remove any system overrides initiated during the test.

Verify and Document

- Supply air temperature controls modulate as intended.
- Actual supply air temperature decreases to meet the new set point within +/- 2°F. Document both supply air temperature setpoint and actual supply air temperature.
- Supply air temperature stabilizes.

13.20 NA7.5.16 Condenser Water Temperature Reset Controls Acceptance

At-A-Glance

NA7.5.16 Condenser Water Supply Temperature Reset Controls Acceptance

Use Document NRCA-MCH-17-A

Purpose of the Test

The intent of the test is to verify that the condenser water supply (entering condenser water) temperature is automatically reset as indicated in the control sequences; based upon building loads, outdoor air wet-bulb temperature, or another appropriate control variable. All cooling tower system components (e.g. fans, spray pumps) should operate per the control sequences to maintain the proper condenser water temperature and pressure set points.

Chilled water plants serve many buildings, responding to the varying cooling loads throughout the year. As the loads vary, the chilled water supply temperatures adjust to satisfy the new operating conditions. Often, water-cooled chilled water plants can decrease the condenser water temperature in times of low cooling load. This occurrence can be demonstrated by running the cooling tower fans at a higher speed, staging on additional fans, or varying water distribution across the tower fill by closing and opening bypass valves. As a result, the cooling tower produces an energy penalty, however the chiller efficiency and the overall plant efficiency improves.

The requirement for condenser water reset acceptance only applies to those chilled water systems with a cooling tower implementing some kind of condenser water temperature reset control.

There is no code requirement that chilled water plants employ this type of control. However, if condenser water temperature reset is implemented, then it must be tested per the Energy Standards. The purpose of this test is not to evaluate whether a particular control sequence is the most appropriate for the facility, but whether the system follows the intended control sequence.

Instrumentation

Performance of this test will require measuring water temperatures, and possibly air temperature, relative humidity, system pressures, and system flow rates. The instrumentation needed to perform the task may include, but is not limited to:

- Hand-held temperature probe to calibrate or check existing sensors
- Humidity sensor or wet bulb temperature probe / psychrometer

Installed sensors should be checked for accuracy, and may be used for testing where appropriate. Any instruments used for testing or checking other sensors must be calibrated within the past year, with date of calibration noted on the Acceptance Document.

Test Conditions

To perform the test, it may be necessary to use the building automation system (BAS) to manipulate system operation to achieve the desired control. BAS programming for the operation of the chillers, cooling towers, air handling units, and pumps must be complete, including but not limited to:

- Chilled water and condenser water temperature control
- Equipment start-stop control
- All installed and calibrated control sensors
- Tuned Control loops

All systems must be installed and ready for system operation, including:

- Chillers, cooling towers, pumps, air handling units, valves, and piping.
- Control sensors (temperature, humidity, flow, pressure, valve position, etc.)
- Safeties, interlocks, and alarms (e.g. high/low water alarms, vibration, back-up system operation)

Verify all piping is pressure tested, balanced, flushed, cleaned, and filled with water. Verify electrical power is supplied to all equipment. Confirm start-up procedures for all equipment must be complete, per manufacturer's recommendations. At a minimum, all components and systems served by the chiller and cooling tower should have completed pre-functional checks and be capable of safe operation.

Document the initial conditions before overrides or manipulation of the BAS. Return all systems to their initial condition after test.

Estimated Time to Complete

Construction inspection: 1 to 3 hours (depending on availability of construction documentation – i.e. plumbing drawings, material cut sheets, specifications, etc. – as well as sensor calibration records.)

Functional testing: 2 to 5 hours (depending on familiarity with BAS, method employed to vary operating parameters, ambient conditions, building loads, and time interval between control command and system response)

Acceptance Criteria

Construction Inspection: All ambient temperature and relative humidity sensors used by the controller must be either calibrated (manufacturer calibrated with calibration certificates or field calibrated by TAB technician), or field checked against a calibrated sensor by the person performing the test.

Functional Test: System must meet the following criteria during the test:

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature decreases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet lower set point.
- Chiller load amps decrease.

Potential Problems and Cautions
Condenser water temperature reset is most effective on a moderately warm day. When testing during cold weather conditions, make sure that freeze protection controls are installed and functional to prevent equipment damage. Also ensure the conditioned spaces do not fall below safe temperatures, as this may cause discomfort or unsafe working conditions. If conducting this test during hot weather conditions, make sure the chiller load amps don't increase as the condenser water temperature decreases. If so, you will need to conduct this test on a cooler day. Likewise, stop the test if the chiller begins to surge. This test does not require operation of the plant equipment across all operating stages, so it is not necessary, nor desirable, that the system experience peak load conditions. However, the system cooling load must be sufficiently high to run the test. If necessary, artificially increase the load to perform the functional tests, or wait until a time of stable chiller operation. If necessary, reverse Steps 1 & 2 in the functional test based on atmospheric conditions and building loads. If the system is designed to employ variable flow simultaneously with temperature reset, allow the system to operate as programmed but take care that the water flow rate stays within the minimum and maximum flow rate limits for the chiller(s) and cooling tower(s). Minimum flow through a cooling tower is important to provide even water distribution and full wetting of the fill to prevent scaling. Exemption: There is an important exemption associated with this functional test to provide flexibility given the range of chilled water plant operations, as follows: If the control sequence differs significantly from that implied by the tests, and / or has already been tested during the building commissioning process, attach a description of the control sequence, a description of the tests that were done to verify the system operates according to the sequence, the test results, and a plot of any associated trend data.

A. Test Application

Newly Constructed and Additions/Alterations: All new condenser water temperature reset controls installed on new or existing systems must be tested.

Some control variables used to reset supply water temperature include, but are not limited to:

- **Outdoor air wet-bulb temperature.** A common control strategy is to reset supply water temperature based on outdoor wet bulb temperature. For example, the entering condenser water set point may be reset at a fixed amount (e.g. 7°F) above the outdoor air wet bulb temperature, with limits to meet the chiller and cooling tower operation. The cooling tower may then meet the set point by increasing or decreasing the amount of water circulating through the tower, staging on or off cooling tower fans, or adjusting tower fan motor speed for VFD-equipped fan motors. The designer determines nominal supply water and outdoor air temperatures, which are available in the design narrative, specifications or control drawings.
- **Condenser water and chilled water temperatures.** A cooling tower may operate to maintain a certain temperature difference between the condenser water supply and chilled water return. This process maintains chiller lift or pressure across the compressor. For example, the control may cycle tower fans on and off, or modulate fan speed, to maintain a 14°F difference between condenser water supply of 70°F – 78°F and chilled water return of 56°F – 62°F.

- **Load signal from chiller**. The condenser water temperature may follow a load signal from the chiller. For example, condenser water temperature may follow a “horseshoe” shape, increasing in times of highest and lowest load, and decreasing during low and moderate chiller loading. This strategy enables the chiller to maintain capacity at high load, benefiting from increased efficiency during times of moderate load, and maintaining adequate lift during times of lowest load.

B. Construction Inspection

Prior to functional testing, verify and document the following:

- Check if the condenser water supply system and control system are installed per the system design, as documented on the building plans or as-builts.
- Check if condenser water supply temperature control sequence, including condenser water supply high and low limits, are available and documented in the building documents.
- Check if all cooling tower fan motors are operational, cooling tower fan speed controls are installed, operational, and connected to cooling tower fan motors per OEM start-up manuals and sequence of operation.
- Check if cooling tower fan control sequence, including tower design wetbulb temperature and approach, are available and documented in the building documents.
- Check if the following temperature sensors are installed per plans: outdoor air drybulb and wetbulb, entering condenser water, and leaving chilled water. Note any discrepancies on the Acceptance Document.

All ambient dry bulb temperature, and relative humidity/wet bulb sensors used by controller must be factory calibrated (with certificate), field calibrated by TAB technician or other technician (with calibration results), or field checked against a calibrated reference standard by test technician (with results). Attach supporting documentation to the Acceptance Document.

When field calibrating temperature sensors, it is recommended that you perform a “through system” calibration that compares the reference reading to the reading at the EMCS front end or inside the controller (e.g. it includes any signal degradation due to wiring and transducer error).

Document the following from the control system or using test sensors:

- Current outdoor air dry bulb and wet bulb temperatures
- Current entering condenser water supply temperature
- Current leaving chilled water temperature

C. Functional Testing

If the control sequence differs significantly from that implied by the tests, and/or has already been tested during the building commissioning process, attach a description of the control sequence, a description of the tests that were done to verify the system operates according to the sequence, the test results, and a plot of any associated trend data.

Document reset control parameter (e.g. outside air wet-bulb temperature) on the Acceptance Document.

Step 1: Adjust the reset control parameter to decrease the condenser water temperature (toward the lower supply temperature limit).

Within the programmed reset strategy, change the reset control variable to its minimum value to decrease condenser water supply temperature downward towards the lower limit. For example, if the control strategy calls for the condenser water supply to reset downwards from 85°F to 70°F with a difference of 10°F above current ambient wet bulb temperature of 75°F, override the sensor reading to read a wet bulb temperature below 70°F.

If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value. For example, in the example above, adjust the sequence to a difference of 6°F between the condenser water supply temperature and ambient wet bulb temperature.

Take care not to allow condenser water temperature to drop below the chiller low temperature limit. Allow time for the system to stabilize.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature decreases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet lower set point.
- Chiller load amps decrease.

Step 2: **Adjust the reset control parameter to increase the condenser water temperature (toward the upper supply temperature limit).**

Using the desired reset strategy, override reset control variable towards its maximum value to increase the condenser water supply temperature upward to its high limit. If the reset control variable input cannot be modified, then change the limit of the variable around the currently occurring value. Allow time for the system to stabilize.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature increases to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet upper set point.
- Chiller load amps increase.

Step 3: Restore reset control parameter and system to automatic control.

Restore all controls and equipment to original settings, and/or restore the high and low limits of the reset control variable. Remove all system overrides initiated during test.

Verify and Document

- Condenser water temperature controls modulate as intended.
- Actual condenser water supply temperature changes to meet new set point within ± 2°F.
- Cooling tower fan(s) stage properly and/or adjust speed accordingly to meet set point.
- All equipment returns to normal operation.

13.21 Energy Management Control System Acceptance

At-A-Glance

Energy Management Control System Acceptance
Use Document NRCA-MCH-18-A
Purpose of the Test
This acceptance test ensures the central control system, when installed, is properly installed and configured and capable of meeting the applicable requirements of the Energy Standards. The EMCS is a complex, highly customized control system with many opportunities for installation and programming problems.
Test Conditions
All systems and components must be installed, powered and ready for system operation, including: • Controllers • Actuators • Sensors • EMCS programming All of the regular installation, start-up, testing, and commissioning tasks that a controls contractor normally performs during an EMCS installation should be complete before this test is conducted.
Estimated Time to Complete
1 to 2 hours, depending on familiarity with the EMCS, complexity of the EMCS, and the number of control points.
Acceptance Criteria
Test passes if all Construction Inspection boxes are checked and all Functional Testing results are “yes’.
Potential Problems and Cautions
This basic list of recommendations is intended to validate the readiness of the EMCS for any required acceptance criteria specified in the Energy Standards. This check should not take the place of a more comprehensive start-up testing or commissioning effort. This acceptance test should be completed prior to conducting the other acceptance tests that rely on the EMCS.

A. Test Application

Newly Constructed and Additions/Alterations: All new energy management control systems (EMCS) installed on new or existing systems must be tested.

B. Construction Inspection

Ensure the following actions have been completed:

- Factory start-up and check-out complete
- I/O point lists available
- Point-to-point verification completed
- Sequence of operations of each system are programmed
- Written sequences are available
- Input sensors are calibrated

Verification Checks

Conduct the following verification checks to validate the functionality of the EMCS:

- Verify the control graphics represent the system configuration.
- Verify control points are properly mapped to the graphics screen.
- Raise and lower a sampling of space temperature setpoints in the software and verify the system responds appropriately.
- Verify the time-of-day start-up and shut-down function initiates a proper system response.
- Verify trending capabilities by establishing trend logs for a sampling of control points.
- Verify alarm conditions are monitored.
- Verify the EMCS panel is installed on an emergency power circuit or has adequate battery back-up.

C. Functional Testing

This section includes test and verification procedures for lighting systems that require acceptance testing as listed below:

Document NRCA-LTI-03-A

- NA 7.6.1 Automatic Daylighting Controls Acceptance

Document NRCA-LTI-02-A

- NA 7.6.2.2 and 7.6.2.3 Occupant sensor Acceptance
- NA 7.6.2.4 and 7.6.2.5 Automatic Time Switch Control Acceptance

Document NRCA-LTI-04-A

- NA 7.6.3 Demand Responsive Controls

Document NRCA-LTO-02-A

- NA 7.8.1.2 Outdoor Motion Sensor Acceptance
- NA 7.8.2 Outdoor Lighting Shut-off Controls

13.22 NA7.6.2 Shut-off Controls Acceptance

NA7.6.2.2 and NA7.6.2.3 Occupancy Sensing Lighting Controls Acceptance

At-A-Glance

Occupant Sensor Acceptance
Use Document NRCA-LTI-02-A
Purpose of the Test
The purpose of the test is to ensure that occupant sensors are functioning properly to achieve the desired lighting control. There are two basic technologies in three configurations utilized in most occupant sensors: 1) infrared; 2) ultrasonic; and 3) a combination of infrared and ultrasonic.
Occupant sensors are used to automatically turn lights ON immediately when a space is occupied, and automatically turn them OFF when the space is vacated after a pre-set time delay. Some sensors are configured so the user must manually switch the lights ON but the sensor will automatically switch the lights OFF (manual-ON controls). These are commonly called ‘vacancy sensors’ and are included in this testing procedure. Automated lighting controls prevent energy waste from unnecessarily lighting an unoccupied space.
Instrumentation
This test verifies the functionality of installed occupant sensors visually and does not require special instrumentation.
Test Conditions
Occupant sensors are installed properly and located in places that avoid obstructions and minimize false signals. All luminaires are wired and powered. During the test, the space remains unoccupied. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours (depending on visual and audible inspection requirements) **Equipment Test**: 0.5 to 1 hours (depending on necessity to adjust time delay or mask sensor to prevent false triggers)
Acceptance Criteria
Standard occupant sensor responds to “typical” occupant movement to turn the lights ON immediately. Manual ON occupant sensor requires occupant to switch lighting on. Multi-level occupant sensors meet uniformity requirements; the first stage activates between 50-70 percent of the lighting power; after that event the occupant has the ability to manually activate the alternate set of lights, activate 100 percent of the lighting, and deactivate all of the lights.

Conditions where partial ON/OFF controls are required in addition to or instead of the basic controls requirements are identified and the controls properly reduce lighting power by at least 50 percent. Ultrasonic occupant sensors do not emit audible sound. Lights controlled by the occupant sensor turn OFF at the preset time delay. The programmed maximum time delay is not greater than 20 minutes. Occupant sensor does not trigger a false ON or OFF. Status indicator or annunciator operates correctly.
Potential Issues and Cautions
It is imperative that the test be performed during a time when the tester can have full control over the occupancy of the space. The time delay can be adjusted to minimize test time, but the time delay setting must be reset upon completion of the test (not to exceed 20 minutes). To avoid detection of significant air movement from an HVAC diffuser or other source, which can cause the sensor to turn the lights ON (this is most critical with ultrasonic sensors). If motion in an adjacent area is causing an unwanted trigger, the technician may adjust the coverage pattern intensity or mask the sensor with an opaque material.

A. Test Application

The purpose of the test is to ensure that an occupant sensor functioning properly to achieve the desired lighting control. Occupant sensors are used to automatically turn lights on and keep them on when a space is occupied, and turn them off automatically when the space is unoccupied after a reasonable time delay. The time delay, typically adjustable, will prevent lights from rapid cycling through ON and OFF when spaces are occupied frequently but temporarily. It also helps avoid false OFF triggering when there is little apparent occupant movement.

B. Construction Inspection

Verify the following:

- Occupant sensors are located to minimize false signals.
- No closer than four feet from a HVAC diffuser.
- Passive infrared sensor pattern does not enter into adjacent zones.
- Occupancy sensors do not encounter any obstacles that could adversely affect desired performance.
- Ultrasonic occupant sensors do not emit audible sound 5 feet from source.
- Occupant sensors have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all occupant sensors are listed on the Energy Commission database as “Certified Appliances & Control Devices” (http://www.energy.ca.gov/appliances/database/).

Prepare for allowable sampling:

- For buildings with up to seven (7) occupancy sensors, all occupancy sensors must be tested and sampling may not be used.
- For buildings with more than seven (7) occupancy sensors, sampling may be done on spaces with similar sensors and space geometries.
  - Sampling shall include a minimum of 1 occupancy sensor for each group of up to 7 additional photocontrols.
  - If the first occupancy sensor in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass.
  - If the first occupancy sensor in the sample group fails the acceptance test the rest of the occupancy sensors in that group must be tested.
- If any tested occupancy sensor fails it shall be repaired, replaced or adjusted until it passes the test within the limits of the technician's authority to do so.

C. Functional Testing

a. **Part 1: Occupant sensor**

Step 1: Simulate an unoccupied condition.

Ensure the space being tested remains unoccupied during the test and wait for the lights to turn off (sensor delay time can be adjusted to shorten test time).

Verify and Document

1. Lights controlled by the occupant sensor turn off after the time delay. If the time delay was not adjusted prior to the test, ensure the maximum delay is not greater than 20 minutes. If the time delay was adjusted to minimize test time, return the time delay to initial conditions or 20 minutes, whichever is less.
2. Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone does not activate the lights. Examples include:
   - Walking past an open door of an enclosed office
   - Walking in an adjacent zone close to the control zone, (consider that designers sometimes employ overlapping sensor coverage areas as part of the design)
   - Movement other than occupants (i.e. air flow from HVAC system or furnishing movement due to external forces)

Step 2: For a representative sample of building spaces, simulate an occupied condition.

Verify and Document

- Status indicator or annunciator operates correctly.
- Most occupant sensors have an LED that will illuminate (typically flash) when motion is detected, where others may emit an audible sound.
- The lights in the control zone turn on immediately, except if the sensor has "manual-ON" capability. The occupant sensors that are required to have "manual-ON" capability are identified on the Lighting Control Worksheet.

b. **Part 2: Partial-OFF Occupant sensor**

Step 1: Simulate an unoccupied condition.

Verify and Document:

1. Lights controlled by the occupant sensor turn off after the time delay. If the time delay was not adjusted prior to the test, ensure the maximum delay is not greater than 20 minutes. If the time delay was adjusted to minimize test time, ensure that the time delay is returned to initial conditions or 20 minutes, whichever is less.
2. Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone does not activate the lights. Examples include:
   - Walking past the end of the aisle or book stack.
   - Walking in an adjacent zone close to the control zone, (consider that designers sometimes employ overlapping sensor coverage areas as part of the design, so ensure that the zone coverage test has a reasonable demarcation).
   - Movement other than occupants (i.e. air flow from HVAC system or furnishing movement due to external forces).
3. The following areas shall be controlled with occupancies sensors to meet the requirements indicated in the Table below.

NRCA-LTI-02-A
Full- or Partial-OFF in the Unoccupied Condition
Occupancy Sensing Control Setting Requirements & Exceptions

AREA	Exception	Minimum Lighting Power Reduction Requirement	Note	Energy Standards Section
Where Full or Partial-OFF occupant sensing controls are required. Comply with the following IN ADDITION to §130.1(c)1.				
Aisle Ways & Open Areas of Warehouses	No exception applied	50 percent	1	§130.1(c)6A
	Installed lighting power is 80 percent or less of the value allowed under the Area Category Method	40 percent		Exception 1 to §130.1(c)6A
	Installed metal halide lighting or high pressure sodium lighting	40 percent		Exception 2 to §130.1(c)6A
Library book stack aisles	No exception applied	50 percent	1, 2	§130.1(c)6B
Corridors & Stairwells	No exception applied	50 percent	3	§130.1(c)6C
Where only Partial-OFF occupant sensing controls are required. Comply with the following INSTEAD OF §130.1(c)1.				
Stairwells & Corridors for High-Rise Res &	No exception applied	50 percent	3, 4	§130.1(c)7A

Hotel/Motel	Installed lighting power is 80 percent or less of the value allowed under the Area Category Method	40 percent		Exception 1 to §130.1(c)7A
Parking Garage, Parking Area & Loading/Unloading Areas	No exception applied	At least one control step between 20 percent & 50 percent	3, 5, 6	§130.1(c)7B
	Installed Metal halide luminaires with a lamp plus ballast mean system efficacy of greater than 75 lumens per watt	At least one control step between 20 percent & 60 percent		Exception 1 to §130.1(c)7B
NOTES				
1	The occupant sensing controls shall independently control lighting in each aisle way, and shall not control lighting beyond the area being controlled by the sensor.			
2	This requirement applies to library book stack aisles that are 10 feet or longer and accessible from only one end or 20 feet or longer and accessible from both ends.			
3	The occupant sensing controls shall be capable of automatically turning the lighting fully ON only in the separately controlled space, and shall be automatically activated from all designed paths of egress.			
4	This applies to stairwells and common area corridors that provide access to guestrooms and dwelling units of high-rise residential buildings and hotel/motels			
5	No more than 500 watts of rated lighting power shall be controlled together as a single zone. A reasonably uniform level of luminance shall be achieved in accordance with the applicable requirements in Table 130.1-A.			
6	Interior areas of parking garages are classified as indoor lighting for compliance with §130.1(c)7B. Parking areas on the roof of a parking structure are classified as outdoor hardscape and shall comply with the applicable provisions in §130.2.			

Step 2: Simulate an occupied condition

Verify and document:

The occupant sensing controls turn lights fully ON in each separately controlled areas, Immediately upon an occupied condition

c. **Part 3: Partial-ON Occupant sensor**

Step 1: Simulate an occupied condition.

Simulate a situation where an occupant enters a space with a partial on sensor arrangement.

Verify and Document

- The occupant sensor will activate the first stage of lighting, between 50 to 70 percent of the total lighting connected load for the specific lighting equipment controlled.
- After the first stage occurs, manual switches are provided to activate the alternate set of lights, bringing the total power consumption up to the full connected load of the controlled lighting equipment.

Step 2: Simulate an unoccupied condition.

Verify and Document

- Both stages of lighting (automatic and manual stages) turn OFF with a maximum of 20 minute from the beginning of the unoccupied condition.
- Occupant sensor does not trigger a false ON. Ensure that any movement outside the desired control zone or HVAC operation does not activate the lights.

d. **Part 4: Occupant Sensor Serving Small Zones In Large Open Office Plan For Power Adjustment Factor (PAF)**

For each controlled zone that is being tested, first complete Functional Test 2 (Occupant Sensor) to confirm that the sensor is switching the lights on and off as required. Then enter the information described below:

- Area served by controlled lighting (square feet) - Size of the controlled zone, which is to say the zone underneath the lighting controlled by this occupant sensor. The boundaries of the controlled zone should lie halfway between one light fixture and the next, if the light fixtures are on a regular grid.
- Enter PAF corresponding to controlled area - From line (a) on the test form, enter the power adjustment factor that corresponds to the size of the controlled zone (≤125sf for PAF=0.4, 126-250sf for PAF=0.3, 251-500sf for PAF=0.2).
- Enter PAF claimed for occupant sensor control in this space from compliance documentation - enter the PAF for this controlled zone, from the Certificate of Compliance
- The PAF corresponding to the controlled area (line b), is less than or equal to the PAF claimed in the compliance documentation (line c) - This step is to ensure that the PAF calculated during the acceptance test is not less than the PAF that was claimed for the same zone on the compliance document.
- Sensors shall not trigger in response to movement in adjacent walkways or workspaces. The sensor switches on the lights only in response to movement within the group of workspace(s) that together constitute the controlled area. The lights must not trigger in response to movement in nearby areas.
- All steps are conducted in Functional Test 2 “Occupancy Sensor (On Off Control)” and all answers are Yes (Y) - This step verifies that Functional Test 2 has been conducted, to verify that the occupant sensor switches the lights between their high and low states as required.

13.23 NA7.6.2.4 and NA7.6.2.5 Automatic Time Switch Lighting Controls Acceptance

At-A-Glance

Automatic Time Switch Acceptance
Use Document NRCA-LTI-02-A
Purpose of the Test
This test ensures all non-exempt lights, per §130.1(c)1, are automatically turned off at a predetermined time and individual lighting circuits can be manually enabled, if necessary, during scheduled OFF periods. Lighting during typically unoccupied periods prevents energy waste.
Instrumentation
This test verifies the functionality of installed automatic time switch controls visually and does not require special instrumentation.
Test Conditions
All luminaires and override switches controlled by the time switch control system must be wired and powered. Lighting control system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer's recommendations. Document the initial conditions before overrides or manipulation of the BAS. All systems must be returned to normal at the end of the test.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours (depending on familiarity with lighting control programming language) **Equipment Test**: 2 to 6 hours (depending on familiarity with lighting control programming language, number of lighting circuits and override switches to be tested, and programmed time delays between ON and OFF signals)
Acceptance Criteria
Automatic time switch controls are programmed with acceptable weekday, weekend, and holiday schedules, per building occupancy profile. The correct date and time are properly set in the lighting controller. Program backup capabilities are present to prevent the loss of the device's schedules for at least 7 days, and the device's time and date setting for at least 72 hours, if power is interrupted All lights may be either turned ON manually or turned ON automatically during the occupied time schedule. All lights turn OFF automatically at the scheduled times. The manual override switch is functional and turns associated lights ON when activated. Override time limit is no more than 2 hours, except for spaces exempt per §131(c)3.B.

If annunciator is installed, verify proper installation. Verify the annunciator warning to the occupants that the lights are about to turn OFF functions correctly.

Ensure that automatic time switches have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all automatic time switches are listed on the Energy Commission database as “Certified Appliances & Control Devices.”

http://www.energy.ca.gov/appliances/database/

Potential Issues and Cautions

The manual override time limit can be adjusted to minimize test time, but the time limit setting must be reset upon completion of the test (not to exceed 2 hours).

When possible, perform the test when the spaces are unoccupied. Turning the lights OFF when other occupants are present can cause problems and unsafe working conditions.

A. Test Application

Newly Constructed and Additions/Alterations: Applies to Occupant sensor, Manual Daylight Controls and Automatic Time Switch Control Acceptance. Functional testing and verification is required.

B. Construction Inspection

1. Verify automatic time switch controls are programmed with acceptable weekday, weekend, and holiday schedules. Non-exempt lights should be scheduled OFF a reasonable time after the space is typically unoccupied (i.e., 1 or 2 hours after most people vacate the space).
2. Verify schedule and other programming parameter documentation is available or posted to the owner. The documentation should include weekday, weekend, and holiday schedules as well as sweep frequency and/or override time period.
3. Verify correct date and time is properly set in the time switch. Lights will not be controlled correctly if the programmed date and time do not match actual values.
4. Verify the battery is installed and energized. The device shall have program backup capabilities that prevent the loss of schedules for at least 7 days, and the time and date settings for at least 72 hours if power is interrupted.
5. Override time limit is no more than 2 hours. When the lights are switched off, each lighting circuit can be turned back on manually. Most systems will either send out another OFF signal through the entire lighting network to command all lights back off, or an override timer will expire to turn off the lights which were manually turned on. Regardless of the control strategy, lights that were manually turned ON during an OFF period should only be operating for up to 2 hours before they are automatically turned off again.
6. Verify that override switch is readily accessible and located so that a person using the device can see the lights being controlled--for example, individual override switch per enclosed office or centrally located switch when serving an open office space.
7. Verify that model numbers of all automatic time switch controls are listed on the Energy Commission database as “Certified Appliances & Control Devices.” http://www.energy.ca.gov/appliances/database/.

C. Functional Testing

Step 1: Simulate occupied condition.

Set ON time schedule to include actual time or adjust time to be within the ON time schedule (whichever is easier).

Verify and Document

Verify all lights can be enabled. Some systems may turn the lights on automatically at the scheduled time, but others may require that lights be turned on manually using their respective area control switch.

Step 2: Simulate unoccupied condition.

Set the OFF time schedule to include the actual time, or adjust the time to be within the OFF time schedule (whichever is easier).

Verify and Document

All non-exempt lights turn off. Most systems warn occupants that the lights are about to turn off by sending a pulse through the lighting circuits to “flicker” the lights or provide another form of visual or audible annunciation.

Manual override switch is functional. Enabling the manual override switch allows only the lights in the selected space where the switch is located to turn ON. This is particularly important in enclosed spaces to ensure only lights within the enclosed space are controlled, however, switches serving open spaces should also control only lights in the designated zone. The lights should remain ON throughout the override time period (refer to §130.1(c)3B for maximum override times) and the system indicates that the lights are about to be turned off again.

All non-exempt lights turn off when the next OFF signal is supplied to the lighting control circuits or the override time has expired. In order to reduce testing time associated with the complete OFF-Manual override-OFF sequence, the override time may be shortened so that the entire sequence can be witnessed within a reasonable amount of time.

Step 3: Return system back to normal operating condition.

Ensure all schedules, setpoints, operating conditions, and control parameters are placed back at their initial conditions. Ensure the override time period is no more than 2 hours.

It is also good practice to leave a schedule in the timeclock itself for easy reference and to leave a blank schedule form so that the users can document any schedule changes.

13.24 NA7.6.1 Automatic Daylighting Control Acceptance

At-A-Glance

Automatic Daylighting Control Acceptance
Use Document NRCA-LTI-03-A
Purpose of the Test
The purpose of this test is to ensure that spaces mandated to have automatic daylighting control (refer to §130.1(d)) are installed and functioning as required by the Energy Standards. Automatic daylighting controls in Primary Sidelit and Skylit Daylit Zones are mandatory if the zone includes more than 120 Watts of lighting equipment. The lighting must have multiple stages of control that meet the requirements of Table 130.1-A and §130.1(d)2Dii. Automatic daylighting controls in Secondary Sidelit Zones are prescriptive and §140.6(d) outlines their functions.
Benefits of the Test
The controls save energy only if they are functioning correctly. Controls passing the test provide adequate illuminance under all daylight conditions while reducing lighting power in response to daylight in the space to save a significant fraction of lighting energy. If the control leaves the space too dark, visual quality is compromised and ultimately the control will be over-ridden resulting in no energy savings. If the control leaves lights on at too high a level, the full savings from the control are not realized.
Instrumentation
To perform the test, it will be necessary to measure ambient light levels and validate overall power reduction. In most cases, the only instrumentation required is: • Light meter (illuminance or foot-candle meter) For dimming ballasts, a default illuminance/power relationship can be used to estimate power consumption. Alternatively, the tester can choose to directly measure power or current or use the manufacturer’s dimming performance data. Additional instrumentation or data that may be needed: • Hand-held amperage meter or power meter • Logging light meter or power meter • Manufacturer’s light versus power curve for continuous dimming and step dimming ballasts
Test Conditions
All luminaires in the Daylit Zone must be wired and powered. Controls installed according to manufacturer’s instructions Simulating a bright condition can be difficult; therefore, performing the test under natural sunny conditions is preferable. Document the initial conditions before testing. All systems must be returned to normal at the end of the test.

Estimated Time to Complete
Construction Inspection: 0.5 to 1 hour (depending on whether sensor calibration is necessary, familiarity with lighting control programming language, and availability of construction documentation – i.e. electrical drawings, material cut sheets, etc.) **Equipment Test**: 1 to 3 hours (depending on ability to manipulate ambient light levels, familiarity with lighting control programming language, and method employed for verifying required power reduction)
Acceptance Criteria
Lighting is correctly controlled so that general lighting fixtures in the Daylit Zone are controlled separately from lighting outside the Daylit zone. Photosensor has been located properly to minimize unauthorized tampering. [§130.1(d)2Di] The photosensor is physically separated from the location where calibration adjustments are made, or is capable of being calibrated in a manner that the person initiating calibration is remote from the sensor during calibration to avoid influencing calibration accuracy. [§110.9(b)2] Sensor located and oriented appropriate to the control type and location of Daylit Zone. Under conditions where no daylight is sensed by the control, the control system increases the light output of each fixture to the design light output. This may be full output, but in a space with multi-level lighting requirements, this could be commissioned to meet the design illuminance requirements. The controlled fixtures reduce lighting power to no greater than 35 percent of full-load power under fully dimmed and/or stepped conditions. [§130.1(d)2Div] For the continuous and stepped dimming control systems, the lamps do not "flicker" at reduced light output. [§110.9(b)3], which cites the Title 20 requirements for dimming. Title 20, Section 1605.3(I)2(F)2 states, "*Dimmer controls that can directly control lamps shall provide electrical outputs to lamps for reduced flicker operation through the dimming range…without causing premature lamp failure."* Because there is no standard for evaluating flicker, this is intended to refer to visible flicker. Automatic daylighting systems shall provide multi-level control capability following the guidance in Table 130.1-A. [§130.1(d)2Dii] Stepped dimming and stepped switching control systems have a minimum time delay of 3 minutes or greater before a decrease in electric lighting. [§110.9(b)2] For the stepped dimming and stepped switching control systems, the dead band between steps is sufficiently large to prevent cycling between steps for the same daylight illuminance. [§110.9(b)2] A "Reference Location" is defined that is served by the controlled lights and receives the least amount of daylight. Usually this is a location that is furthest away from the windows or skylights but is still served by the controlled lighting equipment. A "Reference Illuminance" is defined at the Reference Location – this is the illuminance from electric lighting when no daylight is available. For continuous dimming systems; Under partial daylight conditions, the combined daylight and electric lighting illuminance from continuously dimmable fixtures at the Reference Location is no less than the Reference Illuminance and no greater than 150 percent of the Reference Illuminance.[§130.1(d)2Diii&iv]

When stepped lighting controls dim or turn off a step, the combined daylight and electric lighting illuminance from stepped dimming or stepped switching fixtures at the Reference Location is no less than the Reference Illuminance and no greater than 150 percent of the Reference Illuminance after the electric light is fully diminished. [§130.1(d)2Diii&iv]
Potential Issues and Cautions
Check fixture circuiting while access to wiring is relatively easy (i.e. while lift is available or before obstructions are installed). Simulating bright conditions and achieving proper luminance to perform the test can be difficult. Therefore, it is recommended that the test be performed under natural bright light conditions. For the stepped dimming and switching control systems, it is acceptable to shorten the time delay while performing the tests, but the time delay must be returned to normal operating conditions when the test is complete (at least 3 minutes).

A. Test Application

Newly Constructed and Additions/Alterations: Applies to properly located controls, field calibrated and set to appropriate lighting levels.

Preparing for Sampling:

- All photocontrols serving more than 5,000 ft² of daylit area shall undergo functional testing.
- Photocontrols that are serving smaller spaces may be sampled as follows:
  - For buildings with up to five (5) photocontrols, all photocontrols shall be tested.
  - For buildings with more than five (5) photocontrols, sampling may be done on spaces with similar sensors and cardinal orientations of glazing.
    - Sampling shall include a minimum of 1 photocontrol for each group of up to 5 additional photocontrols.
    - If the first photocontrol in the sample group passes the functional test, the remaining building spaces in the sample group also pass.
    - If the first photocontrol in the sample group fails the functional test, the rest of the photocontrols in the group shall be tested.
- If any tested photocontrol fails the functional test, it shall be repaired, replaced or adjusted until it passes the test.

Definition of the Daylit Zones

The following information on the definitions of the Daylit Zones are only needed if the designer has not documented on the plans the Daylit Zones or if the as built location of windows and skylights do not correspond to the Daylit Zones on the plans. When the plans are incorrectly documenting the Daylit Zones, it is the tester’s responsibility to identify the problem and inspect and test the system based upon the as-built configuration of the Daylit Zones. It is recommended that this is conducted in consultation with the designer.

- **Primary Sidlit Daylit Zone** is the combined Primary Sidelit Daylit Zone for each window without double counting overlapping areas. The floor area for each Primary Sidelit Daylit Zone is directly adjacent to vertical glazing below the ceiling with an area equal to the product of the Primary Sidelit Daylit Zone width and the Primary Sidelit Daylit Zone depth.

- **Primary Sidelit Daylit Zone width** is the width of the window plus, on each side, the smallest of:
  - 0.5 times the window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Primary Sidelit Daylit Zone depth** is the horizontal distance perpendicular to the glazing that is the smaller of:
  - One window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Secondary Sidlit Daylit Zone** is the combined Secondary Sidelit Daylit Zone for each window without double counting overlapping areas. The floor area for each Secondary Sidelit Daylit Zone is directly adjacent to Primary Sidelit Daylit Zone with an area equal to the product of the Secondary Sidelit Daylit Zone width and the Secondary Sidelit Daylit Zone depth.
- **The Secondary Sidelit Daylit Zone width** is the width of the window plus, on each side, the smallest of:
  - 0.5 times the window head height.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **The Secondary Sidelit Daylit Zone depth** is the horizontal distance perpendicular to the glazing that begins from one window head height, and ends at the smaller of:
  - Two window head heights.
  - The distance to any 6 foot or higher permanent vertical obstruction.
  - The distance to any Skylit Daylit Zone.
- **Skylit Daylit Zone** is the combined Skylit Daylit Zone under each skylight without double counting overlapping areas. The daylight area under each skylight is bounded by the rough opening of the skylight, plus horizontally in each direction the smallest of:
  - 70 percent of the floor-to-skylight or skylight well height.
  - The distance to any permanent partition or permanent rack that is taller than 50 percent of the distance from the floor to the bottom of the skylight and oriented in a direction to cause a shadow.

  When the partitions fall within the floor plan rough opening of the skylight, they do not cause shadowing that reduces the overall coverage of the skylight. In these cases, the coverage area should not be limited by the partition.

Figure 13-3: Primary Sidelit Daylit Zone Plan view

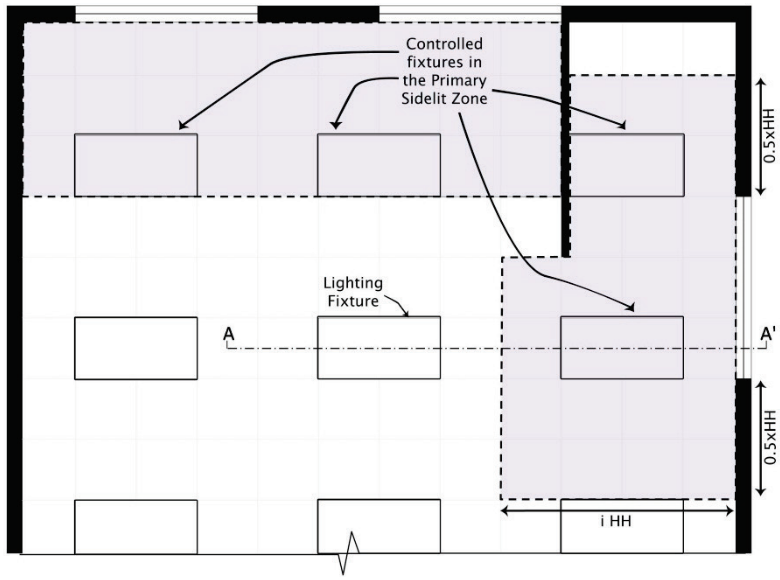
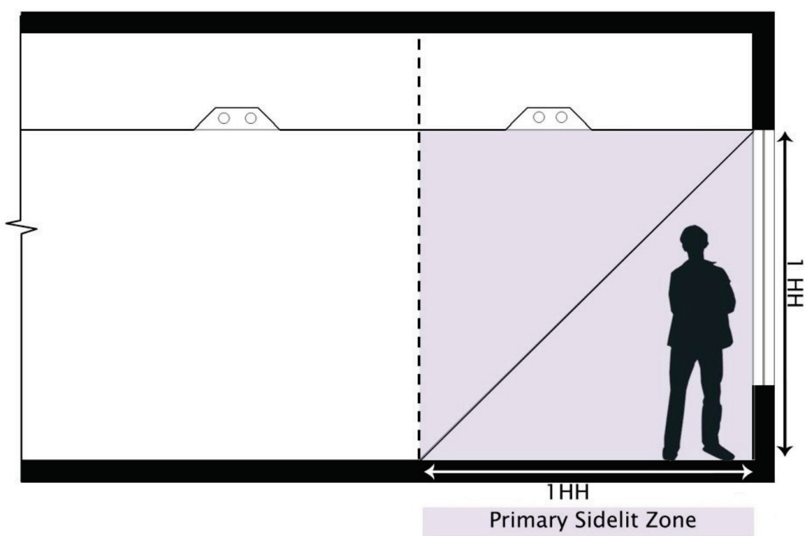


Figure 13-4: Side view of Primary and Secondary Sidelit Zones



- **Clearstory or monitor windows** have a different coverage pattern than the traditional skylight and are treated as windows, but the Daylit Zone is considered a Skylit Daylit Zone. The Skylit (Monitor) Zone depth under each monitor window is defined from the plane of the monitor window, extending towards the back by the smaller of:
    - 100 percent of the floor-to-head height of the monitor.
    - The distance to any permanent partition or permanent rack that is not directly below the monitor well, whichever is taller than fifty percent of the distance from

the floor to the bottom of the ceiling, and is oriented such that it will cast a substantial shadow to the back.

- **The Skylit (Monitor) Daylit Zone width** is the width of the monitor window plus the smaller of:
  - 50 percent of the floor-to-head height of the monitor window.
  - The distance to any permanent partition or permanent rack that is not directly below the monitor well, whichever is taller than fifty percent of the distance from the floor to the bottom of the ceiling, and is oriented such that it will cast a substantial shadow to the side.
  - In buildings with no partitions, the Skylit Daylit Zone under skylights is the footprint of the skylight plus in each direction 70 percent of the ceiling height or halfway to the next skylight, whichever is less. This is shown in Figure 13-5:

Figure 13-5: Elevation View of Skylit Daylit Zone under Skylight (no interior partitions)

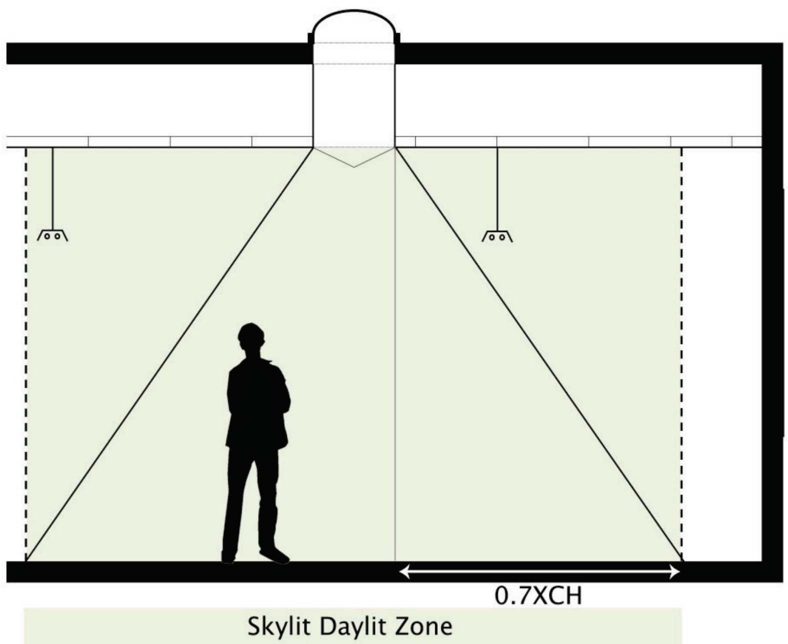
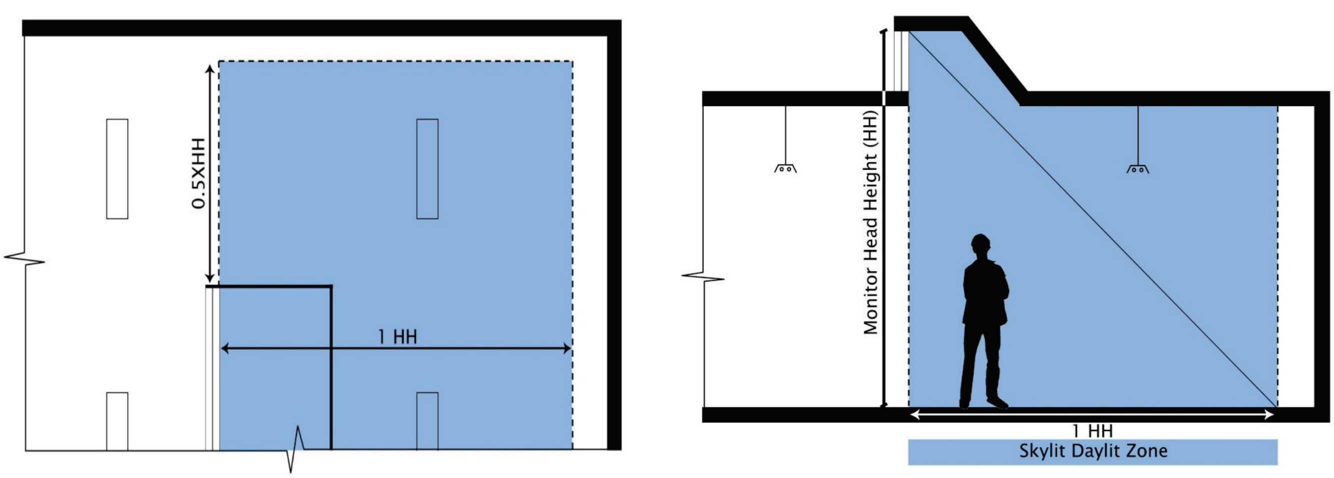


Figure 13-6: Plan and Elevation View of Skylit Daylit Zone under Monitor Window or Clearstory (no interior partitions)



If there are permanent partitions or racks below the skylight, the partitions may block portions of the full extent of the Skylit Daylit Zone. There are two conditions that must occur for a partition to reduce the Daylit Zone. A partition must be greater than 50 percent of the distance from the floor to the bottom of the skylight (or monitor window), and is not directly below the skylight or monitor well, and the partition must be oriented so that the object creates a shadow beyond it. This is illustrated in Figure 13-7 below.

Figure 13-7: Elevation View of Skylit Daylit Zone under Skylight (with interior partitions)

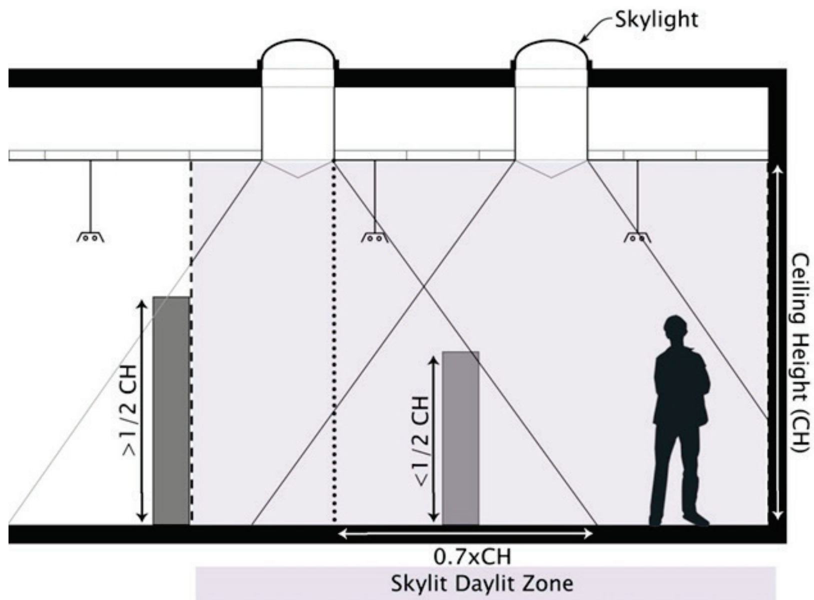


Figure 13-8: Plan View of Skylit Daylit Zone under Skylights (with interior partitions)

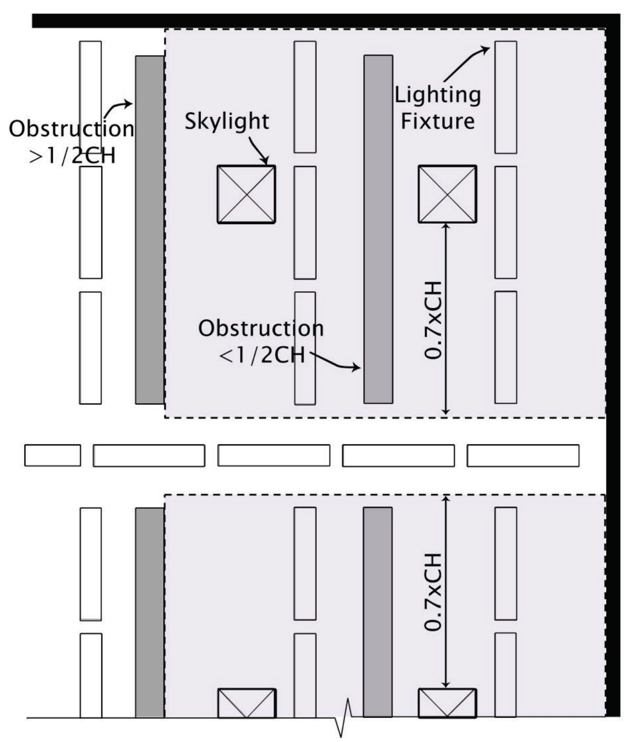
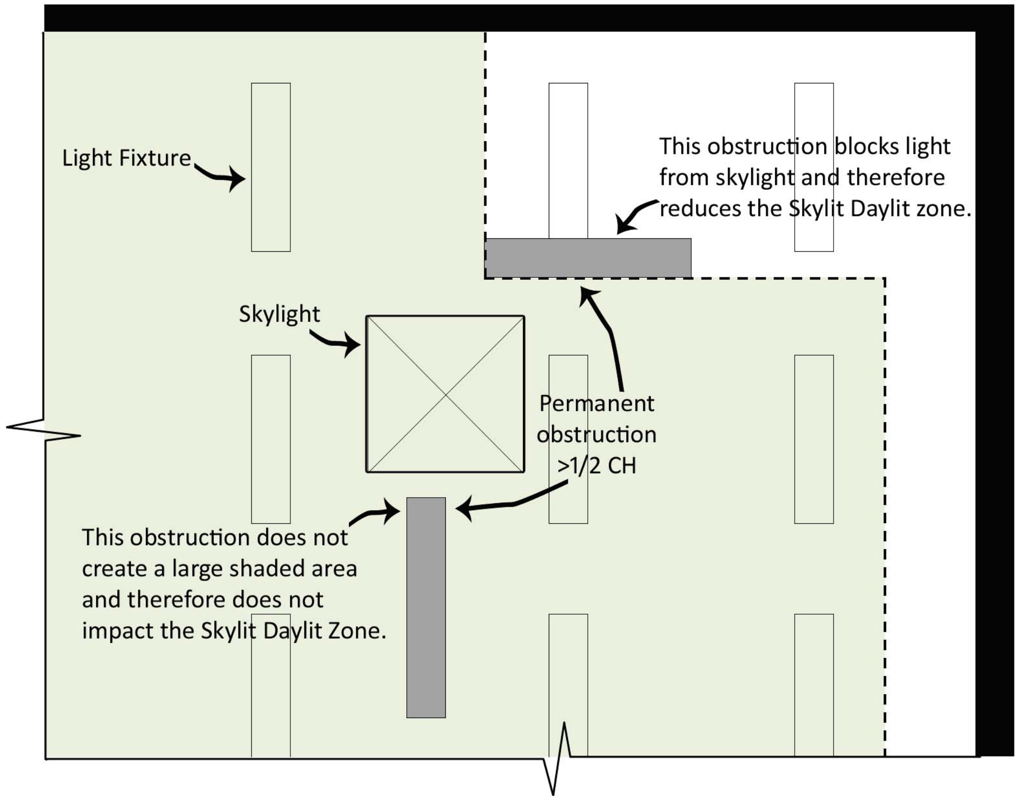


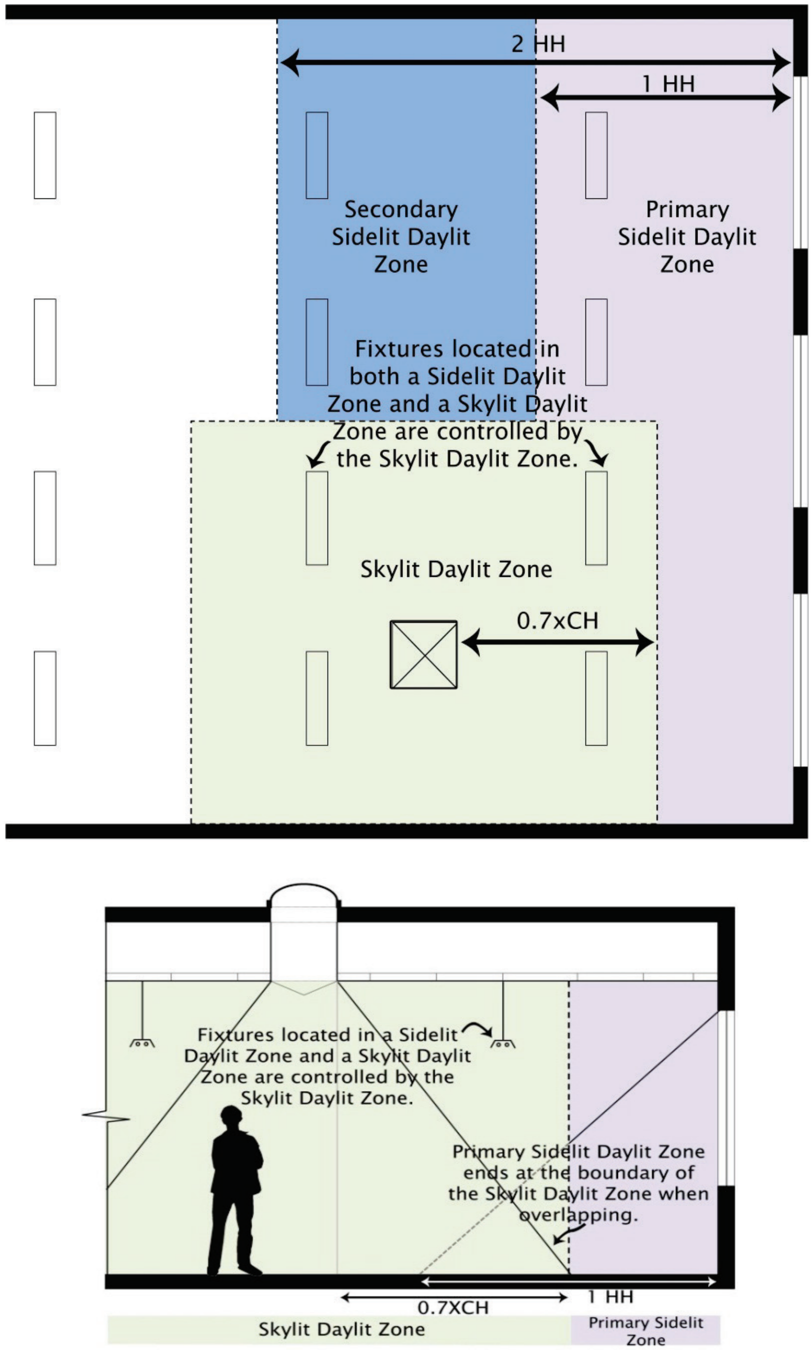
Figure 13-9: Example of Skylit Daylit Zone under Skylight (with interior partitions where one partition is not considered 'blocking')



- **Hierarchy of Zones.** In situations where Zones overlap, there is a hierarchy of Zone assignment so that there is no condition where the lighting equipment is considered in more than a single Zone. The hierarchy is as follows:
  1. Skylit (including monitor windows or clearstories).
  2. Primary Sidelit.
  3. Secondary Sidelit.

  The lighting equipment is assigned based on which Zone it is within or touching, so a light fixture that is partially within two different Zones will be placed in the higher Zone, per the above hierarchy.

Figure 13-10: Plan and Elevation Views Showing Hierarchy of Assigned Daylit Zones



B. Construction Inspection

1. Purpose of the Test

The purpose of this construction inspection is to ensure that the daylighting controls that are installed in the space meet the location, specification and accessibility requirements per §110.9(b)2; and to ensure that control devices have been certified to the Energy Commission in accordance with the applicable provision in §110.9.

2. Criteria for Passing the Test

The system must pass all six key criteria identified in Document NRCA-LTI-03-A Part I:

- All Daylit Zones are clearly marked on plans or drawn on as-built drawings.
- All Daylit Zone type and control type is clearly identified on the Document.
- Sensors and controls are appropriate for the particular requirements of the daylighted area and intended functions, and are located in appropriate locations per §110.9(b)2 and §130.1(d).
- Sensor and control setpoints are documented by the installer.
- Daylighting controls only control those luminaires that are in the daylighted area for which they are intended and luminaires in Sidelit Daylit Zones are controlled separately from luminaires in Skylit Daylit Zones.
- Daylighting controls have been certified to the Energy Commission in accordance with §110.9(a)3.

3. How to Conduct the Test and Fill the Document

Step 1: Daylit Zones Shown on Plans

The building plans are required to have a drawing of the extents of the Daylit Zones when controls are required or controls are used to obtain lighting control credits.

If the plans do not have the Daylit Zones indicated for the spaces containing photocontrols, draw the Daylit Zones on the as-built plans and attach to the acceptance test documents. A copy should be sent to the designer and the building owner.

When there are more than one type of Daylit Zones present and thus daylighting control systems exist on site, these should be clearly marked on the plans, and also noted on the document. The user is able to specify up to three (3) systems per document.

For buildings with several daylighting controls, one may sample the controls for Acceptance Testing. When sampling, clearly note it on the documents. A separate sheet should be attached to the document with names of the other controls and systems that are being represented by the three systems on the document. At least one daylighting control shall be tested for each Daylit Zone category (Skylit, Primary Sidelit, and Secondary Sidelit).

Step 2: System Information

There are three types of Daylit Zones:

- The Skylit Daylit Zones under skylights,
- The Primary Sidelit Daylit Zones adjacent to within one window head height of the vertical glazing, and
- The Secondary Sidelit Daylit Zones, located between the corresponding Primary Sidelit Daylit Zone and two window head heights from the vertical glazing.

The window head height is the distance from the floor to top of the window. This is summarized in the Section titled "*Definition of Daylit Zones.*"

1. *Controlled Lighting Wattage:*

- Note the total wattage of luminaires that are controlled by the given control system. If there are multiple controls systems (A, B, C on the document), identify controlled wattage separately for each type of control system.
- When the Primary Sidelit Daylit Zone or Skylit Daylit Zone in a room (enclosed space) includes greater than 120 watts of lighting equipment, all general lighting in this daylighted area is required to be controlled by an automatic daylighting control.
- General lighting is defined as lighting that is "designed to provide a substantially uniform level of illumination throughout an area, exclusive of any provision for special visual tasks or decorative effect." Linear fluorescent troffers and pendants, high and low bay luminaires and other non-directional light sources are considered general lighting.
- When automatic daylighting controls are required in Primary Sidelit Daylit Zones, these lights must be separately controlled from the Secondary Sidelit Daylit Zone.
- The photocontrol must control only those fixtures in the daylighted area. A luminaire is considered to be in the Daylit Zone if any part of the luminaire touches the defined Daylit Zone. With long pendant fixtures that cross into Daylit Zone, the lamps that touch the Daylit Zone must be controlled separately from those not in the Daylit Zone.
- Luminaires and lamps that touch more than one Daylit Zone follow this hierarchy for assignment; 1. Skylit, 2. Primary Sidelit, 3. Secondary Sidelit.
- Controls for Sidelit Daylit Zones are required to be separate from controls for Skylit Daylit Zones.

Note: Identifying whether fixtures are controlled by a given sensor or control may be difficult without operating the system. For this reason, it may be better to conduct this portion of the construction inspection in conjunction with the functional performance test.

The controlled fixtures are readily identified by noting which fixtures are turned on and off or are dimming in response to the no daylight and full daylight functional performance tests.

2. *Control Type:*

- Identify the type of luminaire control used in each of the control systems identified in the document. There are three types of controls identified on the document:
- Continuous dimming controls are controls that alter the output of lamps in at least 10 steps.
- Step dimming controls alter the output of lamps in less than 10 steps (typically up to four steps between on and off).
- Step switching controls turns lamps or groups of lamps on and off without any steps between on and off.
- Stepped switching controls are able to provide multi-level lighting by having more than one group of lamps being controlled. Partial light output (and partial power consumption) of the stepped switching lighting system is provided by turning some of the lamps on.

3. *Design Footcandles:*

Note the design footcandles for general illumination in the Daylit Zone served by each of the control systems identified in the document. If the design light level is not known for a given control system, clearly identify that it is unknown.

Step 3: Sensors and Controls

- Loop Type and Sensor Location: Verify that all photosensors have been properly located. Per §130.1(d)2D, an individual photosensor must be located so that it is not readily accessible. This placement is intended to make it difficult to tamper with the photosensor. Photocontrols that are part of a wallbox occupant sensor do not comply and shall not be considered an acceptable photocontrol device.
- The photosensor must be located so that can readily sense daylight entering into the daylit area.
- Closed loop sensors – sensors that measure both daylight and the controlled electric light shall be located within the area served by the controlled lighting.
- Open loop sensors – sensors that mostly measure the daylight source shall be outdoors or near a skylight or window and typically oriented toward the window or skylight.

Control Adjustment Location: Adjustments to the controls must be “readily accessible” to authorized personnel or are in ceilings that are 11 ft. or less.

- Readily accessible means that one can walk up to the control adjustment interface and access it without climbing ladders, moving boxes etc. The control can be in a locked cabinet to prevent unauthorized access. Controls that can be adjusted via a wireless handheld device would also qualify as being readily accessible.
- Controls that are mounted in ceiling cavities must be within 2 ft. of the ceiling access and the ceiling access must be no more than 11 ft. above the floor.

Step 4: Control System Documentation

Verify that the setpoints, settings and programming on each of the control system device has been documented and provided by the installer.

Step 5: Daylit Zone Circuiting

Verify that the luminaires in the Daylit Zone are controlled separately from those outside the Daylit Zone. Further, verify that the luminaires in daylit areas near windows are circuited separately from the luminaires in daylit areas under skylights. Verify the correct Daylit Zone category for luminaires following the spacing requirements stated in the above sections. The Skylit Daylit Zone takes top priority in situations where Daylit Zones overlap, then Primary Sidelit, and finally, Secondary Sidelit. Finally, nte that separate circuiting is not a requirement and not necessary with digital systems.

Step 6: Daylighting Control Device Certification

Verify that installed daylighting controls have been certified to the Energy Commission in accordance with the applicable provisions of §110.9:

- Automatic Daylighting Control Devices
- Interior Photosensors

Verify that model numbers of all daylighting controls are listed on the Energy Commission database as "Certified Appliances & Control Devices" by visiting:

http://www.energy.ca.gov/appliances/database/

C. Functional Testing

There are two separate functional performance tests that are specific to the type of control being tested. The first test is suitable for continuous dimming systems and the second test is for step dimming or step switching controls (both described in detail below).

- Continuous dimming controls are controls that alter the output of lamps in at least 10 steps.
- Step dimming controls alter the output of lamps in less than 10 steps (typically up to four steps between on and off).
- Step switching controls turns lamps or groups of lamps on and off without any steps between on and off.
- Stepped switching controls are able to provide multi-level lighting by having more than one group of lamps being controlled. Partial light output (and partial power consumption) of the stepped switching lighting system is provided by turning some of the lamps on.

The tests for stepped switching and stepped dimming controls are combined as the discrete steps of light output render them sufficiently similar for functional testing.

Note: Many of the steps in these acceptance tests can be conducted while setting up the controls according to manufacturer's instructions. Read these tests prior to conducting equipment set-up and bring the documents along while conducting set-up. This way you can conduct the equipment set-up and perform the acceptance test at the same time.

1. Sampled functional performance testing of systems smaller than 5,000 ft²

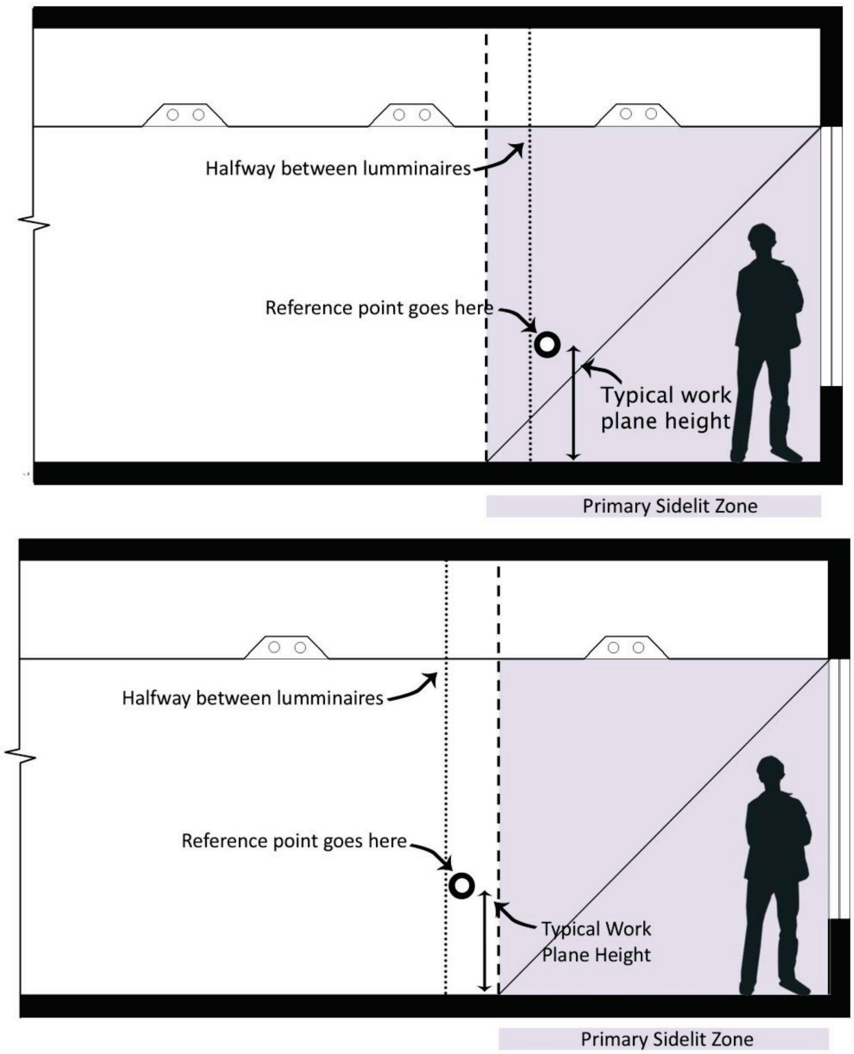
All photocontrols serving a Daylit Zone more than 5,000 ft² shall undergo functional testing. Photocontrols that are serving Daylit Zones less than 5,000 ft² are allowed to be tested on a sampled basis. The sampling rules are as follows:

- For buildings with up to five (5) photocontrols, all photocontrols shall be tested.
- For buildings with more than five (5) photocontrols, sampling may be done within spaces with similar sensor types, cardinal orientations of glazing, and Daylit Zone categories (Skylit, Primary Sidelit, and Secondary Sidelit).
- If the first photocontrol in the sample group passes the functional test, the remaining building spaces in the sample group also pass, with the provision that the basic function of the rest are observed to appear to be functional.
- If any photocontrol in the sample group fails, it shall be repaired or replaced as required until it passes the test and all photocontrols in the sample group must be tested.
- This process shall repeat until all photocontrols have passed the test or the photocontrol tested passes on the first testing.

2. Zone Illuminated by Controlled Luminaires

The functional performance requirements for both continuous dimming and step (dimming or switching) controls call for "all areas being served by controlled lighting" being between 100 and 150 percent of the night time electric lighting illuminance. Without checking all points in the zone served by controlled lighting, verifying that the requirements are met at a worst case location somewhat removed from windows or skylights is sufficient. This location is called the "Reference Location" and is described in the functional performance tests in the next section.

Figure 13-11: Zone Illuminated by Controlled Luminaires and Reference Location for Measuring Reference Illuminance



Also note that the "zone illuminated by the controlled lighting" is not the same as the Primary Sidelit, Secondary Sidelit or Skylit Daylit Zones. The Sidelit and Skylit Daylit Zones define which luminaires must be controlled. Luminaires in the Sidelit or Skylit Daylit Zones must be controlled by automatic daylighting controls, and luminaires outside of these areas must not be controlled by the same automatic daylighting control.

The edge of the zone illuminated by the controlled lighting is halfway between the controlled lighting and the uncontrolled lighting. The only situation this is not so, is when the edge of the daylit zone is defined by a partition. The zone illuminated by the controlled luminaires can be smaller than the daylit area when the uncontrolled luminaires are near the edge of the daylit area [see example (a) of Figure 13-11]. Alternatively the zone illuminated by the controlled luminaires can be larger than the daylit area when the controlled luminaires are near the edge of the daylit area [see example (b) of Figure 13-11].

Continuous Dimming Control Systems – Functional Performance Test

1. *Purpose of the Test:*

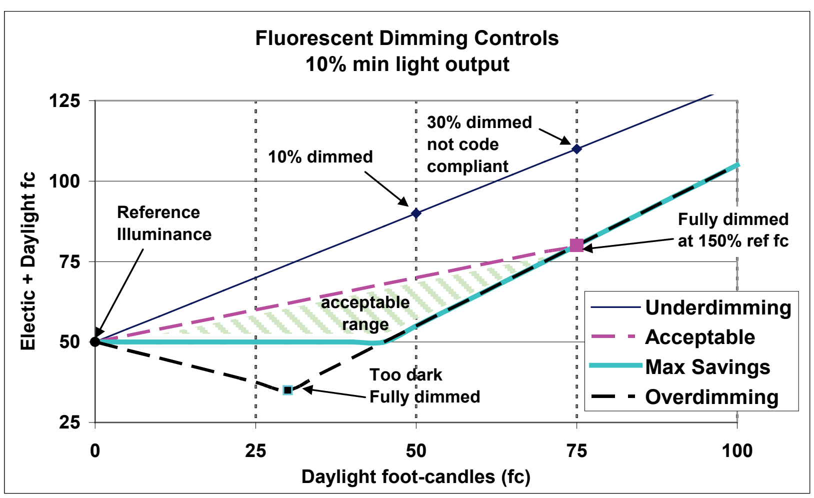
This test is for continuous dimming systems with more than 10 steps of light output from the controlled lighting. For instructions on acceptance testing of other systems with less than 10 steps of control, skip this section and proceed to the next section Stepped Switching or Stepped Dimming Control Systems Functional Performance Test.

2. *Criteria for Passing the Test*

Key criteria for passing the functional performance test are:

- When there is NO daylight in the space, all controlled luminaires are within a reasonable distance from design output or full rated output and power consumption.
- Where there is full daylight in the space (daylight alone provides adequate illumination in space), luminaires in the daylit zone use less than 35 percent of full rated power. Accommodation is made for a task tuned lighting system in this process.
- When there is partial daylight (between 60 and 95 percent of the design illuminance) in the space, the luminaires in the daylit zone are dimmed so that the illuminance at the reference location is between the design illuminance and 150 percent of the design illuminance.
- The shaded triangle labeled “acceptable range” in Figure 13-12, illustrates the range of total illumination levels that will comply with this requirement.

Figure 13-12: Performance of dimming controls - total light (daylight + electric light) versus daylight



3. How to Conduct the Test and Fill the Document

Step 1: Identify Reference Location

The Reference Location is the location in zone served by the controlled lighting that is receiving the least amount of daylight.

The Reference Location will be used for light level (illuminance in foot-candles) measurements in subsequent tests. The Reference Location is used in testing the daylighting controls so that it can be assured that all occupants in the zone served by the controlled lighting always have sufficient light.

The Reference Location can be identified using either the illuminance method or the distance method. The illuminance method is preferred.

Illuminance Method:

- Turn OFF controlled lighting and measure daylight illuminances within zone illuminated by controlled luminaires. Note that the zone illuminated by the controlled luminaires is not necessarily the same as the daylit area. See the Section above with the heading "*Zone Illuminated by Controlled Luminaires*."
- Identify the Reference Location; this is the location with lowest daylight illuminance in the zone illuminated by controlled luminaires. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading "Zone Illuminated by Controlled Luminaires"
- Turn controlled lights back ON.

Distance Method:

- Identify the Reference Location; this is the location within the zone illuminated by controlled luminaires that is furthest way from daylight sources. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading "Zone Illuminated by Controlled Luminaires". Note that this method is not likely to produce the most consistent result and should be avoided in preference to the illuminance method above.

Step 2: "No Daylight" Test

The purpose of the "no daylight" test is to provide a baseline light level, the Reference Illuminance, against which the test professional will be comparing the performance of the system during daylit conditions. This test is also verifying that the control is providing adequate light at night.

When conducting this test, the other lights in the space should be turned off. Simulate or provide conditions without daylight. This condition can be provided by any of the applicable methods:

- Conducting this part of the test at night, or
- Leave a logging light meter at the Reference Location(s) overnight. The logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended. You must disable any occupant sensor or time clock to use this approach.
- Closing blinds or covering fenestration so that very little daylight enters the **test** zone. Very little daylight is less than 1 fc for warehouses and less than 5 fc for all other occupancies. For open loop systems only, one may cover the photosensor to simulate no daylight conditions. Covering the sensor is not allowed for closed loop controls **to** assure that the control will work correctly at night as well during the day.

- When **daylight from the space** is not possible to exclude during this test, the Reference Illuminance can be calculated by subtracting the daylight illuminance from the combined illuminance (footcandles) of the electric lighting and daylight. The daylight illuminance is measured by turning off the controlled lights.

Reference Illuminance (Preferred Method):

Document the Reference Illuminance (fc) – the horizontal electric lighting illuminance (footcandles) at the Reference Location identified in Step 1.

- This measurement is taken by an illuminance sensor (light meter) 30 inches above floor level. The sensor should be facing upwards. Mounting the light meter on a tripod is recommended so that consistent measurements are taken. Try not to shade the meter with your body while taking measurements.

Power Measurement (Optional):

If a current or power measurement is going to be used in Step 3 to show power reduction under fully dimmed conditions, collect full load current or power. To best do this, ensure that the lighting system does not have any task tuning or lumen maintenance adjustments in the control system.

- This is not normally necessary for systems with dimming fluorescent ballasts. It is easier just to compare electric lighting illuminance. For more details see Step 3 "Full Daylight Test."

Full load rating or measurement:

The full load rating can be obtained a number of ways:

- One may also choose to manipulate the calibration adjustments (remember to write down the setting first before changing them) to obtain full light output from the controlled lighting. This might require turning the setpoint very low and turning the high limit very high. It may also require that the control system does not have active task tuning or lumen maintenance adjustments incorporated into the control system. Discuss your approach with the control manufacturer with their recommendations to get full light output. If the photosensor is accessible, covering the photosensor is a way to assure full light output.
- If you cannot eliminate all daylight from the area or other electric light from other luminaires: Turn the controlled lighting on and off. The difference in light level will be the contribution of the controlled lighting.
- If one is measuring power or amps, the rated amps can be directly measured under this condition. Verify that only the controlled lights in the daylit area are being measured. You may want to disconnect and re-energize this circuit to assure you are measuring what you intend.
- The rated amps or power from the manufacturer's cut-sheet is also sufficient.

Step 3: Full daylight test.

Simulate or provide bright conditions so that the illuminance (fc) from daylight only at the Reference Location identified in Step 1 is greater than 150 percent of the Reference Illuminance (fc) measured at this location during the 'no daylight' test documented in Step 2.

- Simulating a bright condition can be accomplished by opening all shading devices to allow natural daylight into the space.
- If natural conditions are not adequate at the time of the test, shine a bright flashlight or other light source onto the photosensor.
- Temporarily change the setpoint to a very low value for the duration of this test. Then return the setpoint to its normal setting.

Verify and document

- Lighting power reduction is at least 65 percent under fully dimmed conditions. Lighting power reduction can be determined as follows:
- Dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric light output is reduced by 75 percent or greater from rated output. With a task tuned lighting system, the dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric light output is reduced by 69 percent or greater.
- Dimming metal halide is deemed to have reduced power by 44 percent when light output is reduced by 75 percent.
- One method of attaining the 65 percent power reduction with dimming metal halide systems is to turn off half of the luminaires and dim the other half.
- The power reduction in higher performing dimming ballasts can be estimated from lighting output reductions if it is accompanied with a manufacturer's ballast cut sheets containing a ballast input power vs. percent light output curve or table.
- Power reduction can be directly measured using either a power meter or an ammeter. The percent reduction in current will be a sufficient representation of the percent reduction in power. Dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric load is reduced by 65 percent or greater from full connected load. With a task tuned lighting system, the dimming fluorescent lighting is deemed to reduce power by 65 percent when the controlled electric load is reduced by 56 percent or greater.

The system lighting power reduction is given by the following relations:

Reduction = Fraction of lights turned off + Fraction of lights dimmed x power reduction of the dimmed lamps

Where,

The power reduction of dimmed lamps =

(Rated power – dimmed power) / rated power

Example: When a metal halide dimming system dims half of the lamps and the other half of the lamps are automatically switched off. The System Power Reduction, SPR is:

SPR = 0.5 + (0.5 x 0.44) = 0.72 or 72 percent

This is above the 65 percent threshold.

- Verify that only luminaires in appropriate Daylit Zone are affected by daylight control.

- Primary Sidelit Daylit Zones have to be separately controlled from Secondary Sidelit Daylit Zones, and vice versa. They may use a single sensor for implementation, but the control response formulas must be distinct.
- Sidelit Daylit Zones have to be separately controlled from Skylit Daylit Zones.

The daylighting control assigned to a specific Daylit Zone shall not control fixtures beyond the Zone, with the exception of Primary and Secondary Sidelit Daylit Zones in which both share a boundary.

- Verify that light output is stable with no discernible flicker.

  The intent of this requirement is to ensure the lights do not flicker because occupants may override the system if light flicker is an annoyance. Flicker refers to a rapid fluctuation in light output that can be detected by the human eye.

Step 4: Partial daylight test.

Simulate or provide bright conditions where illuminance (fc) from daylight only at the Reference Location is between 60 and 95 percent of Reference Illuminance (fc) documented in Step 2. These partial daylight illuminance conditions can be achieved by:

- Scheduling the test so that daylight conditions are within this fairly broad range of illuminances.

Verify and document

- Measured combined illuminance of daylight and controlled electric lighting (fc) at the Reference Location
- Verify this measured illuminance is no less than the Reference Illuminance documented in Step 2, and
- Verify this measured illuminance is no greater than 150 percent of the Reference Illuminance (fc) documented in Step 2

This test assures that the control does not over-dim and leave people with insufficient light in the Reference Location of the Zone served by the controlled lights. This also makes sure that the control does not under-dim thus misses energy savings opportunities. By setting the upper bound of illuminance to 150 percent of the Reference Illuminance, this leaves plenty of room for non-optimal configurations, adaptation compensation, and variations in the sensor field of view.

Note: Adaptation compensation is a control strategy that accounts for people needing less light at night. When someone walks into a store late at night from a parking lot with light levels at 1 fc they may not need or want light at 50 fc. Thus a store may decide to have higher light levels during the day than at night. This protocol would allow daytime light levels that are 50 percent higher than the night time light levels.

Stepped Switching or Stepped Dimming Control Systems Functional Performance Test

1. *Purpose of the Test:*

This functional performance test is for systems that have no more than 10 discrete steps of control of light output. For instructions on how to test systems with more than 10 steps of control including those systems where the dimming appears to be continuous proceed to the previous section: Continuous Dimming Control Systems - Functional Performance Test.

If the control has three steps of control or less, conduct the following tests for all steps of control. If the control has more than three steps of control, testing three steps of control is sufficient for showing compliance.

If these tests are to be conducted manually (spot measurements) it is recommended to test the system with the time delay minimized or otherwise overridden so the test can be conducted more quickly.

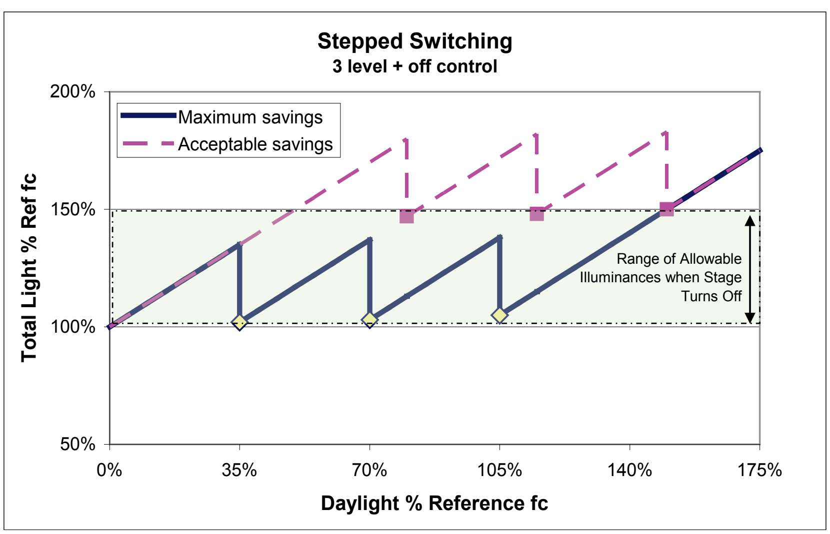
These tests can also be conducted with a logging (recording) light meter. In this case, the time delay should be left on so the recorded data also shows the results of the time delay. In the logging method, one would print out a plot of the day's illuminance at the Reference Location and annotate the plot showing where each stage of lighting had shut off and how the light level just after shutting off for each stage is between the Reference Illuminance and 150 percent of the Reference Illuminance.

2. Criteria for Passing the Test:

Key criteria for passing the functional performance test are:

- When there is NO daylight in the space, all controlled luminaires are at rated lighting output and power consumption.
- When there is full daylight in the space (daylight alone provides greater than 150 percent of the Reference Location illumination in space), luminaires in the daylit zone use less than 35 percent of rated power.
- When there is some daylight in the space, the luminaires in the daylit zone are switched or dimmed appropriately.
- If the control has three steps of control or less all steps of control are tested. If the control has more than three steps of control, testing three steps of control is sufficient for showing compliance.
- There is a time delay of at least 3 minutes between when daylight changes from little daylight to full daylight and the luminaire power consumption reduces through dimming.

Figure 13-13: Performance of compliant switching controls - total light (daylight + electric light) versus daylight



As shown in Figure 13-13, the acceptance tests will confirm that the total illuminance at the reference location is between 100 and 150 percent of the reference illuminance. The highlighted points on the plots (squares and diamonds) indicate the daylight and total light levels at the reference location just after the lights on each stage of control have turned off or dimmed.

The plot of the “Maximum savings” control illustrates how this control maximizes the possible lighting energy savings without under-lighting the space. Systems with lower control setpoints than the “Maximum savings” control would not be compliant as the control would under-light the space during certain times of the day and would likely lead to the control being disabled.

The plot of the “Acceptable savings” control shows how this control maintains light levels above the reference illuminance for all daylight hours but still saves enough energy to be minimally compliant. Systems with higher setpoints than those of the “Acceptable savings” control would not be compliant.

3. How to Conduct the Test and Fill the Document

Step 1: Identify Reference Location

The Reference Location is the location in Zone served by the controlled lighting that is receiving the least amount of daylight. The Reference Location will be used for light level (illuminance in foot-candles) measurements in subsequent tests. The Reference Location is used in testing the daylighting controls so that it can be assured that all occupants in the Zone served by the controlled lighting always have sufficient light.

If lighting controls are staged so that one stage is closer to the daylight source, identify a minimum daylighting location for each stage of control.

If lighting controls are NOT staged based on distance to the daylight source, select a single minimum daylighting location representing all stages of the control. This minimum daylighting location for each stage of control is designated as the Reference Location for that stage of control and will be used for illuminance measurements in subsequent tests.

The Reference Location can be identified using either the illuminance method or the distance method.

Illuminance Method:

- Turn OFF controlled lighting and measure daylight illuminances within zone illuminated by controlled luminaires
- Identify the Reference Location; this is the location with lowest daylight illuminance in the zone illuminated by controlled luminaires.
- Turn controlled lights back ON.

Distance Method:

- Identify the Reference Location; this is the location within the zone illuminated by controlled luminaires that is furthest way from daylight sources. Note that zone illuminated by controlled luminaires is not necessarily the same as the Daylit Zone. See the note above with the heading “Zone Illuminated by Controlled Luminaires”. Note that this method is not likely to produce the most consistent result and should be avoided in preference to the illuminance method above.

Step 2: 'No Daylight' Test

Simulate or provide conditions without daylight for a stepped switching or stepped dimming control system. This condition can be provided by any of the applicable methods:

- Conducting this part of the test at night.
- Leave a logging light meter at the Reference Location(s) overnight, (the logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended). The occupant sensor or time clock system must be overridden for this approach to work.
- Closing blinds or covering fenestration so that very little daylight enters the zone you are testing, (very little daylight is defined as less than 1 fc for warehouses and less than 5 fc for all other occupancies).
- Cover the photosensor.

If the control is manually adjusted (not self-commissioning), make note of the time delay and override time delay or set time delay to minimum setting. This condition shall be in effect through Step 4.

When conducting this test, the other lights in the space should be turned off.

Verify and document

- Automatic daylight control system turns ON all stages of controlled lights.
- Document the Reference Illuminance (fc) – the horizontal electric lighting illuminance (footcandles) at the Reference Location identified in Step 1.
- This measurement is taken by an illuminance sensor (light meter) 30 inches above floor level. The sensor should be facing upwards. Mounting the light meter on a tripod is recommended so that consistent measurements are taken. Try not to shade the meter with your body while taking measurements.
- When it is not possible to exclude daylight from the space during this test, the Reference Illuminance can be calculated by subtracting the daylight illuminance from the combined illuminance (footcandles) of the electric lighting and daylight. The daylight illuminance is measured by turning off all nearby lights including the controlled lights.
- For step dimming controls, calculate power consumption using manufacturer-provided cut-sheet information or measure the power consumption.
- (Optional) If a current or power measurement is going to be used in Step 3 to show power reduction under full daylight conditions, collect full load current or power. *Note:* no power measurements are needed for step switching systems.

Step 3: Full Daylight Test

Simulate or provide bright conditions so that the illuminance (fc) from daylight only at all of the Reference Location(s) identified in Step 1 is greater than 150 percent of the corresponding Reference Illuminance(s) documented in Step 2.

- Simulating a bright condition can be accomplished by opening all shading devices to allow natural daylight into the space.

- If natural conditions are not adequate at the time of the test, shine a bright flashlight or other light source onto the photosensor.
- Temporarily change the setpoint to a very low value for the duration of this test then return the setpoint to its normal settings.

Verify and document

- Lighting power reduction of controlled luminaires is at least 65 percent of rated power consumption. Methods of doing this include:
- For switching systems, at least 2/3s of the lamps are turned off.

  Note: for switching systems, power measurement is unnecessary. The fraction of power reduction is easily estimated without taking power measurements. The fraction of power reduction is calculated by counting the number of lamps that are switched off versus the total number of lamps providing general lighting in the Daylit Zone.
- For stepped dimming systems, either calculate the fraction of rated power at the dimming stage from the ballast manufacturer's cut sheet or calculate from power measurements taken during the No daylight and full daylight tests.
- If using the manufacturer's cut-sheet, wattage at full output and dimmed amounts are given. A copy of this cut-sheet must be attached to the acceptance testing form. Count the number of dimmed fixtures and those fully turned off to calculate reduced power operation. If calculated power is 35 percent or less of the power calculated in Step 2, this meets the criteria.
- If using measured power or current draw of the controlled fixtures. If measured power or current draw is 35 percent or less the value from Step 2, the criteria is met.
- Only luminaires in Daylit Zones (Skylit Daylit Zone, Primary Sidelit Daylit Zone and Secondary Sidelit Daylit Zone) are affected by daylight control.
- Automatic daylight control system reduces the amount of light delivered to the space relatively uniformly as per §130.1(d).
- All lights are dimmed.
- Alternating lamps, alternative fixtures or alternating rows of fixtures are turned off.

Step 4: Partial daylight test

For each stage of control that is tested in this step, the control stages with lower setpoints than the stage tested are left ON and those stages of control with higher setpoints are dimmed or controlled off. This step is repeated for up to three stages of control between full on and full dimmed or full off condition.

One of the stages selected for testing should reduce power draw between 30 and 50 percent of system rated power (for switching systems a stage that turns off between a third and a half of the lamps). That test will help confirm that the system can reduce power between 30 and 50 percent.

Simulate or provide moderately bright conditions so that each control stage turns on and off or dims. Methods to do this include:

- **Adjusting blinds or shades.** Note that the time delay needs to be disabled to use this method. Slowly increase the daylight illuminance until a stage of lighting turns off. Make note of the total combined and electric lighting illuminance at the Reference Location just after the stage of lights turned off. Continue increasing daylight illuminance by opening blinds or shades for at least two more stages of control
- **Light logging.** Leave a logging light meter at the Reference Location(s) for one day with a bright afternoon. Note that the occupant sensor system must be disabled to use this method. The logger should be collecting data on an interval no longer than 1 minute per reading, taking reading on even shorter intervals is recommended.
- **Open loop ratio method.** If the system is open loop (the light sensor senses mainly daylight) the amount of daylight in the space is presumed proportional to the amount measured at the open loop sensor. Adjust setpoint until control turns lights off or are dimmed. Make note of daylight illuminance at the reference location and control setpoint or sensor illuminance display.

If the sensor measures 300 fc while there is 30 fc of daylight at the Reference Location, the ratio of Sensed fc to fc at Reference Location is 10 to 1. If the needed daylight illuminance is 50 fc a setpoint of 500 sensed fc is deemed to provide control at 50 fc.

Verify and document the following for each tested control stage:

The tests do not need to be performed for more than three stages of control.

- The total daylight and electric lighting illuminance level measured at its Reference Location just after the stage of control dims or shuts off the stage of lighting.
- The total measured illumination shall be no less than the Reference Illuminance measured at this location during the No Daylight test documented in Step 2.
- The total measured illumination shall be no greater than 150 percent of the Reference Illuminance.
- The control stage shall not cycle on and off or cycle between different levels while daylight illuminance remains constant.

  Cycling is prevented by having a dead band that is sufficiently large. The dead band is the difference between the setpoint for turning the control stage ON and the setpoint for turning that control stage OFF. The dead band must be greater than the sensor measurement of the light level steps to prevent cycling of lamps on and off.

For manual testing, control time delay is overridden so it is quickly apparent if the dead band is set appropriately.

- If the dead band is too small, the system will cycle. This will be an annoyance and may lead to the system being disabled by irritated occupants.
- If the dead band is set too large, the system will not save as much energy as it could.
- To manually set a dead band, adjust the daylight level or the setpoint so that the setpoint matches the daylight illuminance. Reduce the dead band until the system cycles and then increase the dead band until the system stops cycling.

Step 5: Verify time delay

- Verify that time delay automatically resets to normal mode within 60 minutes of being over ridden.
- Set normal mode time delay to at least 3 minutes.
- Confirm that there is a time delay of at least 3 minutes between the time when illuminance exceeds the setpoint for a given dimming stage and when the control dims or switches off the controlled lights.

Note: One can force a change of state and by dropping the setpoint substantially and timing how long it takes for the control stage to switch off or dim.

13.25 NA 7.6.3 Demand Responsive Controls Acceptance

At-A-Glance

Demand Responsive Controls Acceptance
Use Document NRCA-LTI-04-A
Purpose of the Test
The purpose of the test is to ensure that the demand responsive control is capable of reducing the power consumption of the lighting system to no more than 85 percent of full power (or, if the lighting system is “tuned” to a lower output, 85 percent of the tuned output). The test also confirms that the lighting system produced a reasonably uniform level of light during a demand response event.
With a fully functional demand responsive lighting system, the building owner or operator can save money by reducing their lighting power consumption during periods of high power cost and/or periods of grid instability. As well as saving money, this also improves the reliability of the power grid for all consumers.
Instrumentation
This test requires EITHER an illuminance meter or a power meter (with a current transformer and voltmeter). Alternatively, if the lighting system has an inbuilt method of measuring (not estimating) the lighting power being consumed, this inbuilt measurement may be used instead.
Test Conditions
All luminaires are wired and powered. Put the lighting system into a state that is representative of typical daytime use. Identify the input(s) to the lighting system that are intended to function as demand responsive controls. These will be listed in column H of the lighting control schedule on the Lighting Certificate of Compliance, NRCC-LTI-02-E. If possible, take measurements in non-daylit areas, to make the calculations loss prone to error.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours **Equipment Test**: 0.5 to 1 hours (depending on the number of controlled luminaires)

Acceptance Criteria
The demand response system(s) are able to receive and respond to a suitable demand response signal from a utility or other provider, or from another building system. Note that the functional test does not actually require a demand response signal to be given; it only requires the tester to verify that the system is capable of receiving and responding. The demand response system is capable of reducing the power consumed by the lighting system to no more than 85 percent of full output, while preserving adequate uniformity in task areas.
Potential Issues and Cautions
If using Method 1 (Illuminance Measurement), find a way to mark the exact locations in which the illuminance measurements were made, because even slightly differences in the location of the illuminance meter, or the angle at which it is held, can significantly affect the readings. If possible, take readings away from shadowed areas. If illuminance measurements or power measurements are taken in daylit areas with photocontrols, the values can change very significantly in just a few minutes, due to changes in daylight availability. Try to take measurements as far from sources of daylight as possible.

A. Test Application

Newly Constructed Buildings: Applies to demand responsive lighting controls.

Preparing for Sampling:

- For buildings with up to seven (7) enclosed spaces requiring demand responsive lighting controls, all spaces shall be tested.
- For buildings with more than seven (7) enclosed spaces requiring demand responsive lighting controls, sampling may be done on additional spaces with similar lighting systems.
  - Sampling shall include a minimum of 1 enclosed space for each group of up to 7 additional enclosed spaces.
  - If the first enclosed space with a demand responsive lighting control in the sample group passes the acceptance test, the remaining building spaces in the sample group also pass.
  - If the first enclosed space with a demand responsive lighting control in the sample group fails the acceptance test the rest of the enclosed spaces in that group must be tested.
- If any tested demand responsive lighting control system fails it shall be repaired, replaced or adjusted until it passes the test.

B. Construction Inspection

Verify the following:

- The demand responsive control is capable of receiving a demand response signal directly or indirectly through another device and that it complies with the requirements in §130.5(e).

  §130.5(e): *Demand responsive controls and equipment shall be capable of receiving and automatically responding to at least one standards based messaging* *protocol, which enables demand response after receiving a demand response signal.*

Definition from §101: *DEMAND RESPONSE SIGNAL is a signal sent by the local utility, Independent System Operator (ISO), or designated curtailment service provider or aggregator, to a customer, indicating a price or a request to modify electricity consumption, for a limited time period.*

This requirement has three main elements:

1. "Capable of receiving". The demand response control must have an electronic input that can carry a messaging protocol, as described below. This does not need to be a dedicated input; it can carry other signals in addition to the demand response signal. In practice, this could be an EMCS connection.
2. "Automatically responding to". The control must be capable of responding to the demand response signal automatically, without human assistance or intervention.
3. "Standards based messaging protocol". The term 'protocol' refers to a format for conveying messages, so the input to the demand responsive control must be able to convey different messages. It must be more than just a contact closure or similar binary input.

- If the demand response signal is received from another device (such as an EMCS), that system must itself be capable of receiving a demand response signal from a utility meter or other external source.

  This means that the EMCS or other system must meet the same requirements given above for a demand responsive control. It must be capable of receiving a standards-based protocol, and the lighting system must respond automatically.

C. Functional Testing

The functional test ensures that the demand responsive control can set the lighting to a lower-power condition, in line with the requirements set out in Energy Standards, Reference Appendix NA7.

1. Criteria for Passing the Test

The demand responsive system must:

- Reduce the lighting power to no more than 85 percent of "full output". Full output is defined in the field test as being the output of the lighting system when all manual switches are on, but some luminaires may be dimmed or switched below their maximum output because they are "tuned" or because they are controlled by automatic systems such as photocontrols and vacancy sensors.
- Ensure that the visual conditions for occupants under the demand response condition are still comfortable, and allow them to work uninterrupted during the event. When the demand responsive control is activated, the output of the lighting system must still be at least half of its output in the "full output" condition.
- Ensure that light levels do not go below any preset minimums that have been determined, for instance, by facilities managers. This is the purpose of the "minimum output test".

Simulating a Demand Response Event

If the demand responsive control has a "test mode" that allows the demand response condition to be simulated, this is adequate for the Acceptance Test; the tester does *not* have to confirm that the demand responsive control responds to a real signal.

However, if the control does not have a test mode, then the input signal must be simulated. In some cases this may be simple, for instance if the control responds to a contact closure. However, if the control can only be tested by providing it with a specific demand response signal, then that signal must be generated during the Acceptance Test.

Taking Illuminance Measurements

Using the illuminance measurement method (Method 1) requires the tester to take two illuminance measurements at the same location several minutes apart. This process can incur a high degree of error, which can be minimized by observing these precautions:

- Find easily-repeatable locations. Leave a marker such as a sticky note to record the exact location of the illuminance meter, or put the meter in a clearly defined location such as a join between cubicle partitions.
- Avoid shadows. Shadows can move in between measurements if they're caused by daylight, and if the edge of the shadow falls across the illuminance meter's sensor, the reading will be very unreliable.
- Avoid daylit areas. Daylight can vary in brightness significantly in the course of just a few seconds, so place the illuminance meter as far as possible from windows, ideally not in direct line of sight.
- Hold the meter at arm's length, or squat below the level of the sensor. Many illuminance meters require a button to be held in while taking measurements, and your body and head will shade the sensor. Minimize the error caused by this effect by holding the meter at arm's length or by squatting down to remove your head and body from the path of the incoming light.

Area-Weighting Calculations

The area-weighting calculations required by the functional test are simple, though the equation on the documents is complicated. An example is given below in Table 13-7.

The following measurements were taken in a building, for the full output test. For convenience, all the daylight measurements are zero.

Table 13-7: Example of an Area-Weighting Calculation

Lines a and c have been omitted for clarity		Space number		
		1	2	3
b.	Take one illuminance measurement at a representative location in each space, using an illuminance meter.	30 fc	35 fc	40 fc
d.	Take one illuminance measurement at the same locations as above, with the electric lighting system in the demand response condition.	15 fc	20 fc	40 fc
e.	Turn off the electric lighting and measure the daylighting at the same location (if present)	0 fc	0 fc	0 fc
f.	Calculate the reduction in illuminance in the demand response condition, compared with the design full output condition. [((line b - line e)- (line d – line e)) /(line b - line e)]	50 percent	43 percent	0 percent
g.	Note the area of each controlled space	2000 sf	800 sf	1300 sf
h.	The area-weighted reduction must be at least 0.15 (15 percent) but must not reduce the combined illuminance from electric light and daylight to less than 50 percent of the design illuminance in any individual space.	{(50 percentx2000) + (43 percentx800) + (0 percentx1300)} = 2000 + 800 + 1300 = 32.8 percent……so the space complies.		

13.26 NA 7.7.6.2 Lighting Controls Installed to Earn a Power Adjustment Factor (PAF) for Institutional Tuning

At-A-Glance

Lighting Controls Installed to Earn a Power Adjustment Factor (PAF) for Institutional Tuning
Use Document NRCA-LTI-05-A
Purpose of the Test
Institutional Tuning is the process of adjusting the maximum light output of lighting systems to support visual needs or save energy. Institutional tuning differs from personal tuning in that the control strategy is implemented at the institutional rather than the individual user level, and maximum light level adjustments are available only to authorized personnel. Completion of this acceptance test certifies that lighting systems receiving the Institutional Tuning Power Adjustment Factor, comply with §140.6(a)2J and Reference Nonresidential Appendix NA7.7.6.2.

Instrumentation
Recommended Instrumentation: • Light meter (luminance or foot-candle meter) • Hand-held amperage meter or power meter • Logging light meter or power meter
Test Conditions
All luminaires are wired and powered. Put the lighting system into a fully operational state.
Estimated Time to Complete
Construction Inspection: 0.25 to 0.5 hours **Equipment Test**: 0.5 to 1 hours (depending on the number of controlled luminaires)
Acceptance Criteria
To qualify for the PAF an Institutional Tuning in Table 140.6-A of the Energy Standards, the tuned lighting system shall comply with all of the following requirements: • The lighting controls shall limit the maximum output or maximum power draw of the controlled lighting to 85 percent or less of full light output or full power draw; and • The means of setting the limit is accessible only to authorized personnel; and • The setting of the limit is verified by the acceptance test required by §130.4(a)7; and • The construction documents specify which lighting systems shall have their maximum light output or maximum power draw set to no greater than 85 percent of full light output or full power draw.
Potential Issues and Cautions
Luminaries that qualify for other PAFs may also qualify for the Institutional Tuning PAF. However, PAFs may only be added together if permitted in Table 140.6-A of the Energy Standards.

A. Test Application

Newly Constructed Buildings only. Luminaries that qualify for other PAFs may also qualify for the Institutional Tuning PAF. However, PAFs may only be added together if permitted in Table 140.6-A.

Prepare for Sampling:

- For buildings with up to seven (7) enclosed areas, to claim the Institutional Tuning PAF, all areas must be tested.
- For buildings with more than seven (7) areas, to claim the Institutional Tuning PAF, random sampling may be done on (7) seven of the larger enclosed areas with tuned dimming systems.

- If any of the areas in the sample group of (7) seven areas fails the acceptance test, another group of (7) seven areas must be tested.
- If any tested system fails, it shall be tuned until it passes the test.

B. Construction Inspection

Prior to Functional Testing, verify and document the following:

- The controls or the methods of controlling the maximum output of luminaires is such that the maximum light output of the controlled lighting system can be limited and that normal operation of the controlled lighting does not override the maximum light output.
- The controls are not readily accessible to unauthorized personnel.

C. Functional Testing

For each area to be tested, do the following:

- The acceptance test technician shall either observe the first seven (7) systems being successfully tuned or shall verify systems that have already been tuned using the sampling protocol described in NA7.7.6.2.
- If the acceptance test technician is observing the tuning of the system, the party responsible for the tuning shall certify that the remainder of the system is tuned in a similar manner.

Observation of the systems during Institutional Tuning

Step 1: Determination of maximum power or output prior to Institutional Tuning

- Set all lighting controls to provide maximum output of the tested system without applying the limits specified for institutional tuning.
- Measure the full light output at a location where the luminance is due to the controlled lighting, or measure the power draw of the controlled lighting.

Step 2: Institutional Tuning and Post-tuning Measurement

- Apply the limits specified for institutional tuning to the lighting system. Do not alter any other control settings.
- Verify the light or power reduction after institutional tuning by measuring the light output at the same location as in Step 1 or measure the power draw of the same circuit as in Step 1.
- If the light output or power draw measured in Step 2(b) is 85 percent or less of the light output or power draw measured in Step 1(b), the system passes this test; otherwise the system fails this test.

Verification of systems already tuned

Step 1: Measurement of tuned lighting system

- Set all lighting controls except Institutional Tuning controls to provide maximum output of tested system. Controls set to maximum light output include but not limited to: manual dimmers, multilevel occupancy sensing, and automatic daylighting controls.

- Measure full light output at location where most of the luminance is due to the controlled lighting or measure power draw of the controlled lighting.

Step 2: Measurement of lighting system with Institutional Tuning overridden

- Reset Institutional Tuning controls to allow full light output. Set all lighting controls to provide maximum output of tested system including but not limited to: Institution Tuning control, manual dimmers, multilevel occupancy sensing, and automatic daylighting controls.
- Measure full light output at the same location as in Step 1 or measure the power draw of the same circuit as in Step 1.
- If the light output or power draw measured in Step 1(b) is 85 percent or less of the light output or power draw measured in Step 2(b), the system passes this test; otherwise the system fails this test.

Step 3: Restore Institutional Tuning settings

- If tested system passed the test in Step 2, restore Institutional Tuning to initial settings.

13.27 NA7.8 Outdoor Lighting Shut-off Controls

At-A-Glance

NA7.8 Outdoor Lighting Shut-off Controls
Use Document NRCA-LTO-02-A
Purpose of the Test
The purpose of these tests is to ensure that all outdoor lighting regulated by §130.2(c) are automatically turned off during daytime and are controlled by a motion sensor, photocontrol, astronomical time-switch control, part-night outdoor lighting control or automatic scheduling control, as required. Automated controls to turn off outdoor lighting during daytime hours, and when not needed during nighttime hours, prevent energy waste.
Instrumentation
This test verifies the functionality of installed automatic controls visually and does not require special instrumentation.
Test Conditions
All outdoor luminaires must be wired and powered. Lighting control system must be installed and ready for system operation, including completion of all start-up procedures, per manufacturer’s recommendations.
Estimated Time to Complete
Construction Inspection: 0.5 to 2 hours (depending on familiarity with lighting control programming language) **Equipment Test**: 0.5 to 2 hours (depending on familiarity with lighting control programming language, number of lighting circuits to be tested)

Acceptance Criteria
Lights turn off when daylight is available.
Automatic time switch controls turn off the lighting when not needed at night
Motion sensors reduce lighting power by at least 40 percent but not exceeding 90 percent.
The correct date and time are properly set in the lighting controllers.
Astronomical time switch controls and automatic time switch controls have been certified to the Energy Commission in accordance with the applicable provision in §110.9. Verify that model numbers of all such controls are listed on the Energy Commission database as "Certified Appliances & Control Devices."
http://www.energy.ca.gov/appliances/database/

A. Test Application

Newly Constructed and Additions/Alterations: Applies to functional testing and verification of motion sensor location and ensures the sensor coverage is not blocked by obstruction.

- Verifies the sensor signal sensitivity is adequate.
- Verifies the outdoor lighting shut-off control during daytime hours.
- Verifies the astronomical and standard shutoff controls are programmed for weekdays, weekends and holiday schedules.

NA7.8.1 – and NA 7.8.2 Motion Sensor

The motion sensor must be installed in conjunction with a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.

Prepare for allowable sampling:

- For buildings with up to seven (7) outdoor motion sensors, all outdoor motion sensors shall be tested.
- For buildings with more than seven (7) outdoor motion sensors for outdoor lighting system, sampling may be done on outdoor areas with similar sensors that cover similar unobstructed areas.
  - Sampling shall include a minimum of 1 outdoor motion sensor for each group of up to 7 additional outdoor motion sensors.
  - If the first sensor in the sample group passes the acceptance test, the remaining outdoor areas in the sample group also pass.
  - If the first sensor in the sample group fails the acceptance test, the rest of the sensors in that group shall be tested.
- Any failed sensor in the sample group shall be repaired or replaced and retested until the sensor passes the test.

B. Construction Inspection

Prior to Functional testing, verify and document:

- Motion sensor has been located to minimize false signals.
- Sensor is not triggered by motion outside of adjacent area. Desired motion sensor coverage is not blocked by obstruction that could adversely affect performance.

- Desired sensor coverage is not blocked by obstructions that could adversely affect performance.

C. Functional Testing

Test conditions: Simulate or provide conditions so that outdoor photocontrol or astronomical time switch is in night time mode and is otherwise turning lights ON.

Simulate motion in area under lights controlled by the sensor.

Verify and document

- Status indicator operates correctly.
- Lights controlled by motion sensors turn on immediately upon entry into the area lit by the controlled lights near the motion sensor.
- Signal sensitivity is adequate to achieve desired control.

Simulate no motion in area with lighting controlled by the sensor.

Verify and document

- Lights controlled by motion sensors turn off within a maximum of 20 minutes from the start of an unoccupied condition per §110.9(b).
- The occupant sensor does not trigger a false “on” from movement outside of the controlled area.
- Signal sensitivity is adequate to achieve desired control.

NA 7.8.3 and NA 7.8.4 Photocontrol

B. Construction Inspection

Verify and document:

- The photocontrol is installed.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on.

NA7.8.5 and NA 7.8.6 Astronomical Time-Switch Control

B. Construction Inspection

Prior to Functional Testing, confirm and document:

- Verify the astronomical time-switch control is installed.
- Verify the astronomical time switch control is programmed with acceptable ON schedule and OFF schedule
- Demonstrate and document for the time switch programming including ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the astronomical schedule.
- During nighttime simulation, all controlled outdoor lights are turned off in accordance with the programmed schedule.

NA7.8.7 and NA 7.8.8 Part-night Outdoor Lighting Control

Note: The part-night outdoor lighting control must be installed in conjunction with a photocontrol or astronomical time switch that automatically turns off the outdoor lighting when daylight is available.

B. Construction Inspection

Prior to Functional Testing for time based control type, confirm and document:

- Verify the part-night outdoor lighting control is installed.
- Verify the control is programmed with acceptable schedules.
- Demonstrate and document for the lighting control programming including both ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

Prior to Functional Testing for occupancy-based control type, verify and document:

- Sensor has been located to minimize false signals.
- Sensor is not triggered by motion outside of adjacent area.
- Desired sensor coverage is not blocked by obstructions that could adversely affect performance.

C. Functional Testing

For time-based control type, verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the ON schedule.
- During nighttime simulation, all controlled outdoor lights are turned off or reduced in light level in accordance with the OFF schedule.

For occupancy-based control type, verify and document:

Step 1: Simulate motion in area under lights controlled by the sensor. Verify and document the following:

- Status indicator operates correctly.
- Lights controlled by sensors turn on immediately upon entry into the area lit by the controlled lights near the motion sensor.
- Signal sensitivity is adequate to achieve desired control.

Step 2: Simulate no occupancy in area with lighting controlled by the sensor. Verify and document:

- Lights controlled by the sensor are off or reduces light output within a maximum of 20 minutes from the start of an unoccupied condition.
- The sensor does not trigger a false “on” from movement outside of the controlled area.
- Signal sensitivity is adequate to achieve desired control.

NA7.8.9 and NA 7.8.10 Automatic Scheduling Control

B. Construction Inspection

Prior to functional testing, confirm and document:

- Verify the automatic scheduling control is installed.
- Verify the control is programmed with acceptable schedules.
- Demonstrate and document for the lighting control programming including both ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).
- Verify the correct time and date is properly set in the control.

C. Functional Testing

Verify and document:

- During daytime simulation, all controlled outdoor lights are turned off.
- During nighttime simulation, all controlled outdoor lights are turned on in accordance with the ON schedule.
- During nighttime simulation, all controlled outdoor lights are turned off in accordance with the OFF schedule.

13.28 NA7.13.1 Compressed Air Systems

At-A-Glance

NA7.13 Compressed Air System Acceptance
Use Document NRCA-PRC-01-A
Purpose of the Test
The purpose of functionally testing the controls of a compressed air system is to confirm that the controls are set up in a compliant manner. A compliant system will choose the most efficient combination of compressors, given the current air demand as measured by a sensor, according to §120.6(e)2 of the Energy Standards. This test is designed for flexibility, as this covers both newer compressed air systems designed for use with controls and older compressed air systems under direction of controls for the first time.

Instrumentation

Instrumentation to perform the test includes:
• Power meter(s) for each compressor
• Pressure transducer(s) for each compressor
• Sensor or set of sensors to measure or infer current air demand, including but not limited to:
  o Flow meter
  o Set of pressure transducers
  o Pressure transducers and power meters

Test Conditions
Equipment installation is complete (including compressors, storage, controls, and piping). Compressed air system must be ready for system operation, including completion of all start-up procedures per manufacturer's recommendations. For a new compressed air system, the trim compressor(s) must be identified prior to conducting the test. Document the initial conditions before overrides or manipulation of the settings, if any. All systems must be returned to normal at the end of the test. If using a valve to achieve a steady demand, ensure that this will not affect any equipment downstream.
Estimated Time to Complete
Construction Inspection: 1 to 1.5 hours (depending on complexity of the system) **Functional Testing**: 1 to 3 hours (depending on familiarity with the controls and issues that arise during testing)
Acceptance Criteria
The states of each compressor will be observed throughout the duration of the test. By the end of the 10-minute duration, each compressor must not exhibit short-cycling or blow-off. For new compressed air systems, the trim compressors are the only compressors that can be partially loaded. All base compressors must be either fully loaded or off by the end of the test.
Potential Issues and Cautions
For older systems, it may not be feasible to run at a steady demand for 10 minutes. In these cases, still observe the compressors to ensure that the controls are operating efficiently.

A. Test Application

Newly Constructed and Additions/Alterations: All new compressed air systems, and all additions or alterations of compressed air systems, where the total combined online horsepower of the compressor(s) is 25 horsepower or more, must be tested.

The purpose of the installed controls is to choose the best combination of compressors for a given current demand. This test verifies that the installed controls have been set up to make these choices.

Ideally, the best combination of compressors keeps all base compressors either fully loaded or off with any given demand. The only compressors that should be partially-loaded are compressors that operate well partially-loaded, deemed as trim compressors.

This test is designed for flexibility, as this covers both older and newer compressed air systems. Older compressed air systems may be under direction of controls for the first time and may require compressors to be partially loaded.

Controls need to be able to determine real-time demand with a sensor (or calculate demand by a set of sensors). A flow sensor may do the task directly.

B. Construction Inspection

Prior to the functional test, the system and compressor specifications must be documented. In addition, the method for determining the current air demand and the state of each of the compressors must also be documented. Having this documented will assist in determining if the controls are working properly. The following sections provide instructions on the data that must be verified during the Construction Inspection and included on the Acceptance Document.

a. Compressor Specifications

Note the following data on the Acceptance Document. Most of this information can be identified from compressor specification sheets or the nameplate. This includes:

- Size (in rated horsepower)
- Rated Capacity (in actual cubic feet per minute)
- Control Type
    - Fixed Speed
    - Variable Speed
    - Variable Displacement
    - Inlet Modulation
    - Centrifugal
    - Other
- Designation as a Trim Compressor

If in doubt, contact the plant manager or controls designer, who should have this information readily available.

b. System Specifications

Note the online system capacity on the Acceptance Document. The online system capacity refers to the sum total capacity of all the compressors that will be in operation and connected to the control system. Once the compressor specifications are identified, taking the sum of every compressor’s rated capacity should yield the online system capacity.

Note the operating system pressure on the Acceptance Document. The operating system pressure should match up with the rated operating pressure of each of the compressors, also found in the specification sheets.

c. Method for Determining Current Air Demand

Note the method for determining the current air demand on the Acceptance Document. There are a variety of ways to determine current air demand, which is the load required to safely run all downstream operating equipment. Since equipment operation is variable, the current air demand will also be variable. Tracking the real-time air demand is important to a well-functioning control system.

The controls designer should be aware of this method, as it is crucial to the operation of the controls.

It's important to document the following in this explanation of the method:

- Sensors and tools being used to determine the current air demand.
- What each sensor is measuring.
- Calculations (if necessary) used to determine the current air demand (in acfm).

d. **Method for Determining the State of the Compressors**

A compressor, at any given time, is operating in one of the following states:

- Off (0 percent of Rated Power)
- Unloaded (15-35 percent of Rated Power)
- Partially Loaded
- Fully Loaded (100 percent of Rated Power)

As with current air demand, there are a few ways you can determine the state of the compressor. All states, aside from the Partially Loaded state, can be easily determined with a power meter and the rated power of the compressor. For example, if a compressor is fully loaded, the power meter for this compressor should read near 100 percent of the rated power. If the compressor is unloaded, it will be approximately 15-35 percent of rated power. If the compressor is off, it should be at or near 0 kW of power.

Determining if a compressor is partially loaded would vary based on the compressor's control scheme. A fixed speed compressor would cycle between loaded and unloaded (or off and on) if it were partially loaded.

Both variable speed drive and variable displacement compressors match power and air output somewhat linearly. As air output decreases, then power also decreases in direct proportion. Thus, operating between 35-99 percent rated power may qualify as partially loaded.

The best way to determine if a compressor is Partially Loaded is to install a flowmeter at the discharge of the compressor. If the acfm output is less than the rated acfm of the compressor, it is running Partially Loaded. When there is no flow, but the motor is still running, the compressor is Unloaded. When there is no flow and the motor is not running (the power reading is near 0 kW), the motor is considered OFF.

Note the method for determining the compressors' states on the Acceptance Document.

In addition to these states, it is important that none of the compressors exhibit the following behavior:

- Short-cycling (loading and unloading more often than once per minute)

  Short-cycling is easily measured with a stopwatch and a power meter or flowmeter. Simply observe if any compressors are cycling between the loaded and unloaded state. If so, measure the frequency by counting how many cycles are achieved over the 10 minute duration of the test. If it is more than 10 on-off cycles, then the compressor is short-cycling.

- Blowoff (venting compressed air at the compressor itself)

Blowoff is a state that will need to be observed rather than measured. This is sometimes used to limit flow delivered to a compressed air system, where the air is vented to the atmosphere. This is usually noisy and obvious, though compressors can be outfitted with silencers. For Centrifugal compressors, this is sometimes necessary to prevent surge (and compressor damage) when running at partial load. The reason for exhibiting blowoff at a particular compressor should be noted during the Functional Testing.

C. Functional Testing

Step 1: Verify that the methods from the Construction Inspection have been employed by confirming the following:

- Compressor states can be observed and recorded for every compressor.

  As documented in the Construction Inspection, ensure that the proper tools are installed and operational. Confirm that if external sensors are needed to determine the state of each compressor, they are calibrated. The power meter and flow meter should read levels that are at or below the rated power input and air capacity, respectively (as recorded in Document NRCA-PRC-01-A).

- The current air demand (in acfm) can be measured or inferred.

  The easiest way to accomplish this is to install a flowmeter at the common header. This can be achieved by other methods, but this will need to be documented in the Notes section of Document NRCA-PRC-01-A.

Step 2: Run the compressed air supply system steadily at as close to the expected operational load range as can be practically implemented for at least 10 minutes.

Verify the following:

- System is running steadily for at least 10 minutes.

  It is the intent to observe a system running normally and at steady state.

- System is running near to the expected operational load range.

  Confirm that the controls are operating as expected. Running the system in the typical operational range is one way to accomplish this intent, though will require some communication with the plant manager to get an idea of this range. For example, does the system typically operate closer to 40-50 percent or 80-90 percent of the total online system capacity?

- Downstream equipment is not affected by a test valve being open, if applicable.

  Running a system steadily may be difficult without a valve installed near a common header (in the distribution system upstream of the demand side of the system) that will release air to the atmosphere. If a test valve is not used, it’s recommended that the plant manager be contacted to determine a good time during the day when the system will be running steadily for a period longer than 10 minutes. For the case with a test valve, the pressure may drop below what is safe for some equipment. If there is equipment that must be running during the time of the test, take this into account when deciding how to perform the test.

If it is not possible to achieve a steady air demand for a 10 minute period of time, document the reason why and observe the state of the compressors during the 10 minute test. Observe any anomalies and document this in the Notes section.

Step 3: Observe and record the states of each compressor and the current air demand during the test.

Fill out the table for Step 3 in Document NRCA-PRC-01-A. If any state is difficult to determine, then document your specific observations and measurements in the Notes section.

Step 4: Confirm that the system exhibits the following behavior following the test:

- No compressor exhibits short-cycling.

  If any compressor was cycling between loaded and unloaded during the test, and if the number of on-off cycles exceeds 10, this portion of the test fails. Circle N in Document NRCA-PRC-01-A.
- No compressor exhibits blowoff.

  If any compressor is venting pressurized air to the atmosphere, this portion of the test fails. Circle N in Document NRCA-PRC-01-A
- The trim compressors are the only compressors partially loaded, while the base compressors will either be fully loaded or off by the end of the test. (only applicable for new systems)

  This is a requirement for new systems because these systems are required to have properly sized trim compressors. If the new systems are designed properly, the controls should operate in a manner that has the trim compressors responsible for the trim load on top of fully loaded base compressors.

  If any compressor is in the Partially Loaded state that is not a trim compressor, this portion of the test fails. Circle N in Document NRCA-PRC-01-A.

  For an existing system, circle NA in NRCA-PRC-01-A.

Step 5: Return system to initial operating conditions.

13.29 NRCA-PRC-02-A: Commercial Kitchen Exhaust

At-A-Glance

NA7.11.1 Commercial Kitchen Exhaust
Use Document NRCA-PRC-02-A
Purpose of the Test
The following acceptance tests apply to commercial kitchen exhaust systems with Type I exhaust hoods. All Type I exhaust hoods used in commercial kitchens shall be tested.
Instrumentation
Smoke candles or smoke puffers (smoke bombs are not permitted), actual cooking at the normal production rate is also a reliable method of generating smoke. Space differential pressure sensor. Recording Analog Manometer with Pitot Tube and VelGrid.
Test Conditions
Exhaust and make-up air systems are installed and fully functional. Demand Ventilation Control systems (if installed) are fully functional and have been set up and calibrated by the installing contactor.

For Kitchens with greater than 5,000 cfm of Type I and Type II kitchen hood exhaust, All Type I hoods meet the requirements of Table 140.9-A.
Estimated Time to Complete
Construction inspection: 0.5 hour **Functional testing:** 1 hour (for each system)
Acceptance Criteria
• Smoke was fully captured. • All Type I hoods are drawing exhaust at less than or equal to the values in Table 140.9-A. • DCV and MUA system respond. • Timed override works • DCV and MUA systems respond to full load conditions (all Yes)
Potential Issues and Cautions
Coordinate test procedures with the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed and Additions/Alterations: All newly installed Type 1 exhaust hoods used in commercial kitchens must be tested.

B. Construction Inspection

Verify exhaust and replacement air systems are installed, power is supplied and the control systems such as demand control ventilation are calibrated.

For kitchen/dining facilities having total Type 1 and Type II kitchen hood exhaust airflow rates greater than 5,000 cfm, calculate the maximum allowable exhaust rate for each Type 1 hood per Table 140.9-A.

C. Functional Testing

The following acceptance test applies to systems with and without demand control ventilation exhaust systems. These tests shall be conducted at full load conditions.

Step 1: Operate all sources of outdoor air providing replacement air for the hoods.

Step 2: Operate all sources of recirculated air providing conditioning for the space in which the hoods are located.

Step 3: Operate all appliances under the hoods at operating temperatures.

Step 4: Verify that the thermal plume and smoke is completely captured and contained within each hood at full load conditions by observing smoke or steam produced by actual cooking operation and/or by visually seeding the thermal plume using devices such as smoke candles or smoke puffers. Smoke bombs shall not be used (note: smoke bombs typically create a large volume of effluent from a point source and do not necessarily confirm whether the cooking effluent is being captured). For some appliances (e.g., broilers, griddles, fryers), actual cooking at the normal production rate is a reliable method of generating smoke). Other appliances that typically generate hot moist air without smoke (e.g., ovens, steamers) need seeding of the thermal plume with artificial smoke to verify capture and containment.

Step 5: Verify that space pressurization is appropriate (e.g. kitchen is slightly negative relative to adjacent spaces and all doors open/close properly).

Step 6: Verify that each Type 1 hood has an exhaust rate that is below the maximum allowed.

Step 7: Make adjustments as necessary until full capture and containment and adequate space pressurization are achieved and maximum allowable exhaust rates are not exceeded. Adjustments may include:

- Adjust exhaust hood airflow rates.
- Add hood side panels.
- Add rear seal (back plate).
- Increase hood overhang by pushing equipment back.
- Relocate supply outlets to improve the capture and containment performance.

Step 8: Measure and record final exhaust airflow rate per Type 1 hood.

The following additional acceptance test shall be performed on all exhaust hoods with demand control ventilation exhaust systems.

Step 1: Turn off all kitchen hoods, makeup air and transfer systems.

Step 2: Turn on one of the appliances on the line and bring to operating temperature. Confirm that:

1. DCV system automatically switches from off to the minimum flow setpoint.
2. The minimum flow setpoint does not exceed the larger of:
   - 50 percent of the design flow.
   - The ventilation rate required per §120.1.
3. The makeup air and transfer air system flow rates modulate as appropriate to match the exhaust rate.
4. Appropriate space pressurization is maintained.

Step 3: Press the timed override button. Confirm that system ramps to full speed and back to minimum speed after override times out.

Step 4: Operate all appliances at typical conditions. Apply sample cooking products and/or utilize smoke puffers as appropriate to simulate full load conditions. Confirm that:

1. DCV system automatically ramps to full speed.
2. Hood maintains full capture and containment during ramping to and at full-speed.
3. Appropriate space pressurization is maintained.

13.30 NRCA-PRC-03-F: Parking Garage Exhaust

At-A-Glance

NA7.12.1 Parking Garage Exhaust
Use Document NRCA-PRC-03-F
Purpose of the Test
Verify that airside economizers function properly
Instrumentation
Space differential pressure sensor CO span gas with a concentration of 30 ppm (+/- 2 percent)
Test Conditions
Each CO sensor has a valid factory calibration certificate (+/-5 percent) CO sensors are located in areas of high CO concentration per 120.6(c) CO control setpoint is at or below 25ppm for all sensors per 120.6(c)
Estimated Time to Complete
Construction inspection: 1 hour **Functional testing:** 2 hour
Acceptance Criteria
During a time of low activity • All sensors active and reading a setpoint of <25ppm • Exhaust fans are running at minimum speed. • Exhaust fans are drawing <30 rated power. Applied required CO span gas testing • All sensors active and reading a setpoint of between 25 and 35ppm • Exhaust fans are running at maximum speed. • Exhaust fans go back to minimum speed when span gas is removed. • Temporary override of the programmed sensor calibration/replacement; observation that fans ramp to full speed and an EMCS alarm is set. • System in unoccupied mode: observation that fans ramp to full speed and an alarm is received by the facility operators. • Programmed occupied sensor proximity zone alarm differential; observation that fans ramp to full speed and an alarm is received by the facility operators.
Potential Issues and Cautions
Coordinate test procedures with the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed and Additions/Alterations: All newly installed parking garage ventilation systems with carbon monoxide control must be tested.

B. Construction Inspection

Verify and document the following tests prior to the functional testing:

- Carbon monoxide control sensor is factory-calibrated per §120.6(c).
- The sensor is located in the highest expected concentration location in its zone per §120.6(c).
- Control setpoint is at or below the CO concentration permitted by §120.6(c).

C. Functional Testing

Conduct the following tests with garage ventilation system operating in occupied mode and with actual garage CO concentration well below setpoint.

Step 1: With all sensors active and all sensors reading below 25 ppm, observe that fans are at minimum speed and fan motor demand is no more than 30 percent of design wattage.

Step 2: Apply CO span gas with a concentration of 30 ppm, and a concentration accuracy of +/- 2 percent, one by one to 50 percent of the sensors but no more than 10 sensors per garage and to at least one sensor per proximity zone. For each sensor tested observe:

- CO reading is between 25 and 35 ppm.
- Ventilation system ramps to full speed when span gas is applied.
- Ventilation system ramps to minimum speed when span gas is removed.

Step 3: Temporarily override the programmed sensor calibration/replacement period to 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore calibration/replacement period.

Step 4: Temporarily place the system in unoccupied mode and override the programmed unoccupied sensor alarm differential from 30 percent for 4 hours to 1 percent for 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore programming.

Step 5: Temporarily override the programmed occupied sensor proximity zone alarm differential from 30 percent for 4 hours to 1 percent for 5 minutes. Wait 5 minutes and observe that fans ramp to full speed and an alarm is received by the facility operators. Restore programming.

13.31 NA7.10.2 Evaporator Fan Motor Controls

At-A-Glance

NA7.10.2 Evaporator Fan Motor Controls
Use Document NRCA-PRC-04-A
Purpose of the Test
This test ensures that the evaporator fans modulate their speed in response to either the space temperature or humidity, as required per §120.6(a)3B. Note that control strategies using humidity are very uncommon and accordingly only methods based on temperature will be described below. If humidity is included in the control logic, the design engineer should be involved in designing the test method.
Instrumentation
Performance of this test will require measuring the temperature of the space served by the evaporators under test. The instrumentation needed to perform the task may include, but is not limited to a temperature calibrated to +/- 0.7°F between -30°F and 200°F.
Test Conditions
The test will be performed by varying the control parameters used by the evaporator fan motor control system. Therefore, the evaporator fan control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. The test should not be performed if the evaporator is in defrost, if a scheduled defrost is eminent, or if the evaporator was recently in defrost. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 0.5 hours (for each evaporator) **Functional testing:** 1 hour (for each evaporator)
Acceptance Criteria
• Evaporator fan controls modulate to increase fan speed, and evaporator fan speed increases in response to controls, when the test temperature setpoint is lowered in 1 degree increments below any control dead band range. • Evaporator fan controls modulate to decrease fan speed, and evaporator fan speed decreases in response to controls, when the test temperature setpoint is raised in 1 degree increments below any control dead band range until fans go to minimum speed.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system. Fan speeds change slowly in normal operation, so the test requires adequate time to allow response.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of evaporator motor fan motor variable speed controls.

B. Construction Inspection

The field technician should check the following:

- All temperature and sensors have been calibrated and read accurately.
- All sensors are mounted in a location away from direct evaporator discharge air draft.
- All evaporator motors are operational and rotate in the correct direction.
- Fan speed control is operational and connected to evaporator fan motors.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

Step 1: Measure the current space temperature and program this temperature as the test temperature into the control system**. Allow 5 minutes for system** to **normalize.**

Verify whether the evaporator fans are controlled based on the space temperature. This step brings the temperature setpoint for the evaporator within range to the current conditions of the space.

Step 2: Using the control system, lower the test temperature setpoint in 1 degree increments below any control dead band range.

Verify:

- Evaporator fan controls modulate to increase fan motor speed, by observing control system readout or variable speed drive readout values.
- Evaporator fan motor speed increases in response to controls, by observation of fan speed or sound level.

Step 3: Using the control system, raise the test temperature setpoint in 1 degree increments above any control dead band range until fans go to minimum speed**.**

Verify:

- Evaporator fan controls modulate to decrease fan motor speed, by observing control system readout or variable frequency drive readout values.
- Evaporator fan motor speed decreases in response to controls, by observation of fan speed or sound level.

Document:

- Record the minimum fan motor control speed and how it was determined.

Note: Control system parameters may utilize percent of full speed, frequency (Hz), or sometimes RPM. Variable Frequency Drive (VFD) readouts may also provide these values, and may not read the same as the control system. The control system programmer may be needed to explain readout values.

Step 4: Restore the control system to correct control setpoints.

Confirm that the control system is restored back to initial space temperature setpoint.

13.32 NA7.10.3.1 Evaporative Condenser Fan Motor Variable Speed Controls

At-A-Glance

NA7.10.3.1 Evaporative Condensers and Condenser Fan Motor Variable Speed Controls
Use Document NRCA-PRC-05-A
Purpose of the Test
This test ensures that the condensing temperature of the condenser is reset in response to ambient wet-bulb temperature, per §120.6(a)4E. This test ensures that the condenser fan speed is continuously variable, and the condenser fans are controlled in unison per §120.6(a)4C. This test ensures that the minimum condensing temperature control setpoint is 70°F or lower, per §120.6(a)4C.
Instrumentation
Performance of this test will require measuring the ambient wet-bulb temperature, relative humidity, and condenser operating pressure. The instrumentation needed to perform the task may include, but is not limited to: • A temperature sensor calibrated to +/- 0.7°F between -30°F and 200°F • A relative humidity (RH) sensor calibrated to +/- 1 percent between 5 percent and 90 percent RH • A pressure sensor shall be calibrated to +/- 2.5 psi between 0 and 500 psig
Test Conditions
The test will be performed by varying the control parameters used by the condenser control system. Therefore, the condenser control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one evaporative condenser) **Functional testing:** 3 hour (for one evaporative condenser)
Acceptance Criteria
• The evaporative condenser minimum condensing temperature control setpoint is 70°F or lower. • The target condensing temperature is reset in response to ambient wet-bulb temperature, by using a temperature difference (TD) between the condensing temperature and the ambient wet-bulb temperature.

- The condenser fan speed is continuously variable and the condenser fans are controlled in unison – varying the speed of all fans serving a common high-side at the same time.

Potential Issues and Cautions

Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system.

To ensure proper overall system operation, make sure that the system pressure is not held at excessively low or high values for an extended period of time when varying the saturated condensing temperature (SCT) control setpoint. Avoid abrupt changes in pressure. Coordinate with facility operator or refrigeration contractor.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of fan motor variable speed control for evaporative condensers.

B. Construction Inspection

The field technician should check the following:

- The minimum saturated condensing temperature (SCT) control setpoint is at or below 70°F.
- The SCT value used by the control system is the temperature equivalent reading of the condenser pressure sensor.
- All drain leg pressure regulator valves (if used) are set below the minimum condensing temperature/pressure setpoint and all receiver pressurization valves, such as the outlet pressure regulator (OPR), are set lower than the drain leg pressure regulator valve setting. This ensures that the pressure regulator valve and receiver pressurization valve settings do not force the actual condensing temperature to be higher than the minimum condensing temperature setpoint. (Note: These regulators are only used on small systems and rarely with evaporative condensers.)
- All pressure, temperatures and humidity sensors have been calibrated and read accurately.
- Temperature and humidity sensors are mounted in a location away from direct sunlight.
- All sensor readings used by the condenser controller convert or calculate to the correct conversion units at the controller (e.g., saturated pressure reading is correctly converted to appropriate saturated temperature; dry-bulb and relative humidity sensor readings are correctly converted to wetbulb temperature, etc.).
- All condenser motors are operational and rotate in the correct direction.
- All condenser fan speed controls are operational and connected to condenser fan motors, and not in bypass.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high to run the test, i.e. with a condensing temperature above the minimum SCT setpoint. The loads can often be increased somewhat as required to perform the Functional Testing. For example, the cooling loads can be temporarily increased by lowering the zone temperature setpoint or allowing more infiltration into the space by opening doors.

If there is insufficient load or the weather is too cold to operate the condensers above the minimum SCT setpoints, there are several options: The test could be scheduled for a warmer day, additional load could be arranged, or a portion of the condenser capacity could be reduced. Methods for reducing condenser capacity include turning off part of the spray pumps, or covering part of the condenser surface (e.g. with cardboard) or fans (taking care not to overload motors).

Step 1: Override any possible conflicting controls. This may include, but is not limited to heat reclaim, hot gas defrost, or defrost head pressure override before performing functional tests.

Work with refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current conditions

- Ambient dry-bulb temperature (DBT), wet-bulb temperature (WBT), and relative humidity (RH).
- Current condenser control temperature difference (Control TD) parameter in the control system. Some control systems may use a pressure equivalent.
- Refrigeration system condensing temperature (SCT) or condensing pressure in psig.
- Calculate the actual condenser temperature difference (Actual TD) which is the temperature difference between the current SCT and the current WBT. This value may be the same as the Control TD.
- Current head pressure control setpoint in °F SCT or psig.

Step 3: Program into the control system a condensing temperature/pressure setpoint equal to the reading or calculation obtained in Step 2. This is typically accomplished by setting the condenser Control TD parameter to the Actual TD from Step 2. The resulting SCT or psig setpoint will be referred to as the “Test Setpoint.” Allow 5 minutes for condenser fan speed to normalize.

Step 4: Using the control system, raise the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to minimum fan motor speed. Raising the test setpoint can be accomplished by increasing the Control TD parameter. The fans may cycle off completely if the control range limit is met so it is important to increase the Test Setpoint in small increments to produce a slow control response.

Verify:

- Condenser fan motor speed decreases.
- All condenser fan motors serving common condenser loop decrease speed in unison in response to controller output; observed at the control system and at the condensers(s).

Document:

- Minimum fan motor control speed (rpm, percent of full speed, or Hz) as observed in the control system and VFD readouts, as available.

Step 5: Using the control system, lower the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to increase fan motor speed**.** Lowering the Test Setpoint can be accomplished by decreasing the Control TD parameter.

Verify:

- Condenser fan motor speed increases.
- All condenser fan motors serving common condenser loop increase speed in unison in response to controller output observed at the control system and at the condensers(s).

Step 6: Document the current minimum saturated condensing temperature (Min. SCT) setpoint, which should be set to 70°F SCT or lower.

Document:

- Current minimum SCT setpoint in the control system

Using the control system, change the Min. SCT setpoint to a value greater than the current system SCT**.**

Depending on system load or weather condition:

1. Reduce the Control TD and/or reduce system load to reduce the operating SCT until actual operation is observed at the Min. SCT value. Verify that fan speed modulates to maintain the Min SCT Value.
2. If weather conditions are too warm, and on load is too high to accomplish the previous test from part A, the Min. SCT setpoint can be increased (above the 70°F value) to observe control at the higher value. Verify that fan speed modulates to maintain this temporary Min. SCT value.

Step 7: Using the control system, restore the system head pressure controls to original settings documented in Steps #2 and 6 (Control TD, Min SCT)**.**

Verify that the control system is restored back to correct control setpoints.

Step 8: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.33 NA7.10.3.2 Air Cooled Condenser Fan Motor Variable Speed Controls

At-A-Glance

NA7.10.3.2 Air Cooled Condenser Fan Motor Variable Speed Controls
Use Document NRCA-PRC-06-A
Purpose of the Test
This test ensures that the condenser fan speed is continuously variable, and the condenser fans are controlled in unison per §120.6(a)4D. This test ensures that the air cooled condenser minimum condensing temperature control setpoint is 70°F or lower, per §120.6(a)4D. This test ensures that the condensing temperature of the condenser is reset in response to ambient dry-bulb temperature, per §120.6(a)4E.
Instrumentation
Performance of this test will require measuring the ambient drybulb temperature and condenser operating pressure. The instrumentation needed to perform the task may include, but is not limited to: • A temperature sensor calibrated to +/- 0.7°F between -30°F and 200°F. • A pressure sensor shall be calibrated to +/- 2.5 psi between 0 and 500 psig.
Test Conditions
The test will be performed by varying the control parameters used by the condenser control system. Therefore, the condenser control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one air cooled condenser) **Functional testing:** 3 hour (for one air cooled condenser)
Acceptance Criteria
• The condenser minimum condensing temperature control setpoint is 70°F or lower. • The target condensing temperature of the condenser is reset in response to ambient drybulb temperature, by using a constant temperature difference (TD) between the condensing temperature and the ambient drybulb temperature. • The condenser fan speed is continuously variable, and the condenser fans are controlled in unison – varying the speed of all fans serving a common high-side at the same time.

Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system. To ensure proper overall system operation, make sure that the system pressure is not held at excessively low or high values for an extended period of time when varying the saturated condensing temperature (SCT) control setpoint. Avoid abrupt changes in pressure. Coordinate with facility operator or refrigeration contractor.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of fan motor variable speed controls for air-cooled condensers.

B. Construction Inspection

The field technician should check the following:

- The minimum saturated condensing temperature (SCT) control setpoint is at or below 70°F.
- The SCT value used by the control system is the temperature equivalent reading of the condenser pressure sensor.
- All drain leg pressure regulator valves (if used) are set below the minimum condensing temperature/pressure setpoint and all receiver pressurization valves, such as the outlet pressure regulator (OPR), are set lower than the drain leg pressure regulator valve setting. This ensures that the pressure regulator valve and receiver pressurization valve settings do not force the actual condensing temperature to be higher than the minimum condensing temperature setpoint. (Note: These pressure regulators are only used on small systems.)
- All pressure and temperature sensors have been calibrated and read accurately.
- Temperature and humidity sensors are mounted in a location away from direct sunlight.
- All sensor readings used by the condenser controller convert or calculate to the correct conversion units at the controller (e.g., saturated pressure reading is correctly converted to appropriate saturated temperature).
- All condenser motors are operational and rotate in the correct direction.
- All condenser fan speed controls are operational and connected to condenser fan motors, and not in bypass.
- All speed controls are in “auto” mode.
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high to run the test, i.e. with a condensing temperature above the minimum SCT setpoint. The loads can often be increased somewhat as required to perform the Functional Testing. For example, the cooling loads can be temporarily increased by lowering the zone temperature setpoint or allowing more infiltration into the space by opening doors.

If there is insufficient load or the weather is too cold to operate the condensers above the minimum SCT setpoints, there are several options:

The test could be scheduled for a warmer day, additional load could be arranged, or a portion of the condenser capacity could be reduced. Methods for reducing condenser capacity include covering part of the condenser surface (e.g. with cardboard) or fans (taking care not to overload motors).

Step 1: Override any possible conflicting controls. This may include, but is not limited to heat reclaim, hot gas defrost, or defrost head pressure override before performing functional tests.

Work with the refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current conditions

- Ambient drybulb temperature (DBT).
- Current the condenser control temperature difference (Control TD) parameter in the control system (some control systems may use a pressure equivalent).
- Refrigeration system condensing temperature (SCT) or condensing pressure in psig.
- Calculate actual condenser temperature difference (Actual TD), which is the temperature difference between the current SCT and the current DBT. This value may be the same as the Control TD.
- Current head pressure control setpoint in °F SCT or psig.

Step 3: Program into the control system a condensing temperature/pressure setpoint equal to the reading or calculation obtained in Step 2. This is typically accomplished by setting the condenser Control TD parameter to the Actual TD from Step 2. The resulting SCT or psig setpoint will be referred to as the “Test Setpoint.” Allow 5 minutes for condenser fan speed to normalize.

Step 4: Using the control system, raise the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to minimum fan motor speed. Raising the test setpoint can be accomplished by increasing the Control TD parameter. The fans may cycle off completely if the control range limit is met so it is important to increase the Test Setpoint in small increments to produce a slow control response**.**

Verify:

- Condenser fan motor speed decreases.
- All condenser fan motors serving common condenser loop decrease speed in unison in response to controller output; observed at the control system and at the condenser(s).

Document:

- Minimum fan motor control speed (rpm, percent of full speed, or Hz) as observed in the control system and at the condenser(s).

Step 5: Using the control system, lower the Test Setpoint in 1 degree (or 3 psi) increments until the condenser fan control modulates to increase fan motor speed**.** Lowering the Test Setpoint can be accomplished by decreasing the Control TD parameter.

Verify:

- Condenser fan motor speed increases.
- All condenser fan motors serving common condenser loop increase speed in unison in response to controller output; observed at the control system and at the condenser(s).

Step 6: Document the current minimum saturated condensing temperature (Min. SCT) setpoint that should be set to 70°F SCT or lower.

Document:

- Current minimum SCT setpoint in the control system.

Step 7: Using the control system, change the Min. SCT setpoint to a value greater than the current system SCT**.**

Depending on system load or weather condition:

1. Reduce the Control TD and/or reduce system load to reduce the operating SCT until actual operation is observed at the Min. SCT value. Verify that fan speed modulates to maintain the Min SCT Value.
2. When weather conditions are too warm, and on load is too high to accomplish the previous test from Part A, the Min. SCT setpoint can be increased (above the 70°F value) to observe control at the higher value. Verify that fan speed modulates to maintain this temporary Min SCT value.

Verify:

- Condenser fan controls modulate to decrease capacity (speed).
- All condenser fans serving common condenser loop modulate in unison.
- Condenser fan controls stabilize within a 5 minute period.

Step 8: Using the control system, restore the system head pressure controls to original settings documented in Steps #2 and 6 (Control TD, Min SCT)**.**

Verify that the control system is restored back to correct control setpoints.

Step 9: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.34 NA7.10.4 Compressor Variable Speed Controls

At-A-Glance

NA7.10.4 Compressor Variable Speed Controls
Use Document NRCA-PRC-07-A
Purpose of the Test
The test ensures that the applicable compressors control compressor speed in response to the refrigeration load, per §120.6(a)5B.
Instrumentation
None
Test Conditions
To perform the test, it will be necessary to override the normal operation of the controls. The control system for the compressor must be complete, including: • Variable speed drive on all applicable screw compressors. • Controls to control the compressor motor speed. Document the initial control settings before executing system overrides or manipulation of the setpoints. The compressor control system must be returned to normal operation at the end of the test.
Estimated Time to Complete
Construction inspection: 1 hour (for one compressor) **Functional testing:** 2 hour (for one compressor)
Acceptance Criteria
• Compressor speed decreases with decrease in load, and the slide valve (or other unloading means) are held at 100 percent capacity until the compressor speed reaches the minimum allowable setpoint. • With an increase in load, the compressor slide valve (or other unloading means) should load to 100 percent capacity, and then the compressor speed should start in increase.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor, or the facility supervisor since they may be needed to assist with the manipulation of the control system.

A. Test Application

Newly Constructed Buildings: Applies to functional testing and verification of compressor variable speed controls.

B. Construction Inspection

The field technician should check the following:

- All applicable single open-drive screw compressors dedicated to a suction group have variable speed control.
- All pressure and temperature sensors have been calibrated and read accurately.
- All sensor readings used by the compressor controller convert or calculate to the correct conversion units at the controller (e.g., saturated suction pressure reading is correctly converted to appropriate saturated suction temperature (SST)).
- All compressor motor speed controls are operational and connected to compressor motors.
- All speed controls are in “auto” mode.
- Compressor panel control readings for “RPMs”, “percent speed”, “kW”, and “amps” match the readings from the PLC or other control systems.
- Compressor data is correctly entered into the PLC or other control system, to the extent required for proper control (e.g. minimum speed)
- Records showing calibration was performed, what offsets or control system calibration values were used, and documentation of the instrumentation used for calibration.

C. Functional Testing

The system cooling load must be sufficiently high for the test, but the compressor should be not operating at fully capacity. Artificially increase the load by decreasing the zone setpoint, or decrease the load by increasing the zone setpoint or turning off evaporators as needed to perform the Functional Testing.

Step 1: Override any floating suction pressure functionality before performing functional tests.

Work with the refrigeration contractor or facility staff to disable controls that may interfere with the Functional Testing.

Step 2: Document current operating conditions. Note these may be the same as the current setpoint.

- Current suction pressure
- Current saturated suction temperature

Step 3: Document current setpoint: *S*uction pressure setpoint or saturated suction temperature setpoint.

Program into the control system a target setpoint equal to the current operating condition measured in Step #2. Allow 5 minutes for system to normalize. This will be referred to as the “test suction pressure/saturated suction temperature setpoint”.

Step 4: Using the control system, increase the test suction setpoint in small increments until the compressor controller modulates to decrease compressor speed. An increase of 1psi or 1°F SST will be appropriate. The increase will need to consider any control dead band or time delay that is in place.

Verify:

- Compressor speed decreases
- Compressor speed continues to decrease to minimum speed
- Any slide valve or other unloading means does not unload until after the compressor has reached its minimum speed.

Step 5: Using the control system, decrease the test suction setpoint in small increments until the compressor controller modulates to increase compressor speed**.** A decrease of 1psi or 1°F SST will be appropriate. The decrease will need to consider any control dead band or time delay that is in place. You must wait a sufficient amount of time so that any timer or delay can expire.

Verify:

- Any slide valve or other unloading means first goes to 100 percent before compressor speed increases from minimum
- Compressor begins to increase speed
- Compressor speed continues to increase to 100 percent

Step 6: Using the control system, program the suction pressure or saturated suction temperature setpoint back to original settings as documented in Step #3**.**

Confirm that the control system is restored back to correct control setpoints.

Step 7: Restore any controls that were disabled in Step 1.

Verify that the control system is restored back to original conditions.

13.35 NA7.10.1 Electric Resistance Underfloor Heating Systems

At-A-Glance

NA7.10.1 Electric Resistance Underfloor Heating Systems
Use Document NRCA-PRC-08-A
Purpose of the Test
This test ensures that the electric resistance underfloor heating system is thermostatically controlled and disabled during the summer on-peak period defined by the electric utility provider. The test verifies that the electric resistance heater is controlled according to the underfloor temperature, and is forced off during the summer on-peak period, as required per §120.6(a)2.
Instrumentation
Performance of this test will require measuring the amperage of the electrical circuit(s) powering the underfloor heating system. The instrumentation needed to perform the task may include, but is not limited to: • A clamp on amp meter

Test Conditions
The test will be performed by varying the control parameters used by the underfloor heater control system. Therefore, the underfloor heater control system must be installed and operating, including completion of all start-up procedures per manufacturer’s or designer’s recommendations, to perform the test. Document the value of the initial control parameters before starting the test.
Estimated Time to Complete
Construction inspection: 2 hours (for one system) **Functional testing:** 4 hours (for one system)
Acceptance Criteria
The underfloor electric resistance heater must do the following: • Turn off when the temperature setpoint is lower than the underfloor temperature (including any dead band or offset). • Turn on when the temperature setpoint is higher than the underfloor temperature (including any dead band or offset). • Automatically turn off (and remain off) if the date and time of the control system falls within the summer on-peak period of the electric utility provider, regardless of the underfloor temperature.
Potential Issues and Cautions
Coordinate test procedures with the refrigeration or controls contractor or the facility supervisor since they may be needed to assist with manipulation of the control system.

A. Test Application

Newly Constructed Buildings with Electric Underfloor Heating Systems: Applies to functional testing and verification of the electric resistance underfloor heating system controls.

B. Construction Inspection

The Field Technician should review that the summer on-peak period is programmed into the electric resistance underfloor heating systems.

C. Functional Testing

Step 1: Using the control system, lower the underfloor temperature setpoint to cycle off the electric resistance heater.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is off.

Step 2: Using the control system, raise the underfloor temperature setpoint to cycle on the electric resistance heater.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is on.

Step 3: Using the control system, change the control system's date and time to correspond to the local utility company summer on-peak period.

Verify and Document:

- Measure the current of the electric heater circuits(s) to confirm the electric resistance heater circuit is off.

Step 4: Restore the control system to correct date and time, and underfloor temperature control setpoints.

Confirm that the control system is restored back to correct date and time, and that the control system is restored to the initial conditions for the underfloor temperature setpoint and schedules.

13.36 NA7.14.1 Elevator Lighting and Ventilation Controls

At-A-Glance

NA7.14.1 Elevator Lighting and Ventilation Controls
Use Document NRCA-PRC-12-F
Purpose of the Test
This test is to ensure that the shut off control turns off the lighting and ventilation fan when the elevator is not occupied for more than 15 minutes. The control system must be able to detect occupancy, and keep the ventilation fan on, in the event that someone is occupying the elevator cabin and the elevator conveyance or doors malfunction §120.6(f).
Instrumentation
This test verifies the functionality of installed automatic controls visually after a prolonged period of time. A clock or stopwatch will be needed.
Test Conditions
The test will be performed by varying the control parameters used by the elevator lighting and ventilation fan control system. Therefore, the elevator lighting and ventilation fan control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test.
Estimated Time to Complete
Construction inspection: 15 min (for one system) **Functional testing:** 1 hour (for one system)
Acceptance Criteria
The elevator lighting and ventilation fan control systems must do the following: Turn off when the cabin doors have been closed for more than 15 • Turn on when the elevator is activated • Remain on after more than 15 minutes with the doors closed
Potential Issues and Cautions
Verifying the lighting and ventilation fans remain on with the doors closed for more than 15 minutes.

A. Test Application

Newly Constructed Buildings and Additions/Alterations: Applies to functional testing and verification of the lighting and ventilation fan system controls.

B. Construction Inspection

The Field Technician must verify that the occupancy sensors have been installed in a location that will minimize false signals, such as pedestrian traffic in the elevator lobby. Also, if an ultrasonic sensor is being used the Field Technician must verify that the sensor does not emit an audible sound.

C. Functional Testing

Step 1: Open the elevator doors.

Verify and Document:

- The lighting and ventilation system turn on.

Step 2: Exit the elevator and allow the doors to close. After 15 minutes, open the elevator doors.

Verify and Document:

- The lighting and ventilation system were off and activated as the elevator doors open. If this method proves too hard to visually verify the lighting and ventilation system were off, then measure the power output of the elevator controls and verify that the lighting and fan power turns off after 15 minutes of being unoccupied.

Step 3: Enter the elevator cabin. Once the doors close, wait 15 minutes.

Verify and Document:

The lighting and ventilation system remained on after 15 minutes.

13.37 NA7.15.1 Escalator and Moving Walkway Speed Control

At-A-Glance

NA7.15.1 Escalator and Moving Walkway Speed Control
Use Document NRCA-PRC-13-F
Purpose of the Test
This test is to ensure that the speed of the escalator or moving walkway slows when not occupied. The control system must be able to detect occupancy, and approaching pedestrians in either direction. §120.6(g).
Instrumentation
This test verifies the functionality of installed automatic controls visually after a prolonged period of time. A clock or stopwatch and calculator will be needed.
Test Conditions
The test will be performed by varying the control parameters used by the escalator or moving walkway control system. Therefore, the control system must be installed and operating, including completion of all start-up procedures per manufacturer's or designer's recommendations, to perform the test.

Estimated Time to Complete
Construction inspection: 30 min (for one system) **Functional testing:** 1 hour (for one system)
Acceptance Criteria
The control systems must do the following: • Reduces speed to a minimum when passengers are not detected • Ramp up to maximum speed when the controls detect an approaching passenger • Sound an alarm if a pedestrian is approaching the conveyance in the wrong direction.
Potential Issues and Cautions
Verifying the sensors are located in the corrected, unobstructed location.

A. Test Application

Newly Constructed Buildings and Additions/Alterations: Applies to functional testing and verification of the speed control system.

B. Construction Inspection

Verify and Document:

- The variable speed drive is installed
- The occupancy sensors have been located to minimize false signals, such as from pedestrians using an adjacent conveyance
- The occupancy sensors do not encounter any obstructions
- Ultrasonic occupancy sensors do not emit an audible sound

C. Functional Testing

Step 1: Determine the Speed of the conveyance using the controller interface (If this method is not applicable skip this step and proceed to Step 2)

Verify and Document:

- The full speed is less than 100 ft/min
- The slow speed is 10 ft/min
- The acceleration and deceleration does not exceed 1 ft/sec

If the speed of the conveyance is determined using this method, then skip steps 2, 4, 6 and 9.

Step 2: Measure the diagonal length of the conveyance

Document:

- The diagonal length in feet.

Step 3: Measure the speed of the conveyance

Document:

- Using a stopwatch, board the conveyance and measure the travel time from one landing to the other. Document the time in seconds.

Step 4: Calculate the speed of the conveyance.

Document:

- Using the data from Steps 2 and 3, divide the length (in feet) by the travel time (in seconds).
- Convert the ft/sec to ft/min by multiplying the ft/sec by 60.

Step 5: Conveyance reduces speed

Verify and Document:

- Using a stopwatch, stand away from the escalator and wait approximately 3 times the escalator travel time. (Step 3 multiplied by 3).
- Verify that the conveyance has slowed to a minimum speed.

Step 6: Verify the minimum speed of the conveyance.

Verify and Document:

- Using a stopwatch, record the time it takes for one step of the conveyance to travel from one landing to the other.
- Using the length from Step 2, Divide the length by the time measured above. This will determine the minimum speed.

Step 7: Verify the occupancy controls

Verify and Document:

- While the conveyance is still at minimum speed, approach at a normal walking pace and verify the conveyance ramps up to full speed before boarding.
- After waiting for the conveyance to reduce speed to a minimum. Approach the conveyance from multiple angles and verify the conveyance ramps up to full speed.

Step 8: Verify the alarm

Verify and Document:

- After waiting for the conveyance to reduce speed to a minimum approach the conveyance from the wrong direction (the exit).
- Verify that the conveyance ramps up to full speed
- Verify that an audible alarm is triggered to alert passengers that they are entering from the wrong direction.

Step 9: Calculate the acceleration of the conveyance

Verify and Document:

- When the conveyance is at minimum speed, approach the conveyance and record the amount of time it takes to reach maximum speed.
- Take the difference of the high and low speeds in ft/sec and divide it by the recorded time above. Verify that the acceleration does not exceed 1 ft/sec.

13.38 Acceptance Test Technician Certification Provider (ATTCP)

13.38.1 Provider Qualifications

The requirements to become either a Lighting Controls or Mechanical Nonresidential Acceptance Test Technician Certification Provider (ATTCP) are very similar. Therefore, in this section we will address both the Lighting Controls and Mechanical ATTCP application requirements together, calling out specific differences when warranted. The perspective ATTCP must submit a written application to the Energy Commission that contains the following three major elements:

A. **Organizational Structure**

a. ***Requirement:*** ATTCPs shall provide written explanations of the organization type, by-laws, and ownership structure. ATTCPs shall explain in writing how their certification program meets the qualification requirements of §10-103.1(c) (or §10-103.2(c)). ATTCPs shall explain in their application to the Energy Commission their organizational structure and their procedures for independent oversight, quality assurance, supervision and support of the acceptance test training and certification processes (§10-103.1(c)1 and §10-103.2(c)1).

b. ***Intent:*** This requirement is necessary to ensure, at a minimum, that the organizations providing certification services to the building industry have a business structure that is conducive to train, certify and oversee Acceptance Test Technicians (ATTs).

c. ***Compliance:*** The Energy Commission has approved several ATTCP applicants and all applications included Articles of Incorporation, Bylaws, Trust Agreements and in one case, the Section 501(c) status (with the corresponding employer identification number) of the organization. Also, a copy of the ethics policy for the ATTCP, while optional, is recommended. This section of the application should also include a description of how the organization is conducive to providing training, certification, oversight and support to the technicians that they will be certifying.

   The ATTCP may also describe what qualifications and experience the ATTCP may have to operate and oversee an accreditation program.

B. **Certification of Employers**

a. ***Requirement:*** The ATTCPs shall provide written explanations of their certification and oversight of Acceptance Test Employers (ATEs). This explanation shall document how the ATTCP ensures that the employers are providing quality control and appropriate supervision and support for their Acceptance Test Technicians (§ 10-103.1(c)2 and § 10-103.2(c)2).

b. ***Intent:*** ATEs must have an understanding of what tasks the ATT is responsible to complete. Additionally, the ATE must manage and provide support to the ATT in performing their tasks. The ATTCP is required to describe the training and requirements that they will place on the ATE for these endeavors and issue certificates to qualified ATE applicants.

c. ***Compliance:*** The Energy Commission recognizes that there are many roads to compliance in regards to ATE training, certification and oversight. Technical training typically consists of 4 to 24 hours of instruction. Quality control, supervision and support requirements implemented by the ATTCP on the ATE can vary considerably. Some elements that the ATTCP might consider implementing, but that are not specifically required by the Energy Commission regulations include the following:

- The ATTCP may develop a policy to address where a change in employment results in no ATE manager or supervisor having completed the ATE training.
- The ATTCP may adopt an ethics policy for ATEs.
- Union contracting requirements: The ATTCP may be restricted to serving unionized technicians only and as a result the ATTCP may require that the ATE be a party in good standing with a union contract. This may entail several significant requirements for the ATE.
- Third-party certificate holders: The ATTCP may require that the ATE hold a valid certificate from a third party such as specific types of Testing and Air Balancing (TAB) training.
- Multiple office management requirements: The ATTCP may consider how they will implement ATE training and certification requirements where an ATE has multiple offices. The ATTCP may consider requiring that an ATE with multiple offices shall ensure a middle or senior management level employee at each office has completed the ATE certification training.
- Restrictive employment practices: the ATTCP may restrict the ATE from employing an ATT that is certified by a different ATTCP. Additionally, the ATTCP may restrict the ATE from holding certificates from multiple ATTCPs.
- Licensing, insurance and safe practices requirements: The ATTCP may require the ATE to provide initial and ongoing proof of workers compensation and general liability insurance (typically a minimum dollar amount is specified), local business licenses, Injury and Illness Prevention Program and Code of Safe Practices (typically required to be consistent with the California Code of Regulations, Sections 1509 and 3203).
- Equipment Policy: The ATTCP may require the ATE to agree to requirements for ensuring that the ATE and ATT possess and properly maintain diagnostic equipment.

C. Certification of Technicians

a. ***Requirement:*** ATTCPs shall include with their application a complete copy of all training and testing procedures, manuals, handbooks and materials. ATTCPs shall explain in writing how their training and certification procedures include, but are not limited to, the following (§10-103.1(c)3 et sec and §10-103.2(c)3 et sec):

i. Training Scope. The scope of the training shall include both hands-on experience and theoretical training to certify competency in the technologies and skills necessary to perform the acceptance tests.

ii. ATT Training.

- **Curricula**. ATTCP training curricula for ATTs shall include, but not be limited to, the analysis, theory, and practical application as required in regulation. The curricula requirements for the Lighting Controls and Mechanical ATT training are significantly different from each other and can be found in §10-103.1(c)3Bi and §10-103.2(c)3Bi.
- **Hands-on training**. The ATTCP shall describe in their application the design and technical specifications of the laboratory boards, equipment and other elements that will be used to meet the hands-on requirements of the training and certification.
- **Prequalification**. Participation in the technician certification program shall be limited to persons who have at least three years of professional experience and expertise (in either lighting controls and electrical systems or mechanical systems) as determined by the ATTCP.
- **Instructor to Trainee Ratio**. The ATTCP shall document in its application to the Energy Commission why its instructor to trainee ratio is sufficient to ensure the integrity and efficacy of the curriculum and program based on industry standards and other relevant information.
- **Tests**. The ATTCP shall describe the written and practical tests used to demonstrate each certification applicant's competence in all specified subjects. The ATTCPs shall retain all results of these tests for five years from the date of the test.
- **Recertification**. The ATTCP shall recertify all ATTs and ATEs prior to the implementation of each adopted update to the Energy Standards as these updates affect the acceptance test requirements.

iii. ATE Training. Training for ATEs shall consist of at least a single class or webinar consisting of at least four hours of instruction that covers the scope and process of the acceptance tests in the Energy Standards.

iv. Complaint Procedures. The ATTCPs shall describe in their applications to the Energy Commission procedures for accepting and addressing complaints regarding the performance of any ATT or ATE certified by the ATTCP, and explain how building departments and the public will be notified of these proceedings.

v. Certification Revocation Procedures. The ATTCPs shall describe in their applications to the Energy Commission procedures for revoking their certification of ATTs and ATEs based upon poor quality or ineffective work, failure to perform acceptance tests, falsification of documents, failure to comply with the documentation requirements of these regulations or other specified actions that justify decertification.

vi. Quality Assurance and Accountability. The ATTCP shall describe in their application to the Energy Commission how their certification business practices include quality assurance and accountability measures, including but not limited to independent oversight of the certification processes and procedures, visits to building sites where certified technicians are completing acceptance tests, certification process evaluations, building department surveys to determine acceptance testing effectiveness, and expert review of the training curricula developed for Building Energy Efficiency Standards, §130.4. The ATTCP shall review a random sample of no less than 1 percent of each ATT's completed compliance documents, and shall perform randomly selected on-site audits of no less than 1 percent of each ATT's completed acceptance tests. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

vii. Certification Identification Number and Verification of ATT Certification Status. Upon certification of an ATT, the ATTCP shall issue a unique certification identification number to the ATT. The ATTCP shall maintain an accurate record of the certification status for all ATTs that the ATTCP has certified. The ATTCP shall provide verification of current ATT certification status upon request to authorized document Registration Provider personnel or enforcement agency personnel to determine the ATT's eligibility to sign Certificate of Acceptance documentation.

b. ***Intent:*** These requirements are the most significant of the ATTCP regulations. They encapsulate all the required training, testing, certification and oversight for the ATTs that the ATTCP must provide. These requirements describe the level of experience, education, professionalism and accountability of the ATT that the Energy Commission is seeking and that the ATTCP must enforce.

c. ***Compliance:***

- The training must include both classroom and laboratory training. In essence, the technician must be instructed on all acceptance tests and then practice those instructions in a laboratory setting. Furthermore, the ATT must be educated on the general science regarding acceptance testing, as well as the procedure to complete and submit the correct acceptance test documents.
- The classroom training must include all of the curricula listed in the regulation, in addition to training on the acceptance tests themselves. Several ATTCPs require extensive classroom training to accomplish this educational requirement. However, one ATTCP requires that each applicant hold a third party certificate of training that the Energy Commission found to be equivalent to the curricula required.
- Each ATT applicant must be prequalified with three years of professional experience (in either lighting controls and electrical systems or mechanical systems). Professional experience is defined by the ATTCP, but generally means experience in a professional occupation that provides training and work experience related to the systems subject to lighting control or mechanical acceptance testing. The ATTCP must clarify the process that they will used to determine what experience is considered professional and relevant to either lighting controls or mechanical acceptance testing as well as to what extent the ATTCP will verify that experience. The following are some relevant questions that the ATTCP should consider when establishing an ATT applicant's prequalified experience but are not required by regulation:
    - How is the experience documented (for example letters from employers or other written evidence) and how is it related to lighting control or mechanical acceptance testing requirements?

  - Should professional experience be demonstrated by requiring applicants to be certified in specifically identified professions, such as:
    - California licensed electrical contractors
    - California licensed mechanical or HVAC contractors
    - California certified general electricians
    - California licensed air conditioning repair contractors
    - California licensed professional engineers
    - Lighting control manufacturer representative
    - Certified commissioning professionals
    - Other professional occupations that are demonstrated to provide industry accepted training and work experience relevant to the systems subject to lighting control or mechanical acceptance testing.

- ATTCPs must have a sufficient number of instructors to effectively train the amount of participants in both classroom and laboratory work. Typically, the instructor to student ratio for classroom training is much higher than for laboratory training. In the applications that the Energy Commission has approved, classroom instructor to student ratios were between 1:25 and 1:35; for laboratory training, the ratios were between 1:6 and 1:12. Most importantly, each ATTCP application included a discussion of the basis for each ratio.
- All ATT applicants will have to take both a written and practical test to demonstrate the applicant's competence in all specified subjects to become a certified ATT. The ATTCP is required to retain all results of these tests for five years from the date the test was taken. When developing and implementing both written and practical tests, the ATTCP may consider the following issues:
  - Consider validating exams by subject matter experts for content.
  - Pilot testing and statistical analysis by qualified psychometricians can identify poor quality questions and bias as well as validating a passing score.
  - Checking exam question response option frequency and other measurements of consistency may help validate the exam rigor and justify passing scores and performance standards.
  - Annually evaluate exam questions to confirm reliability, rigor and lack of bias.
  - Validation for lack of bias consistent with the Uniform Guidelines on Employee Selection Procedures (1978) Federal Register, 43(166), 38290-38315.
  - Adopt measures to ensure exam security such as having multiple versions of exams with random question generation and at least twice the number of questions in a validated question bank than are scored on any given test.
- ATTCPs are required to recertify ATTs each time the Energy Standards are updated with new or modified acceptance test requirements. Recertification is required for all ATTs following an update to the Energy Standards and the Energy Commission approval of the ATTCP training and testing materials. The ATTCP will submit their training and testing materials and recertification process to the Energy Commission for approval. Once approved, the ATTCP will implement the recertification process.

- ATTCPs are required to have procedures for accepting and addressing complaints regarding the performance of any certified ATT or ATE and must have a clear explanation on how building departments and the public can complete these procedures.
- ATTCPs have the authority to decertify ATTs and ATEs based upon poor quality or ineffective work, failure to perform acceptance tests, falsification of documents, failure to comply with the documentation requirements of these regulations or other specified actions that justify decertification.
  - ATTCPs must include quality assurance, independent oversight and accountability measures, such as, independent oversight of the certification processes and procedures, visits to building sites where certified ATTs are completing acceptance tests, certification process evaluations, enforcement agency surveys to determine acceptance testing effectiveness, and expert review of the training curricula developed for the Standards. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard. The regulations require that the ATTCP review a random sample of no less than 1 percent of each technician’s completed compliance documents, and perform randomly selected on-site audits of no less than 1 percent of each ATT’s completed acceptance tests. The consequences of failed audits should be fully described by the ATTCP. ATTCPS might consider whether to require a higher percentage of document and on-site audits the first few years of operation in order to ensure that any initial issues with training or compliance are identified and addressed. For example, one ATTCP proposed the following: For the first three years of operation, review a random sample of 6 percent of each technician's completed documents and perform on-site audits of 6 percent of acceptance tests.
  - For years 4 and 5 of the ATTCP operation, review a random sample of 4 percent of each technician's completed documents and perform on-site audits of 4 percent of acceptance tests.
  - After 5 years of operation, reduce a random sample of 2 percent of each ATT's completed compliance documents and perform on-site audits of 2 percent of acceptance tests.
- Once approved, the ATTCP will issue a unique certification identification number to the ATT and maintain an accurate record of the certification status of the ATT. The regulations require that ATTCPs provide verification of current ATTs' certification status upon request to authorized document Registration Provider personnel or enforcement agency personnel to determine the ATTs' eligibility to sign Certificate of Acceptance documentation according to all applicable regulations. Energy Standards compliance will also be facilitated by requiring the ATT to include their assigned certification number on the compliance documentation, thereby allowing the enforcement agency and the Energy Commission to track the effectiveness of this certification program.
- The ATTCP is not required to implement an on-line presence of any kind for the purposes of compliance with these regulations. However, the applications that the Energy Commission has approved all include the implementation of an on-line presence to contend with the ATT/ATE application processing, complaints process, certification status and ATT/ATE contact information.

13.38.2 Requirements for ATTCPs to Provide Regular Reports

A. Requirements: The ATTCP shall provide the following regular reports to the Energy Commission (§10-103.1(d) and §10-013.2(d)):

a. ***Annual Report:*** The ATTCP shall provide an annual report to the Energy Commission summarizing the certification services provided over the reporting period, including the total number of Acceptance Test Technicians and Employers certified by the ATTCP:

i. During the reporting period.

ii. To date.

The annual report shall include a summary of all actions taken against any Acceptance Test Technician or Employer as a result of the complaint or quality assurance procedures described by the ATTCP as required under §10-103.1(c)3D and §10-103.1(c)3F and §10-103.2(c)3D and §10-103.2(c)3F.

b. ***Update Report:*** The ATTCP shall have not less than six months following the adoption of an update to the Energy Standards to prepare an Update Report. The ATTCP shall submit an Update Report to the Energy Commission not less than six months prior to the effective date of any newly adopted update to the Energy Standards, The ATTCP shall report to the Energy Commission what adjustments have been made to the training curricula, if any, to address changes to the Energy Standards Acceptance Testing requirements, adopted updates to the Energy Standards or to ensure training is reflective of the variety of lighting controls (or mechanical systems) that are currently encountered in the field. All required update reports shall contain a signed certification that the ATTCP has met all requirements under §10-103.1(c) or §10-103.2(c)). Update reports shall be approved through the Amendment Process provided under §10-103.1(f).

All required reports shall contain a signed certification that the ATTCP has met all requirements for this program.

B. Intent: There are two basic reporting requirements for the ATTCP. These reporting requirements are intended to ensure that the Energy Commission has a reasonable level of control on the ATTCP without being unnecessarily involved in the day to day operations of the ATTCP.

C. Compliance:

- The regulations require the ATTCP to submit two periodic reports to the Energy Commission. The first is an annual report documenting the training and certification activities during that year. This report can include adjustments that are proposed, however, these proposals must be approved by the Energy Commission staff or possibly at a formal Energy Commission business meeting. The second report is an update report, where the ATTCP identifies what changes they will need to make to their training and certification requirements in response to changes the Energy Commission has made to the Energy Standards.

13.38.3 Amendment of ATTCP Approved Applications

A. Requirement: The ATTCP may amend a submitted or approved application as described in this Section (§10-103.1(f) and §10-103.2(f)).

a. ***Amendment Scope.***

i. **Nonsubstantive Changes.** A nonsubstantive change is a change that does not substantively alter the requirements of the application materials for the ATTCP, ATT, or ATT Employer. For amendments making only nonsubstantive changes, the ATTCP shall submit a letter describing the change to the Energy Commission as an addendum to the application.

ii. **Substantive Changes.** A substantive change is a change that substantively alters the requirements of the application materials for the ATTCP, ATT, or ATT Employer. For amendments making any substantive changes, the ATTCP shall submit the following:

- A document describing the scope of the change to the application, the reason for the change and the potential impact to the ATTCP, ATT, and ATT Employer as an addendum to the application;
- A replacement copy of the affected sections of the ATTCP application with the changes incorporated; and
- A copy of the affected sections of the ATTCP application showing the changes in underline and strikeout format.

b. ***Amendment Review.*** Amendments submitted prior to approval of an ATTCP application shall be included in the application's Application Review and Determination process specified in §10-103.1(e) or §10-103.2(e).

Amendments submitted after approval of an ATTCP's application that contain only nonsubstantive changes shall be reviewed by the Executive Director for consistency with §10-103.1 or §10-103.2. Amendments determined to be consistent with this Section shall be incorporated into the approval as errata.

Amendments submitted after approval of an ATTCP's application that contain any substantive changes shall be subject to the Application Review and Determination process specified in §10-103.1(e) or §10-103.2(e). If the Energy Commission finds that the amended application does not meet the requirements of §10-103.1or §10-103.2, then the ATTCP shall either abide by the terms of their previously approved application or have their approval suspended.

B. Intent: The amendment process is intended to give the ATTCP an opportunity both during their initial application approval process and post-approval to modify their application or operations. The intent is for ATTCPs to operate as openly as possible with the Energy Commission and address issues as they arise.

C. Compliance: the amendment process is divided in to two groups, substantive and nonsubstantive changes, both during an application review and after the approval of an application. The substantive issues will generally result in an approval from the Energy Commission at a regular Business Meeting. While nonsubstantive issues can be resolved by Staff.

13.38.4 Nonresidential Mechanical Acceptance Test Training and Certification

The Mechanical ATTCP has one additional consideration that is no longer a requirement for the Lighting Controls ATTCP. The Lighting Controls ATTCP has satisfied the Industry Certification Thresholds, which requires that only Certified ATTs can be the signatory for the lighting controls acceptance testing. The Mechanical ATTCP, as of this writing, has not surpassed this threshold.

A. Requirement: Industry Certification Thresholds

Field Technicians can complete acceptance tests for mechanical found in §120.5 without being a certified Mechanical Acceptance Test Technician until the following ATTCP requirements are met (§10-103.2(b)):

1. A minimum of 300 Mechanical Acceptance Test Technicians have been trained and certified to complete the acceptance tests of §120.5 by ATTCP(s) approved by the Energy Commission.
2. ATTCPs provide reasonable access, determined by the Energy Commission, for the training and certification for the majority of professions qualified to complete the work of mechanical field technicians. These professions include: Professional engineers, HVAC installers, mechanical contractors, TABB certified technicians, controls installation and startup contractors and certified commissioning professionals who have verifiable training, experience and expertise in HVAC systems. The Energy Commission will consider, in its determination of "reasonable access," factors such as certification costs commensurate with the complexity of the training being provided, prequalification criteria, curriculum and, class availability throughout the state.

B. Intent

The Threshold requirements have several goals:

1. To make sure that there are enough certified technicians to cover the entire acceptance testing workload that exists in all counties of California.
2. To make sure that any qualified person has access to become certified if they so choose.
3. To ensure that the market is not impacted significantly by a scarcity of certified ATTs.

C. Compliance

When appropriate, the Energy Commission will take up the question of the Threshold requirements for the Nonresidential Mechanical ATTCP program.

NOTE: For Documents and User Instructions, please visit our website at:
http://energy.ca.gov/title24/2016standards

CERTIFICATE OF COMPLIANCE			
NRCC-CXR-01-E	Commissioning Review	Enforce Agency	Commissioning - Design Review Kickoff
NRCC-CXR-02-E	Commissioning Review	Enforce Agency	Commissioning - Construction Documents-General
NRCC-CXR-03-E	Commissioning Review	Enforce Agency	Commissioning - Construction Documents-Simple HVAC Systems
NRCC-CXR-04-E	Commissioning Review	Enforce Agency	Commissioning - Construction Documents-Complex HVAC Systems
NRCC-CXR-05-E	Commissioning Review	Enforce Agency	Commissioning - Design Review Signature Page
NRCC-ELC-01-E	Electrical	Enforce Agency	Electrical Power Distribution
NRCC-ENV-01-E	Envelope	Enforce Agency	Envelope Component Approach
NRCC-ENV-02-E	Envelope	Enforce Agency	Fenestration Component Approach
NRCC-ENV-03-E	Envelope	Enforce Agency	Solar Reflective Index (SRI) Calculation Worksheet
NRCC-ENV-04-E	Envelope	Enforce Agency	Envelope - Daylit Zone Worksheet
NRCC-ENV-05-E	Envelope	Enforce Agency	Fenestration Certificate Label
NRCC-ENV-06-E	Envelope	Enforce Agency	Area Weighted Average Calculation Worksheet
NRCC-LTI-01-E	Lighting - Indoor	Enforce Agency	Indoor Lighting
NRCC-LTI-02-E	Lighting - Indoor	Enforce Agency	Indoor Lighting Controls
NRCC-LTI-03-E	Lighting - Indoor	Enforce Agency	Indoor Lighting Power Allowance
NRCC-LTI-04-E	Lighting - Indoor	Enforce Agency	Tailored Method
NRCC-LTI-05-E	Lighting - Indoor	Enforce Agency	Line-Voltage Track Lighting Worksheet

NRCC-LTI-06-E	Lighting – Indoor	Enforce Agency	Indoor Lighting Existing Conditions
NRCC-LTO-01-E	Lighting - Outdoor	Enforce Agency	Outdoor Lighting
NRCC-LTO-02-E	Lighting - Outdoor	Enforce Agency	Outdoor Lighting Controls
NRCC-LTO-03-E	Lighting - Outdoor	Enforce Agency	Outdoor Lighting Power Allowance
NRCC-LTO-04-E	Lighting - Outdoor	Enforce Agency	Outdoor Lighting Existing Conditions
NRCC-LTS-01-E	Lighting - Sign	Enforce Agency	Sign Lighting
NRCC-MCH-01-E	Mechanical	Enforce Agency	Prescriptive - Mechanical Systems
NRCC-MCH-02-E	Mechanical	Enforce Agency	Prescriptive - HVAC System Requirements
NRCC-MCH-03-E	Mechanical	Enforce Agency	Prescriptive - Mechanical Ventilation and Reheat
NRCC-MCH-04-E	Mechanical	Enforce Agency	Prescriptive - Required Acceptance Tests
NRCC-MCH-05-E	Mechanical	Enforce Agency	Prescriptive - Requirements for Packaged Single Zone Units
NRCC-MCH-06-E	Mechanical	Enforce Agency	Maximum Cycles of Concentration Worksheet
NRCC-MCH-07-E	Mechanical	Enforce Agency	Prescriptive - Fan Power Consumption
NRCC-PLB-01-E	Plumbing	Enforce Agency	Water Heating Systems
NRCC-PRC-01-E	Process	Enforce Agency	Process Compliance Forms & Worksheets
NRCC-PRC-02-E	Process	Enforce Agency	Garage Exhaust
NRCC-PRC-03-E	Process	Enforce Agency	Commercial Kitchen Requirements
NRCC-PRC-04-E	Process	Enforce Agency	Computer Room Requirements
NRCC-PRC-05-E	Process	Enforce Agency	Commercial Refrigeration

NRCC-PRC-06-E	Process	Enforce Agency	Refrigerated Warehouse
NRCC-PRC-07-E	Process	Enforce Agency	Refrigerated Warehouse - 3,000 ft^2 or Greater
NRCC-PRC-08-E	Process	Enforce Agency	Refrigerated Warehouses - 3,000 ft^2 or Greater and Served by the Same Refrigeration System.
NRCC-PRC-09-E	Process	Enforce Agency	Laboratory Exhaust
NRCC-PRC-10-E	Process	Enforce Agency	Compressed Air System
NRCC-PRC-11-E	Process	Enforce Agency	Process Boiler Requirements
NRCC-PRC-12-E	Process	Enforce Agency	Elevator Lighting & Ventilation Controls
NRCC-PRC-13-E	Process	Enforce Agency	Escalators & Moving Walkways Speed Controls
NRCC-SRA-01-E	Solar Ready Area	Enforce Agency	Solar Ready Areas
NRCC-SRA-02-E	Solar Ready Area	Enforce Agency	Minimum Solar Zone Area Worksheet
NRCC-STH-01-E	Solar Thermal Heating	Enforce Agency	OG 100 Solar Water Heating Worksheet

CERTIFICATE OF INSTALLATION			
NRCI-ELC-01-E	Electrical	Enforce Agency	Electrical Power Distribution
NRCI-ENV-01-E	Envelope	Enforce Agency	Envelope
NRCI-LTI-01-E	Lighting - Indoor	Enforce Agency	Indoor Lighting
NRCI-LTI-02-E	Lighting - Indoor	Enforce Agency	Energy Management Control System (EMCS) or Lighting Control System
NRCI-LTI-03-E	Lighting - Indoor	Enforce Agency	Track Lighting Integral Current Limiter or Supplementary Overcurrent Protection Panel
NRCI-LTI-04-E	Lighting - Indoor	Enforce Agency	Two Interlocked Lighting Systems

NRCI-LTI-05-E	Lighting - Indoor	Enforce Agency	Power Adjustment Factors
NRCI-LTI-06-E	Lighting - Indoor	Enforce Agency	Videoconference Studio Lighting
NRCI-LTO-01-E	Lighting - Outdoor	Enforce Agency	Outdoor Lighting
NRCI-LTO-02-E	Lighting - Outdoor	Enforce Agency	Energy Management Control System (EMCS) or Lighting Control System
NRCI-LTS-01-E	Lighting - Sign	Enforce Agency	Sign Lighting
NRCI-MCH-01-E	Mechanical	Enforce Agency	Mechanical
NRCI-PLB-01-E	Plumbing	Enforce Agency	Plumbing
NRCI-PLB-02-E	Plumbing	Enforce Agency	High Rise Residential/Hotel/Motel Central Hot Water System Distribution
NRCI-PLB-03-E	Plumbing	Enforce Agency	High Rise Residential/Hotel/Motel Single Dwelling Unit Hot Water System Distribution
NRCI-PLB-21-H	Plumbing	HERS Rater	HERS Verified Multifamily Central Hot Water System Distribution
NRCI-PLB-22-H	Plumbing	HERS Rater	HERS Verified Single Dwelling Unit Hot Water System Distribution
NRCI-PRC-01-E	Process	Enforce Agency	Covered Processes
NRCI-SPV-01-E	Solar Photovoltaic	Enforce Agency	Solar Photovoltaic System
NRCI-STH-01-E	Solar Thermal Heating	Enforce Agency	Solar Water Heating Systems

CERTIFICATE OF ACCEPTANCE			
NRCA-ENV-02-F	Envelope	Field Tech	Fenestration Acceptance
NRCA-LTI-02-A	Lighting - Indoor	Accept Tech	Lighting Control Acceptance Document
NRCA-LTI-03-A	Lighting - Indoor	Accept Tech	Automatic Daylighting Control Acceptance Document
NRCA-LTI-04-A	Lighting - Indoor	Accept Tech	Demand Responsive Lighting Control Acceptance Document

NRCA-LTI-05-A	Lighting – Indoor	Accept Tech	Institutional Tuning PAF Acceptance Document
NRCA-LTO-02-A	Lighting - Outdoor	Accept Tech	Outdoor Lighting Acceptance Tests
NRCA-MCH-02-A	Mechanical	Accept Tech	Outdoor Air Acceptance
NRCA-MCH-03-A	Mechanical	Accept Tech	Constant Volume, Single Zone, Unitary (Packaged & Split) AC & Heat Pump Systems
NRCA-MCH-04-H	Mechanical	HERS Rater	Air Distribution Duct Leakage
NRCA-MCH-05-A	Mechanical	Accept Tech	Air Economizer Controls Acceptance
NRCA-MCH-06-A	Mechanical	Accept Tech	Demand Control Ventilation (DVC) Systems Acceptance
NRCA-MCH-07-A	Mechanical	Accept Tech	Supply Fan Variable Flow Controls (VFC) Acceptance
NRCA-MCH-08-A	Mechanical	Accept Tech	Valve Leakage Test
NRCA-MCH-09-A	Mechanical	Accept Tech	Supply Water Temperature Reset Controls Acceptance
NRCA-MCH-10-A	Mechanical	Accept Tech	Hydronic System Variable Flow Controls Acceptance
NRCA-MCH-11-A	Mechanical	Accept Tech	Automatic Demand Shed Control Acceptance
NRCA-MCH-12-A	Mechanical	Accept Tech	Fault Detection & Diagnostics for Packaged DX Units
NRCA-MCH-13-A	Mechanical	Accept Tech	Automatic Fault Detection & Diagnostics for Air Handling & Zone Terminal Units Acceptance
NRCA-MCH-14-A	Mechanical	Accept Tech	Distributed Energy Storage DX AC Systems Acceptance
NRCA-MCH-15-A	Mechanical	Accept Tech	Thermal Energy Storage (TES) System Acceptance
NRCA-MCH-16-A	Mechanical	Accept Tech	Supply Air Temperature Reset Controls Acceptance
NRCA-MCH-17-A	Mechanical	Accept Tech	Condenser Water Temperature Reset Controls Acceptance
NRCA-MCH-18-A	Mechanical	Accept Tech	Energy Management Control System (EMCS) Acceptance

NRCA-PRC-01-F	Process	Field Tech	Compressed Air System Acceptance
NRCA-PRC-02-F	Process	Field Tech	Commercial Kitchen Exhaust System Acceptance
NRCA-PRC-03-F	Process	Field Tech	Enclosed Parking Garage Exhaust System Acceptance
NRCA-PRC-04-F	Process	Field Tech	Refrigerated Warehouse - Evaporator Fan Motor Controls
NRCA-PRC-05-F	Process	Field Tech	Refrigerated Warehouse - Evaporative Condenser Controls Acceptance
NRCA-PRC-06-F	Process	Field Tech	Refrigerated Warehouse - Air-Cooled Condenser Controls Acceptance
NRCA-PRC-07-F	Process	Field Tech	Refrigerated Warehouse - Variable Speed Compressor Acceptance
NRCA-PRC-08-F	Process	Field Tech	Refrigerated Warehouse - Electric Resistance Underslab Heating System
NRCA-PRC-12-F	Process	Field Tech	Elevator Lighting & Ventilation Controls
NRCA-PRC-13-F	Process	Field Tech	Escalators & Moving Walkways Speed Controls

CERTIFICATE OF VERIFICATION			
NRCV-MCH-04a-H	Mechanical	HERS Rater	Duct Leakage Diagnostic Test - New System
NRCV-MCH-04c-H	Mechanical	HERS Rater	Duct Leakage Diagnostic Test - Low Leakage Air-Handling Units
NRCV-MCH-04d-H	Mechanical	HERS Rater	Duct Leakage Diagnostic Test - Altered (Existing) System
NRCV-MCH-04e-H	Mechanical	HERS Rater	Duct Leakage Diagnostic Test - Sealing of All Accessible Leaks
NRCV-PLB-21-H	Plumbing	HERS Rater	HERS Verified Multifamily Central Hot Water System Distribution
NRCV-PLB-22-H	Plumbing	HERS Rater	HERS Verified Single Dwelling Unit Hot Water System Distribution

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Appendix B Excerpts from the Appliance Efficiency Regulations

Table T-1
Normal Impedance Ranges for Liquid-Immersed Transformers

Single-phase		*Three-phase*	
kVA	***Impedance (%)***	***kVA***	***Impedance (%)***
10	1.0–4.5	15	1.0–4.5
15	1.0–4.5	30	1.0–4.5
25	1.0–4.5	45	1.0–4.5
37.5	1.0–4.5	75	1.0–5.0
50	1.5–4.5	112.5	1.2–6.0
75	1.5–4.5	150	1.2–6.0
100	1.5–4.5	225	1.2–6.0
167	1.5–4.5	300	1.2–6.0
250	1.5–6.0	500	1.5–7.0
333	1.5–6.0	750	5.0–7.5
500	1.5–7.0	1000	5.0–7.5
667	5.0–7.5	1500	5.0–7.5
833	5.0–7.5	2000	5.0–7.5
		2500	5.0–7.5

Table T-2
Normal Impedance Ranges for Dry-Type Transformers

Single-phase		*Three-phase*	
kVA	***Impedance (%)***	***kVA***	***Impedance (%)***
15	1.5–6.0	15	1.5–6.0
25	1.5–6.0	30	1.5–6.0
37.5	1.5–6.0	45	1.5–6.0
50	1.5–6.0	75	1.5–6.0
75	2.0–7.0	112.5	1.5–6.0
100	2.0–7.0	150	1.5–6.0
167	2.5–8.0	225	3.0–7.0
250	3.5–8.0	300	3.0–7.0
333	3.5–8.0	500	4.5–8.0
500	3.5–8.0	750	5.0–8.0
667	5.0–8.0	1000	5.0–8.0
833	5.0–8.0	1500	5.0–8.0
		2000	5.0–8.0
		2500	5.0–8.0

Table A-1
Non-Commercial Refrigerator, Refrigerator-Freezer, and Freezer Test Methods

Appliance	*Test Method*
Non-commercial refrigerators, designed for the refrigerated storage of food at temperatures above 32°F and below 39°F, configured for general refrigerated food storage; refrigerator-freezers; and freezers.	10 C.F.R. sections 430.23(a) (Appendix A1 to Subpart B of part 430) and 430.23(b) (Appendix B1 to Subpart B of part 430), as applicable for models manufactured before September 15, 2014 10 C.F.R. sections 430.23(a) (Appendix A to Subpart B of part 430) and 430.23(b) (Appendix B to Subpart B of part 430), as applicable for models manufactured on or after September 15, 2014
Wine chillers that are consumer products	10 C.F.R. section 430.23(a) (Appendix A1 to Subpart B of part 430), with the following modifications: Standardized temperature as referred to in Section 3.2 of Appendix A1 shall be 55°F (12.8°C). The calculation of test cycle energy expended (ET) in section 5.2.1.1 of Appendix A1 shall be made using the modified formula: ET=(EP x 1440 x k)/T Where k = 0.85

Table A-2
Commercial Refrigerators, Refrigerator-Freezer, and Freezer Test Methods

Appliance	*Test Method*
Automatic commercial ice makers	10 C.F.R. sections 431.133 and 431.134
Refrigerated bottled or canned beverage vending machines	10 C.F.R. sections 431.293 and 431.294
Refrigerated buffet and preparation tables	ANSI/ASTM F2143-01
Other commercial refrigerators, refrigerator-freezers, and freezers, with doors	10 C.F.R. sections 431.63 and 431.64
Other commercial refrigerators, refrigerator-freezers, and freezers, without doors	10 C.F.R. sections 431.63 and 431.64
Walk-in coolers and walk-in freezers	10 C.F.R. sections 431.303 and 431.304

Table B-1
Room Air Conditioner, Room Air-Conditioning Heat Pump, Packaged Terminal Air Conditioner, and Packaged Terminal Heat Pump Test Methods

Appliance	*Test Method*
Room air conditioners and room air-conditioning heat pumps	10 C.F.R. section 430.23(f) (Appendix F to Subpart B of part 430)
Packaged terminal air conditioners and packaged terminal heat pumps	10 C.F.R. sections 431.95 and 431.96

Table C-1
Central Air Conditioner Test Methods

Appliance	*Test Method*
Computer Room Air Conditioners	
evaporatively-cooled	ANSI/ASHRAE 127-2001
air-cooled, glycol-cooled, water-cooled	10 C.F.R. sections 431.95 and 431.96
Other electric-powered unitary air-conditioners and electric-powered heat pumps	
air-cooled air conditioners and air-source heat pumps	10 C.F.R. section 430.23(m) (Appendix M to Subpart B of part 430)
< 65,000 Btu/hr, single-phase	10 C.F.R. sections 431.95 and 431.96
< 65,000 Btu/hr, three-phase	10 C.F.R. sections 431.95 and 431.96
≥ 65,000 and < 760,000 Btu/hr	
evaporatively-cooled air conditioners < 240,000 Btu/hr	10 C.F.R. sections 431.95 and 431.96
water-cooled air conditioners and water-source heat pumps	
< 240,000 Btu/hr	10 C.F.R. sections 431.95 and 431.96
ground water-source heat pumps	ARI/ISO-13256-1:1998
ground-source closed-loop heat pumps	ARI/ISO-13256-1:1998
Variable Refrigerant Flow Multi-split Systems	10 C.F.R. sections 431.95 and 431.96
Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps	10 C.F.R. sections 431.95 and 431.96
Gas-fired air conditioners and gas-fired heat pumps	ANSI Z21.40.4-1996 as modified by CEC, Efficiency Calculation Method for Gas-Fired Heat Pumps as a New Compliance Option (1996)

Table D-1
Spot Air Conditioner, Ceiling Fan, Ceiling Fan Light Kit, Evaporative Cooler, Whole House Fan, Residential Exhaust Fan, and Dehumidifier Test Methods

Appliance	***Test Method***
Spot Air Conditioners	ANSI/ASHRAE 128-2001
Ceiling Fans, Except Low-Profile Ceiling Fans	10 C.F.R. section 430.23(w) (Appendix U to Subpart B of part 430)
Ceiling Fan Light Kits	10 C.F.R. section 430.23(x) (Appendix V to Subpart B of part 430)
Evaporative Coolers	ANSI/ASHRAE 133-2008 for packaged direct evaporative coolers and packaged indirect/direct evaporative coolers; ANSI/ASHRAE 143-2007 for packaged indirect evaporative coolers
Whole House Fans	HVI-916, tested with manufacturer-provided louvers in place (2009)
Dehumidifiers	10 C.F.R. section 430.23(z) (Appendix X to Subpart B of part 430) OR 10 C.F.R. section 430.23(z) (Appendix X1 to Subpart B of part 430) (at manufacturer's discretion) for models manufactured before April 29, 2013 10 C.F.R. section 430.23(z) (Appendix X1 to Subpart B of part 430) for models manufactured on or after April 29, 2013
Residential Exhaust Fans	HVI-916 (2009)

Table E-1
Gas and Oil Space Heater Test Methods

Appliance	*Test Method*
Central furnaces	
< 225,000 Btu/hr, single phase	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430)
< 225,000 Btu/hr, three phase	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) or 10 C.F.R. sections 431.75 and 431.76 (at manufacturer's option)
≥ 225,000 Btu/hr	10 C.F.R. sections 431.75 and 431.76
Gas infrared heaters	
patio heaters	ASTM F2644-07
gas-fired high-intensity infrared heaters	ANSI Z83.19-001
gas-fired low-intensity infrared heaters	ANSI Z83.20-001
Unit heaters gas-	
fired	ANSI Z83.8-2002*
oil-fired	UL 731-1995*
Gas duct furnaces	ANSI Z83.8-2002
Boilers	
< 300,000 Btu/hr	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430)
≥ 300,000 Btu/hr	10 C.F.R. sections 431.85 and 431.86
Wall furnaces, floor furnaces, and room heaters	10 C.F.R. section 430.23(o) (Appendix O to Subpart B of part 430)
*To calculate maximum energy consumption during standby, measure the gas energy used in one hour (in Btus) and the electrical energy used (in watt-hours) over a one-hour period, when the main burner is off. Divide Btus and watt-hours by one hour to obtain Btus per hour and watts. Divide Btus per hour by 3.412 to obtain watts. Add watts of gas energy to watts of electrical energy to obtain standby energy consumption in watts.	

Table F-1
Small Water Heater Test Methods

Appliance	***Test Method***
Small water heaters that are federally-regulated consumer products	10 CFR Section 430.23(e) (Appendix E to Subpart B of Part 430) (2008)
Small water heaters that are not federally-regulated consumer products	
Gas and oil storage-type < 20 gallons rated capacity	ANSI/ASHRAE 118.2-1993
Booster water heaters	ANSI/ASTM F2022-00 (for all matters other than volume) ANSI Z21.10.3-1998 (for volume)
Hot water dispensers	Test Method in 1604(f)(4)
Mini-tank electric water heaters	Test Method in 1604(f)(5)
All others	10 CFR Section 430.23(e) (Appendix E to Subpart B of Part 430) (2008)

Table F-2
Standards for Large Water Heaters Effective October 29, 2003

Appliance	***Input to Volume Ratio***	***Size (Volume)***	***Minimum Thermal Efficiency (%)***	***Maximum Standby Loss[1,2]***
Gas storage water heaters	< 4,000 Btu/hr/gal	Any	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil storage water heaters	< 4,000 Btu/hr/gal	Any	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Electric storage water heaters	< 4,000 Btu/hr/gal	Any	–	$0.3 + 27/V_m$ %/hr

[1] Standby loss is based on a 70°F temperature difference between stored water and ambient requirements. In the standby loss equations, Vr is the rated volume in gallons, Vm is the measured volume in gallons, and Q is the nameplate input rate in Btu/hr.

[2] Water heaters and hot water supply boilers having more than 140 gallons of storage capacity are not required to meet the standby loss requirement if the tank surface is thermally insulated to R- 12.5, if a standing pilot light is not installed, and for gas- or oil-fired storage water heaters, there is a flue damper or fan-assisted combustion.

Table G-1
Pool Heater Test Methods

Appliance	***Test Method***
Gas-fired and oil-fired pool heaters	10 C.F.R. section 430.23(p) (Appendix P to Subpart B of part 430)
Electric resistance pool heaters	ANSI/ASHRAE 146-1998
Heat pump pool heaters	ANSI/ASHRAE 146-1998, as modified by Addendum Test Procedure published by Pool Heat Pump Manufacturers Association dated April, 1999, Rev 4: Feb. 28, 2000:

Reading	***Standard Temperature Rating***	***Low-Temperature Rating***	***Spa Conditions Rating***
Air Temperature Dry-bulb Wet-bulb	 27.0°C (80.6°F) 21.7°C (71.0°F)	 10.0°C (50.0°F) 6.9°C (44.4°F)	 27.0°C (80.6°F) 21.7°C (71.0°F)
Relative Humidity	63%	63%	63%
Pool Water Temperature	26.7°C (80.0°F)	26.7°C (80.0°F)	40.0°C (104.0°F)

Table R-1
Cooking Product and Food Service Equipment Test Methods

Appliance	***Test Method***
Cooking products that are consumer products	10 CFR Section 430.23(i) (Appendix I to Subpart B of Part 430) (2008)
Commercial hot food holding cabinets	ANSI/ASTM F2140-01 (Test for idle energy rate-dry test) and US EPA's Energy Star Guidelines, "Measuring Interior Volume" (Test for interior volume)
Commercial convection ovens	ANSI/ASTM F1496-99 (Test for energy input rate and idle energy consumption only)
Commercial range tops	ANSI/ASTM F1521-96 (Test for cooking energy efficiency only)

Table A-3 Standards for Non-Commercial Refrigerators, Refrigerator-Freezers, and Freezers

Appliance	Defrost	Compact, Built- in, Neither	Ice		Maximum Energy Consumption (kWh/year)	
			Equipped with Automatic Ice Maker?	Dispense Ice Through Door?	July 1, 2001[1]	Sept. 15, 2014[2]
Refrigerators						
Not 'all refrigerator'	Manual	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
Not 'all refrigerator'	Manual	Compact	--	--	10.70AV + 299.0	9.03AV + 252.3
'All refrigerator'	Manual	Compact	--	--	10.70AV + 299.0	7.84AV + 219.1
'All refrigerator'	Manual	Neither	--	--	--	6.79AV + 193.6
'All refrigerator'	Automatic	Neither	--	--	9.80AV + 276.0	7.07AV + 201.6
'All refrigerator'	Automatic	Built-in	--	--	--	8.02AV + 228.5
'All refrigerator'	Automatic	Compact	--	--	12.70AV + 355.0	9.17AV + 259.3
Refrigerator-freezers	Manual	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
	Partial	Neither	--	--	8.82AV + 248.4	7.99AV + 225.0
	Manual	Compact	--	--	--	9.03AV + 252.3
	Partial	Compact	--	--	7.00AV + 398.0	5.91AV + 335.8
Refrigerator-freezers Bottom-Freezer	Automatic	Neither	No	--	4.60AV + 459.0	8.85AV + 317.0
	Automatic	Neither	Yes	No	--	8.85AV + 401.0
	Automatic	Neither	Yes	Yes	--	9.25AV + 475.4
	Automatic	Compact	No	--	13.10AV + 367.0	11.80AV + 339.2
	Automatic	Compact	Yes	--	--	11.80AV + 423.2
	Automatic	Built-in	No	--	--	9.40AV + 336.9
	Automatic	Built-in	Yes	No	--	9.40AV + 420.9
	Automatic	Built-in	Yes	Yes	--	9.83AV + 499.9
Refrigerator-freezers Side-by-side	Automatic	Neither	No	--	4.91AV+507.5	8.51AV + 297.8
	Automatic	Neither	Yes	No	--	8.51AV + 381.8
	Automatic	Neither	Yes	Yes	10.10AV + 406.0	8.54AV + 432.8
	Automatic	Compact	No	--	7.60AV + 501.0	6.82AV + 456.9
	Automatic	Compact	Yes	--	--	6.82AV + 540.9
	Automatic	Built-in	No	--	--	10.22AV + 357.4
	Automatic	Built-in	Yes	No	--	10.22AV + 441.4
	Automatic	Built-in	Yes	Yes	--	10.25AV + 502.6
Refrigerator-freezers Top-Freezer	Automatic	Neither	No	--	9.80AV + 276.0	8.07AV + 233.7
	Automatic	Neither	Yes	No	--	8.07AV + 317.7
	Automatic	Neither	Yes	Yes	10.20AV + 356.0	8.40AV + 385.4
	Automatic	Compact	No	--	12.70AV + 355.0	11.80AV + 339.2
	Automatic	Compact	Yes	--	--	11.80AV + 423.2
	Automatic	Built-in	No	--	--	9.15AV + 264.9
	Automatic	Built-in	Yes	No	--	9.15AV + 348.9
Freezers Upright Freezer	Manual	Neither	No	--	7.55AV + 258.3	5.57AV + 193.7
	Manual	Compact	--	--	9.78AV + 250.8	8.65AV + 225.7
	Automatic	Neither	No	--	12.43AV + 326.1	8.62AV + 228.3
	Automatic	Neither	Yes	--	--	8.62AV + 312.3
	Automatic	Compact	--	--	11.40AV + 391.0	10.17AV + 351.9
	Automatic	Built-in	No	--	--	9.86AV + 260.9
	Automatic	Built-in	Yes	--	--	9.86AV + 344.9
Freezers Chest Freezer	Manual	NOT Compact	No	--	--	7.29AV + 107.8
	Partial	NOT Compact	No	--	--	7.29AV + 107.8
	Automatic	NOT Compact	No	--	9.88AV + 143.7	10.24AV + 148.1
	--	Compact	--	--	10.45AV + 152.0	9.25AV + 136.8

Freezers Neither Chest Freezer nor Upright Freezer	--	NOT Compact	No	--	--	7.29AV + 107.8
[1]AV = adjusted total volume, expressed in ft³, as determined in 10 C.F.R., part 430, Appendices A1 and B1 of Subpart B, which is: [1.44 x freezer volume (ft³)] + refrigerator volume (ft³) for refrigerators; [1.63 x freezer volume (ft³)] + refrigerator volume (ft³) for refrigerator-freezers; [1.73 x freezer volume (ft³)] for freezers. [2]AV = adjusted total volume, expressed in ft³, as determined in 10 C.F.R., part 430, Appendices A and B of Subpart B.						
Note: Maximum energy consumption standards for refrigerator-freezers with internal freezers are same as those for refrigerator-freezers with top-mounted freezers.						

Table A-4
Standards for Commercial Refrigerators and Freezers with a Self-Contained Condensing Unit That are Not Commercial Hybrid Units

	Condensing Unit Configuration	***Equipment Family***	***Rating Temperature (°F)***	***Operating Temperature (°F)***	***Equipment Class Designation****	***Maximum Daily Energy Consumption (kWh)***
Refrigerators and Freezers Effective January 1, 2010	Self Contained (SC)	Vertical Closed Transparent (VCT)	38 (M) 0 (L)	≥ 32 < 32	VCT, SC, M VCT, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
		Horizontal Closed Transparent (HCT)	38 (M) 0 (L)	≥ 32 < 32	HCT, SC, M HCT, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
		Vertical Closed Solid (VCS)	38 (M) 0 (L)	≥ 32 < 32	VCS, SC, M VCS, SC, L	0.10 × V + 2.04 0.40 × V + 1.38
		Horizontal Closed Solid (HCS)	38 (M) 0 (L)	≥ 32 < 32	HCS, SC, M HCS, SC, L	0.10 × V + 2.04 0.40 × V + 1.38
		Service Over Counter (SOC)	38 (M) 0 (L)	≥ 32 < 32	SOC, SC, M SOC, SC, L	0.12 × V + 3.34 0.75 × V + 4.10
Refrigerators with transparent doors designed for pull-down temperature applications Effective January 1, 2010	Self Contained (SC)	Vertical Closed Transparent (VCT)	38 (P)	≥ 32	VCT, SC, P	0.126 × V + 3.51
		Horizontal Closed Transparent (HCT)	38 (P)	≥ 32	HCT, SC, P	0.126 × V + 3.51
Refrigerators and Freezers without doors Effective January 1, 2012	Self Contained (SC)	Vertical Open (VOP)	38 (M) 0 (L)	≥ 32 < 32	VOP, SC, M VOP, SC, L	1.74 × TDA + 4.71 4.37 × TDA +11.82
		Semivertical Open (SVO)	38 (M) 0 (L)	≥ 32 < 32	SVO, SC, M SVO, SC, L	1.73 × TDA + 4.59 4.34 × TDA +11.51
		Horizontal Open (HZO)	38 (M) 0 (L)	≥ 32 < 32	HZO, SC, M HZO, SC, L	0.77 × TDA + 5.55 1.92 × TDA + 7.08
* The meaning of the letters in this column is indicated in the *Condensing Unit Configuration*, *Equipment Family*, and *Rating Temperature (°F)* columns to the left.						

Table A-5
Standards for Commercial Refrigerators and Freezers with a Remote Condensing Unit That are Not Commercial Hybrid Units

Equipment Category	*Condensing Unit Configuration*	*Equipment Family*	*Rating Temperature (°F)*	*Operating Temperature (°F)*	*Equipment Class Designation**	*Maximum Daily Energy Consumption (kWh)*
Refrigerators and Freezers	Remote (RC)	Vertical Open (VOP)	38 (M) 0 (L)	≥ 32 < 32	VOP, RC, M VOP, RC, L	0.82 × TDA + 4.07 2.27 × TDA + 6.85
Effective January 1, 2012		Semivertical Open (SVO)	38 (M) 0 (L)	≥ 32 < 32	SVO, RC, M SVO, RC, L	0.83 × TDA + 3.18 2.27 × TDA + 6.85
		Horizontal Open (HZO)	38 (M) 0 (L)	≥ 32 < 32	HZO, RC, M HZO, RC, L	0.35 × TDA + 2.88 0.57 × TDA + 6.88
		Vertical Closed Transparent (VCT)	38 (M) 0 (L)	≥ 32 < 32	VCT, RC, M VCT, RC, L	0.22 × TDA + 1.95 0.56 × TDA + 2.61
		Horizontal Closed Transparent (HCT)	38 (M) 0 (L)	≥ 32 < 32	HCT, RC, M HCT, RC, L	0.16 × TDA + 0.13 0.34 × TDA + 0.26
		Vertical Closed Solid (VCS)	38 (M) 0 (L)	≥ 32 < 32	VCS, RC, M VCS, RC, L	0.11 × V + 0.26 0.23 × V + 0.54
		Horizontal Closed Solid (HCS)	38 (M) 0 (L)	≥ 32 < 32	HCS, RC, M HCS, RC, L	0.11 × V + 0.26 0.23 × V + 0.54
		Service Over Counter (SOC)	38 (M) 0 (L)	≥ 32 < 32	SOC, RC, M SOC, RC, L	0.51 × TDA + 0.11 1.08 × TDA + 0.22

* The meaning of the letters in this column is indicated in the *Condensing Unit Configuration*, *Equipment Family*, and *Rating Temperature (°F)* columns to the left.

Table A-7
Standards for Automatic Commercial Ice Makers Manufactured on or After January 1, 2010

Equipment type	***Type of cooling***	***Harvest rate (lbs ice/24 hours)***	***Maximum energy use (kWh/100 lbs ice)***	***Maximum condenser water use* (gal/100 lbs ice)***
Ice Making Head	Water	< 500	7.80–0.0055H	200–0.022H.
Ice Making Head	Water	≥ 500 and < 1436	5.58–0.0011H	200–0.022H.
Ice Making Head	Water	≥ 1436	4.0	200–0.022H.
Ice Making Head	Air	< 450	10.26–0.0086H	Not applicable.
Ice Making Head	Air	≥ 450	6.89–0.0011H	Not applicable.
Remote Condensing (but not remote compressor)	Air	< 1000	8.85–0.0038H	Not applicable.
Remote Condensing (but not remote compressor)	Air	≥ 1000	5.1	Not applicable.
Remote Condensing and Remote Compressor	Air	< 934	8.85–0.0038H	Not applicable.
Remote Condensing and Remote Compressor	Air	≥ 934	5.3	Not applicable.
Self Contained	Water	< 200	11. 40–0.019H	191–0.0315H.
Self Contained	Water	≥ 200	7.6	191–0.0315H.
Self Contained	Air	< 175	18.0–0.0469H	Not applicable.
Self Contained	Air	≥ 175	9.8	Not applicable.

H Harvest rate in pounds per 24 hours.
*Water use is for the condenser only and does not include potable water used to make ice.

Table B-2
Standards for Room Air Conditioners and Room Air-Conditioning Heat Pumps Manufactured on or After October 1, 2000 and before June 1, 2014

Appliance	*Louvered Sides*	*Cooling Capacity (Btu/hr)*	*Minimum EER*
Room Air Conditioner	Yes	< 6,000	9.7
Room Air Conditioner	Yes	≥ 6,000 – 7,999	9.7
Room Air Conditioner	Yes	≥ 8,000 – 13,999	9.8
Room Air Conditioner	Yes	≥ 14,000 – 19,999	9.7
Room Air Conditioner	Yes	≥ 20,000	8.5
Room Air Conditioner	No	< 6,000	9.0
Room Air Conditioner	No	≥ 6,000 – 7,999	9.0
Room Air Conditioner	No	≥ 8,000 – 19,999	8.5
Room Air Conditioner	No	≥ 20,000	8.5
Room Air Conditioning Heat Pump	Yes	< 20,000	9.0
Room Air Conditioning Heat Pump	Yes	≥ 20,000	8.5
Room Air Conditioning Heat Pump	No	< 14,000	8.5
Room Air Conditioning Heat Pump	No	≥ 14,000	8.0
Casement-Only Room Air Conditioner	Either	Any	8.7
Casement-Slider Room Air Conditioner	Either	Any	9.5

Table B-3
Standards for Room Air Conditioners and Room Air-Conditioning Heat Pumps Manufactured On or After June 1, 2014

Appliance	*Louvered Sides*	*Cooling Capacity (Btu/hr)*	*Minimum Combined EER*
Room Air Conditioner	Yes	< 6,000	11.0
Room Air Conditioner	Yes	≥ 6,000 – 7,999	11.0
Room Air Conditioner	Yes	≥ 8,000 – 13,999	10.9
Room Air Conditioner	Yes	≥ 14,000 – 19,999	10.7
Room Air Conditioner	Yes	≥ 20,000 – 27,999	9.4
Room Air Conditioner	Yes	≥ 28,000	9.0
Room Air Conditioner	No	< 6,000	10.0
Room Air Conditioner	No	≥6,000 – 7,999	10.0
Room Air Conditioner	No	≥ 8,000 – 10,999	9.6
Room Air Conditioner	No	≥ 11,000 – 13,999	9.5
Room Air Conditioner	No	≥ 14,000 – 19,999	9.3
Room Air Conditioner	No	≥ 20,000	9.4
Room Air Conditioning Heat Pump	Yes	< 20,000	9.8
Room Air Conditioning Heat Pump	Yes	≥ 20,000	9.3
Room Air Conditioning Heat Pump	No	< 14,000	9.3
Room Air Conditioning Heat Pump	No	≥ 14,000	8.7
Casement-Only Room Air Conditioner	Either	Any	9.5
Casement-Slider Room Air Conditioner	Either	Any	10.4

Table B-6 Standards for Standard Size Packaged Terminal Air Conditioners and Standard Size Packaged Terminal Heat Pumps Manufactured On or After October 8, 2012

Appliance	*Cooling Capacity (Btu/hour)*	*Minimum Efficiency*	
		Minimum EER	*Minimum COP*
Packaged Terminal Air Conditioners	< 7,000	11.7	—
	≥ 7,000 < 15,000	13.8 – (0.300 x Cap[1])	—
	≥ 15,000	9.3	—
Packaged Terminal Heat Pumps	< 7,000	11.9	3.3
	≥ 7,000 < 15,000	14.0 – (0.300 x Cap[1])	3.7 - (0.052 x Cap[1])
	≥ 15,000	9.5	2.9

[1] Cap means cooling capacity in thousand British thermal units per hour (Btu/h) at 95°F outdoor dry-bulb temperature.

Table C-2
Standards for Single Phase Air-Cooled Air Conditioners with Cooling Capacity Less than 65,000 Btu per Hour and Single Phase Air-Source Heat Pumps with Cooling Capacity Less than 65,000 Btu per Hour, Not Subject to EPAct

Appliance	*Minimum Efficiency*					
	Effective January 23, 2006		*Effective January 1, 2015*			
	Minimum SEER	*Minimum HSPF*	*Minimum SEER*	*Minimum HSPF*	*Minimum EER*	*Average Off-Mode Power Consumption $P_{w.\,pff}$ (watts)*
Split system air conditioners with rated cooling capacity < 45,000 Btu/hour[1]	13.0	—	14.0	—	12.2	30
Split system air conditioners with rated cooling capacity ≥ 45,000 Btu/hour[1]			14.0	—	11.7	30
Split system heat pumps	13.0	7.7	14.0	8.2	—	33
Single package air conditioners[1]	13.0	—	14.0	—	11.0	30
Single package heat pumps	13.0	7.7	14.0	8.0	—	33
Space constrained air conditioners – split system	12.0		12.0	—	—	30
Space constrained heat pumps – split system	12.0	7.4	12.0	7.4	—	33
Space constrained air conditioners – single package	12.0		12.0	—	—	30
Space constrained heat pumps – single package	12.0	7.4	12.0	7.4	—	33
Small duct, high velocity air conditioner systems	13.0		13.0	—	—	30
Small duct, high velocity heat pump systems	13.0	7.7	13.0	7.7	—	30

[1] See 10 C.F.R. section 430.32(c) for less stringent federal standards applicable to these units that are manufactured on or after January 1, 2015 and installed in states other than Arizona, California, Nevada, or New Mexico

Table C-3
Standards for Air-Cooled Air Conditioners and Air-Source Heat Pumps Subject to EPAct
(Standards Effective January 1, 2010 do not apply To Single Package Vertical Air Conditioners)

Appliance	*Cooling Capacity (Btu/hr)*	*System Type*	*Minimum Efficiency*		
			Effective June 15, 2008	*Effective January 1, 2010*	
				Air Conditioners	*Heat Pumps*
Air-cooled unitary air conditioners and heat pumps (cooling mode)	< 65,000 *	Split system	13.0 SEER		
	< 65,000 *	Single package	13.0 SEER		
	≥ 65,000 and < 135,000	All		11.2 EER[3] 11.0 EER[4]	11.0 EER[3] 10.8 EER[4]
	≥ 135,000 and < 240,000	All		11.0 EER[3] 10.8 EER[4]	10.6 EER[3] 10.4 EER[4]
	≥ 240,000 and < 760,000	All		10.0 EER[3] 9.8 EER[4]	9.5 EER[3] 9.3 EER[4]
Air-cooled unitary air-conditioning heat pumps (heating mode)	< 65,000 *	Split system	7.7 HSPF		
	< 65,000 *	Single package	7.7 HSPF		
	≥ 65,000 and < 135,000	All		3.3 COP	
	≥ 135,000 and < 240,000	All		3.2 COP	
	≥ 240,000 and < 760,000	All		3.2 COP	

* Three phase models only.
[3] Applies to equipment that has electric resistance heat or no heating.
[4] Applies to equipment with all other heating-system types that are integrated into the unitary equipment.

Table C-4
Standards for Water-Cooled Air Conditioners, Evaporatively Cooled Air Conditioners, and Water-Source Heat Pumps

Appliance	Cooling Capacity (Btu per hour)	*Minimum Efficiency*							
		Effective Prior to October 29, 2012		*Effective January 10, 2011*		*Effective †October 29, 2012 or ††October 29, 2013*		*Effective *June 1, 2013 or **June 1, 2014*	
		Minimum EER	*COP*	*Minimum EER*	*COP*	*Minimum EER*	*COP*	*Minimum EER*	*COP*
Water-cooled air conditioners and evaporatively cooled air	< 17,000	12.1	—						
Water-source heat pumps	< 17,000	11.2	4.2						
Water-source VRF multi-split heat pumps	< 17,000	—	4.2			12.0[1]†	4.2		
Water-cooled air conditioners and evaporatively cooled air	≥17,000 and < 65,000	12.1	—						
Water-source heat pumps, including VRF	≥17,000 and < 65,000	12.0	4.2						
Water-cooled air conditioners and evaporatively cooled air	≥65,000 and < 135,000	11.5[1]	–					12.1[1]*	—
Water-source heat pumps, including VRF	≥65,000 and < 135,000	12.0	4.2					11.9*	4.2
Water-cooled air conditioners	≥135,000 and < 240,000	11.0	—					12.5[1]**	—
Evaporatively cooled air conditioners	≥135,000 and < 240,000	11.0	—					12.0[1]**	—
Water-source heat pumps	≥135,000 and < 240,000	11.0	2.9					12.3**	2.9
Water-source VRF multi-split heat pumps	≥135,000 and < 760,000					10.0[1]††	3.9††		
Water-cooled air conditioners	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			12.4[1]**	—
Evaporatively cooled air conditioners	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			11.9[1]**	—
Water-source heat pumps	≥240,000 and < 760,000	11.0[1]	–	11.0[1]	—			12.2**	—

[1] Deduct 0.2 from the required EER for units with heating sections other than electric resistance heat. For VRF multi-split heat pumps this applies to units with heat recovery.

Table C-5
Standards for Single Package Vertical Air Conditioners and Single Package Vertical Heat Pumps Manufactured on or After January 1, 2010

Appliance	*Cooling Capacity (BTU/hr)*	*System Type*	*Minimum Efficiency*	
			Cooling Mode	*Heating Mode*
Single package vertical air conditioners	< 65,000	Single-phase	9.0 EER	N/A
	< 65,000	3-phase	9.0 EER	N/A
	≥ 65,000 and < 135,000	All	8.9 EER	N/A
	≥ 135,000 and < 240,000	All	8.6 EER	N/A
Single package vertical heat pumps	< 65,000	Single-phase	9.0 EER	3.0 COP
	< 65,000	3-phase	9.0 EER	3.0 COP
	≥ 65,000 and < 135,000	All	8.9 EER	3.0 COP
	≥ 135,000 and < 240,000	All	8.6 EER	2.9 COP

Table D-2
Standards for Dehumidifiers

Product capacity (pint/day)	*Minimum energy factor (liters/kWh)*	
	Effective October 1, 2007	*Effective October 1, 2012*
25.00 or less	1.00	1.35
25.01 – 35.00	1.20	1.35
35.01 – 45.00	1.30	1.50
45.01 – 54.00	1.30	1.60
54.01 – 74.99	1.50	1.70
75.00 or more	2.25	2.50

Table E-2
Standards for Gas Wall Furnaces, Floor Furnaces, and Room Heaters

Appliance	*Design Type*	*Capacity (Btu per hour)*	*Minimum AFUE (%)*	
			Effective Before April 16, 2013	*Effective On or After April 16, 2013*
Wall furnace	Fan	≤ 42,000	73	75
Wall furnace	Fan	> 42,000	74	76
Wall furnace	Gravity	≤10,000	59	65
Wall furnace	Gravity	> 10,000 and ≤ 12,000	60	
Wall furnace	Gravity	> 12,000 and ≤ 15,000	61	
Wall furnace	Gravity	> 15,000 and ≤ 19,000	62	
Wall furnace	Gravity	> 19,000 and ≤ 27,000	63	
Wall furnace	Gravity	> 27,000 and ≤ 46,000	64	66
Wall furnace	Gravity	> 46,000	65	67
Floor furnace	All	≤ 37,000	56	57
Floor furnace	All	> 37,000	57	58
Room heater	All	≤ 18,000	57	61
Room heater	All	> 18,000 and ≤ 20,000	58	
Room heater	All	> 20,000 and ≤ 27,000	63	66
Room heater	All	> 27,000 and ≤ 46,000	64	67
Room heater	All	> 46,000	65	68

Table E-3
Standards for Gas- and Oil-Fired Central Boilers < 300,000 Btu/hr input and Electric Residential Boilers

Appliance	***Minimum AFUE (%)***	
	Effective January 1, 1992	
	75	***Effective September 1, 2012***
Gas steam boilers with single phase electrical supply	80	80 [1]
Gas hot water boilers with single phase electrical supply	—	82 [1,2]
Oil steam boilers with single phase electrical supply	—	82
Oil hot water boilers with single phase electrical supply	—	84 [2]
Electric steam residential boilers	—	NONE
Electric hot water residential boilers	80	NONE [2]
All other boilers with single phase electrical supply	—	—
[1] No constant burning pilot light design standard effective September 1, 2012. [2] Automatic means for adjusting temperature design standard effective September 1, 2012. (Boilers equipped with tankless domestic water heating coils do not need to comply with this requirement.)		

Table E-5
Standards for Gas- and Oil-Fired Central Furnaces

Appliance	***Rated Input (Btu/hr)***	***Minimum Thermal Efficiency***
Gas central furnaces	≥ 225,000	80
Oil central furnaces	≥ 225,000	81

Table F-2
Standards for Large Water Heaters Effective October 29, 2003

Appliance	*Input to Volume Ratio*	*Size (Volume)*	*Minimum Thermal Efficiency (%)*	*Maximum Standby Loss[1,2]*
Gas storage water heaters	< 4,000 Btu/hr/gal	any	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Gas hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil storage water heaters	< 4,000 Btu/hr/gal	any	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil instantaneous water heaters	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Oil hot water supply boilers	≥ 4,000 Btu/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(V_r)^{1/2}$ Btu/hr
Electric storage water heaters	< 4,000 Btu/hr/gal	Any	–	$0.3 + 27/V_m$ %/hr

[1] Standby loss is based on a 70° F temperature difference between stored water and ambient requirements. In the standby loss equations, V_r is the rated volume in gallons, V_m is the measured volume in gallons, and Q is the nameplate input rate in Btu/hr.

[2] Water heaters and hot water supply boilers having more than 140 gallons of storage capacity are not required to meet the standby loss requirement if the tank surface is thermally insulated to R-12.5, if a standing pilot light is not installed, and for gas- or oil-fired storage water heaters, there is a flue damper or fan-assisted combustion.

Table F-3
Standards for Small Federally-Regulated Water Heaters

Appliance	*Rated Storage Volume (gallons)*	*Minimum Energy Factor*	
		Effective January 20, 2004	*Effective April 16, 2015*
Gas-fired storage-type water heaters	≤ 55	0.67 – (.0019 x V)	0.675−(0.0015 × V)
	> 55		0.8012−(0.00078 × V)
Oil-fired water heaters (storage and instantaneous)	Any	0.59 – (.0019 x V)	0.68 – (.0019 x V)
Electric storage water heaters (excluding tabletop water heaters)	≤ 55	0.97 – (.00132 x V)	0.960−(0.0003 × V)
	> 55		2.057−(0.00113 × V)
Electric tabletop water heaters	Any	0.93 – (.00132 x V)	0.93 – (.00132 x V)
Gas-fired instantaneous water heaters	Any	0.62 – (.0019 x V)	0.82 – (.0019 x V)
Electric instantaneous water heaters (excluding tabletop water heaters)	Any	0.93 – (.00132 x V)	0.93 – (.00132 x V)
Heat pump water heaters	Any	0.97 – (.00132 x V)	0.97 – (.00132 x V)
V = Rated storage volume in gallons.			

Table H-1
Standards for Plumbing Fittings

Appliance	*Maximum Flow Rate*
Showerheads	2.5 gpm at 80 psi
Lavatory faucets	2.2 gpm at 60 psi
Kitchen faucets	2.2 gpm at 60 psi
Replacement aerators	2.2 gpm at 60 psi
Wash fountains	$2.2 \times \frac{\text{rim space (inches)}}{20}$ gpm at 60 psi
Metering faucets	0.25 gallons/cycle[1,2]
Metering faucets for wash fountains	$0.25 \times \frac{\text{rim space (inches)}}{20}$ gpm at 60 psi [1,2]

1 **Sprayheads with independently-controlled orifices and metered controls.** The maximum flow rate of each orifice that delivers a pre-set volume of water before gradually shutting itself off shall not exceed the maximum flow rate for a metering faucet.

2 **Sprayheads with collectively-controlled orifices and metered controls.** The maximum flow rate of a sprayhead that delivers a pre-set volume of water before gradually shutting itself off shall be the product of (a) the maximum flow rate for a metering faucet and (b) the number of component lavatories (rim space of the lavatory in inches (millimeters) divided by 20 inches (508 millimeters)).

Table J-1
Standards for Fluorescent Lamp Ballasts and Replacement Fluorescent Lamp Ballasts

Application for Operation of	*Ballast Input Voltage*	*Total Nominal Lamp Watts*	*Minimum Ballast Efficacy Factor*	
one F40T12 lamp	120 or 277	40	2.29[1]	1.805[2]
two F40T12 lamps	120	80	1.17[1]	1.060[2]
	277	80	1.17[1]	1.050[2]
two F96T12 lamps	120 or 277	150	0.63[1]	0.570[2]
two F96T12HO lamps	120 or 277	220	0.39[1]	0.390[2]

[1] For fluorescent lamp ballasts manufactured on or after April 1, 2005; sold by the manufacturer on or after July 1, 2005; or incorporated into a luminaire by a luminaire manufacturer on or after April 1, 2006.
[2] For fluorescent lamp ballasts designed, marked, and shipped as replacement ballasts.

Table J-2
Standards for Fluorescent Lamp Ballasts[1]

Application for Operation of	*Ballast Input Voltage*	*Total Nominal Lamp Watts*	*Minimum Ballast Efficacy Factor*
one F34T12 lamp	120 or 277	34	2.61
two F34T12 lamps	120 or 277	68	1.35
two F96T12/ES lamps	120 or 277	120	0.77
two F96T12HO/ES lamps	120 or 277	190	0.42

[1] For fluorescent lamp ballasts manufactured on or after July 1, 2009; sold by the manufacturer on or after October 1, 2009; or fluorescent lamp ballasts incorporated into a luminaire by a luminaire manufacturer on or after July 1, 2010.

Table K-1
Standards for Federally-Regulated General Service Fluorescent Lamps Manufactured Before July 15, 2012

Appliance	*Nominal Lamp Wattage*	*Minimum Color Rendering Index (CRI)*	*Minimum Average Lamp Efficacy (LPW)*
4-foot medium bi-pin lamps	> 35	69	75.0
	≤ 35	45	75.0
2-foot U-shaped lamps	> 35	69	68.0
	≤ 35	45	64.0
8-foot slimline lamps	> 65	69	80.0
	≤ 65	45	80.0
8-foot high output lamps	> 100	69	80.0
	≤ 100	45	80.0

Table K-2
Standards for Federally-Regulated General Service Fluorescent Lamps Manufactured On or After July 15, 2012

Appliance	*Correlated Color Temperature*	*Minimum Average Lamp Efficacy (LPW)*
4-foot medium bipin lamps	≤ 4,500K	89
	> 4,500K and ≤ 7,000K	88
2-foot U-shaped lamps	≤ 4,500K	84
	> 4,500K and ≤ 7,000K	81
8-foot slimline lamps	≤ 4,500K	97
	> 4,500K and ≤ 7,000K	93
8-foot high output lamps	≤ 4,500K	92
	> 4,500K and ≤ 7,000K	88
4-foot miniature bipin standard output	≤ 4,500K	86
	> 4,500K and ≤ 7,000K	81
4-foot miniature bipin high output	≤ 4,500K	76
	> 4,500K and ≤ 7,000K	72

Table K-3
Standards for Federally-Regulated Incandescent Reflector Lamps Manufactured Before July 15, 2012

Nominal Lamp Wattage	*Minimum Average Lamp Efficacy (LPW)*
40-50	10.5
51-66	11.0
67-85	12.5
86-115	14.0
116-155	14.5
156-205	15.0

Table K-4
Standards for Federally-Regulated Incandescent Reflector Lamps
Manufactured On or After July 15, 2012

Lamp Spectrum	*Lamp Diameter (inches)*	*Rated Voltage*	*Minimum Average Lamp Efficacy (LPW)*[1]
Standard Spectrum	> 2.5	≥ 125	$6.8 \times P^{0.27}$
		< 125	$5.9 \times P^{0.27}$
	≤ 2.5	≥ 125	$5.7 \times P^{0.27}$
		< 125	$5.0 \times P^{0.27}$
Modified Spectrum	> 2.5	≥ 125	$5.8 \times P^{0.27}$
		< 125	$5.0 \times P^{0.27}$
	≤ 2.5	≥ 125	$4.9 \times P^{0.27}$
		< 125	$4.2 \times P^{0.27}$
[1]P = Rated Lamp Wattage, in Watts			

Table K-5
Standards for Medium Base Compact Fluorescent Lamps

Factor	*Requirements*
Lamp Power (Watts) and Configuration[1]	*Minimum Efficacy: lumens/watt (Based upon initial lumen data)*[2]
Bare Lamp: Lamp Power < 15 Lamp Power ≥ 15	 45.0 60.0
Covered Lamp (no reflector) Lamp Power < 15 15 ≥ Lamp Power < 19 19 ≥ Lamp Power < 25 Lamp Power ≥ 25	 40.0 48.0 50.0 55.0
1,000-hour Lumen Maintenance	The average of at least 5 lamps must be a minimum 90% of initial (100-hour) lumen output @ 1,000 hours of rated life.
Lumen Maintenance	80% of initial (100-hour) rating at 40 percent of rated life (per ANSI C78.5 Clause 4.10).
Rapid Cycle Stress Test	Per ANSI C78.5 and IESNA LM-65 (Clauses 2, 3, 5, and 6) *Exception:* Cycle times must be 5 minutes on, 5 minutes off. Lamp will be cycled once for every two hours of rated life. At least 5 lamps *must meet or exceed* the minimum number of cycles.
Average Rated Lamp Life	≥ 6,000 hours as declared by the manufacturer on the packaging. 80% of rated life, statistical methods may be used to confirm lifetime claims based on sampling performance.
[1] Take performance and electrical requirements at the end of the 100-hour aging period according to ANSI Standard C78.5. The lamp efficacy shall be the average of the lesser of the lumens per watt measured in the base up and/or other specified positions. Use wattages placed on packaging to select proper specification efficacy in this table, not measured wattage. Labeled wattages are for reference only.	
[2] Efficacies are based on measured values for lumens and wattages from pertinent test data. Wattages and lumens placed on packages may not be used in calculation and are not governed by this specification. For multi-level or dimmable systems, measurements shall be at the highest setting. Acceptable measurement error is ±3%.	

Table K-6
Standards for Federally-Regulated General Service Incandescent Lamps

Rated Lumen Ranges	*Maximum Rate Wattage*	*Minimum Rate Lifetime*	*Effective Date*
1490-2600	72	1,000 hours	January 1, 2012
1050 – 1489	53	1,000 hours	January 1, 2013
750 – 1049	43	1,000 hours	January 1, 2014
310 – 749	29	1,000 hours	January 1, 2014

Table K-7
Standards for Federally-Regulated Modified Spectrum General Service Incandescent Lamps

Rated Lumen Ranges	*Maximum Rate Wattage*	*Minimum Rate Lifetime*	*Effective Date*
1118-1950	72	1,000 hours	January 1, 2012
788-1117	53	1,000 hours	January 1, 2013
563-787	43	1,000 hours	January 1, 2014
232-562	29	1,000 hours	January 1, 2014

Table M-1
Standards for Traffic Signals for Vehicle and Pedestrian Control

Appliance	*Maximum Wattage (at 74°C)*	*Nominal Wattage (at 25°C)*
Traffic Signal Module Type:		
12-inch; Red Ball	17	11
8-inch; Red Ball	13	8
12-inch; Red Arrow	12	9
12-inch; Green Ball	15	15
8-inch; Green Ball	12	12
12-inch; Green Arrow	11	11
Pedestrian Module Type:		
Combination Walking Man/Hand	16	13
Walking Man	12	9
Orange Hand	16	13

Table O
Standards for Dishwashers

Appliance	*Effective January 1, 2010*		*Effective May 30, 2013*	
	Maximum Energy Use (kWh/year)	*Maximum Water Use (gallons/cycle)*	*Maximum Energy Use (kWh/year)*	*Maximum Water Use (gallons/cycle)*
Compact dishwashers	260	4.5	222	3.5
Standard dishwashers	355	6.5	307	5.0

Table P-1
Standards for Residential Clothes Washers Manufactured On or After January 1, 2007 and Manufactured Before March 7, 2015

Appliance	*Minimum Modified Energy Factor Effective January 1, 2007*	*Maximum Water Factor Effective January 1, 2011*
Top-loading compact clothes washers	0.65	--
Top-loading standard clothes washers	1.26	9.5
Top-loading, semi-automatic	N/A[1]	--
Front-loading clothes washers	1.26	9.5
Suds-saving	N/A[1]	--
[1] Must have an unheated rinse water option.		

Table P-2
Standards for Residential Clothes Washers Manufactured On or After March 7, 2015

Appliance	*Minimum Integrated Modified Energy Factor*		*Maximum Integrated Water Factor*	
	March 7, 2015	*January 1, 2018*	*March 7, 2015*	*January 1, 2018*
Top-loading, Compact	0.86	1.15	14.4	12.0
Top-loading, Standard	1.29	1.57	8.4	6.5
Front-loading, Compact	1.13	1.13	8.3	8.3
Front-loading, Standard	1.84	1.84	4.7	4.7

Table P-3
Standards for Clothes Washers

Appliance	Minimum Modified Energy Factor		Maximum Water Factor	
	Effective January 1, 2007	Effective January 8, 2013	Effective January 1, 2007	Effective January 8, 2013
Top-loading clothes washers	1.26	1.60	9.5	8.5
Front-loading clothes washers	1.26	2.00	9.5	5.5

Table Q-1
Standards for Clothes Dryers Manufactured On or After May 14, 1994 and Before January 1, 2015

Appliance	Minimum Energy Factor (lbs/kWh)
Electric, standard clothes dryers	3.01
Electric, compact, 120 volt clothes dryers	3.13
Electric, compact, 240 volt clothes dryers	2.90
Gas clothes dryers	2.67

Table S-1
Standards for Electric Motors

Motor Horsepower/Standard Kilowatt Equivalent	Minimum Nominal Full-Load Efficiency					
	Open Motors			Enclosed Motors		
	6 poles	4 poles	2 poles	6 poles	4 poles	2 poles
1/0.75	80.0	82.5	. . .	80.0	82.5	75.5
1.5/1.1	84.0	84.0	82.5	85.5	84.0	82.5
2/1.5	85.5	84.0	84.0	86.5	84.0	84.0
3/2.2	86.5	86.5	84.0	87.5	87.5	85.5
5/3.7	87.5	87.5	85.5	87.5	87.5	87.5
7.5/5.5	88.5	88.5	87.5	89.5	89.5	88.5
10/7.5	90.2	89.5	88.5	89.5	89.5	89.5
15/11	90.2	91.0	89.5	90.2	91.0	90.2
20/15	91.0	91.0	90.2	90.2	91.0	90.2
25/18.5	91.7	91.7	91.0	91.7	92.4	91.0
30/22	92.4	92.4	91.0	91.7	92.4	91.0
40/30	93.0	93.0	91.7	93.0	93.0	91.7
50/37	93.0	93.0	92.4	93.0	93.0	92.4
60/45	93.6	93.6	93.0	93.6	93.6	93.0
75/55	93.6	94.1	93.0	93.6	94.1	93.0
100/75	94.1	94.1	93.0	94.1	94.5	93.6
125/90	94.1	94.5	93.6	94.1	94.5	94.5
150/110	94.5	95.0	93.6	95.0	95.0	94.5
200/150	94.5	95.0	94.5	95.0	95.0	95.0

Table T-3
Standards for Low-Voltage Dry-Type Distribution Transformers

Single phase			***Three phase***		
kVA	***Efficiency (%)[1]***		***kVA***	***Efficiency (%)[1]***	
	Effective January 1, 2007	***Effective January 1, 2016***		***Effective January 1, 2007***	***Effective January 1, 2016***
15	97.7	97.70	15	97.0	97.89
25	98.0	98.00	30	97.5	98.23
37.5	98.2	98.20	45	97.7	98.40
50	98.3	98.30	75	98.0	98.60
75	98.5	98.50	112.5	98.2	98.74
100	98.6	98.60	150	98.3	98.83
167	98.7	98.70	225	98.5	98.94
250	98.8	98.80	300	98.6	99.02
333	98.9	98.90	500	98.7	99.14
			750	98.8	99.23
			1000	98.9	99.28

[1] Efficiencies are determined at the following reference conditions:
(1) for no-load losses, at the temperature of 20°C, and (2) for load-losses, at the temperature of 75°C and 35 percent of nameplate load.
(Source: Table 4–2 of NEMA Standard TP–1–2002, “Guide for Determining Energy Efficiency for Distribution Transformers.”)

Table T-4
Standards for Liquid-Immersed Distribution Transformers

Single phase			Three phase		
kVA	Efficiency (%)[1]		kVA	Efficiency (%)[1]	
	Effective January 1, 2007	*Effective January 1, 2016*		*Effective January 1, 2007*	*Effective January 1, 2016*
10	98.62	98.70	15	98.36	98.65
15	98.76	98.82	30	98.62	98.83
25	98.91	98.95	45	98.76	98.92
37.5	99.01	99.05	75	98.91	99.03
50	99.08	99.11	112.5	99.01	99.11
75	99.17	99.19	150	99.08	99.16
100	99.23	99.25	225	99.17	99.23
167	99.25	99.33	300	99.23	99.27
250	99.32	99.39	500	99.25	99.35
333	99.36	99.43	750	99.32	99.40
500	99.42	99.49	1000	99.36	99.43
667	99.46	99.52	1500	99.42	99.48
833	99.49	99.55	2000	99.46	99.51
			2500	99.49	99.53

[1] Note: All efficiency values are at 50 percent of nameplate-rated load, determined when tested according to the test procedure in Section 1604(t).

Table T-5
Standards for Medium-Voltage Dry-Type Distribution Transformers Manufactured On or After January 1, 2010 and Before January 1, 2016

Single phase				*Three phase*			
BIL kVA	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***	***BIL kVA***	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.12	
75	98.73	98.57	98.53	112.5	98.49	98.30	
100	98.82	98.67	98.63	150	98.60	98.42	
167	98.96	98.83	98.80	225	98.73	98.57	98.53
250	99.07	98.95	98.91	300	98.82	98.67	98.63
333	99.14	99.03	98.99	500	98.96	98.83	98.80
500	99.22	99.12	99.09	750	99.07	98.95	98.91
667	99.27	99.18	99.15	1000	99.14	99.03	98.99
833	99.31	99.23	99.20	1500	99.22	99.12	99.09
				2000	99.27	99.18	99.15
				2500	99.31	99.23	99.20

[1] All efficiency values are at 50 percent of nameplate rated load, determined when tested according to the test procedure in Section 1604(t).

Table T-6
Standards for Medium-Voltage Dry-Type Distribution Transformers
Manufactured On or After January 1, 2016

Single phase				*Three phase*			
BIL kVA	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***	***BIL kVA***	***20-45 kV Efficiency[1] (%)***	***46-95 kV efficiency[1] (%)***	***≥ 96 kV efficiency[1] (%)***
15	98.10	97.86		15	97.50	97.18	
25	98.33	98.12		30	97.90	97.63	
37.5	98.49	98.30		45	98.10	97.86	
50	98.60	98.42		75	98.33	98.13	
75	98.73	98.57	98.53	112.5	98.52	98.36	
100	98.82	98.67	98.63	150	98.65	98.51	
167	98.96	98.83	98.80	225	98.82	98.69	98.57
250	99.07	98.95	98.91	300	98.93	98.81	98.69
333	99.14	99.03	98.99	500	99.09	98.99	98.89
500	99.22	99.12	99.09	750	99.21	99.12	99.02
667	99.27	99.18	99.15	1000	99.28	99.20	99.11
833	99.31	99.23	99.20	1500	99.37	99.30	99.21
				2000	99.43	99.36	99.28
				2500	99.47	99.41	99.33

[1] All efficiency values are at 50 percent of nameplate rated load, determined when tested according to the test procedure in Section 1604(t).

Table U-1
Standards for Class A External Power Supplies That are Federally Regulated

Nameplate Output	***Minimum Efficiency in Active Mode (Decimal equivalent of a Percentage)***
< 1 watt	0.5 * Nameplate Output
≥ 1 and ≤ 51 watts	0.09*Ln(Nameplate Output) + 0.5
> 51 watts	0.85
	Maximum Energy Consumption in No-Load Mode
≤ 250 watts	0.5 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

Table A-9
Standards for Wine Chillers

Appliance	*Maximum Annual Energy Consumption (kWh)*
Wine chillers with manual defrost	13.7V + 267
Wine chillers with automatic defrost	17.4V + 344
V = volume in ft^3.	

Table A-10
Standards for Freezers that are Consumer Products

Appliance	*Maximum Annual Energy Consumption (kWh)*
Upright Freezers with manual defrost	7.55AV + 258.3
Upright Freezers with automatic defrost	12.43AV + 326.1
Chest Freezers	9.88AV + 143.7
AV = adjusted total volume, expressed in ft^3, which is 1.73 x freezer volume (ft^3).	

Table A-12
Standards for Refrigerated Canned and Bottled Beverage Vending Machines

Appliance	*Doors*	*Maximum Daily Energy Consumption (kWh)*	
		January 1, 2006	*January 1, 2007*
Refrigerated canned and bottled beverage vending machines when tested at 90° F ambient temperature except multi-package units	Not applicable	0.55(8.66 + (0.009 × C))	0.55(8.66 + (0.009 × C))
Refrigerated multi-package canned and bottled beverage vending machines when tested at 75° F ambient temperature	Not applicable	0.55(8.66 + (0.009 × C))	0.55(8.66 + (0.009 × C))
V = total volume (ft^3) AV = Adjusted Volume = [1.63 x freezer volume (ft^3)] + refrigerator volume (ft^3) C=Rated capacity (number of 12 ounce cans)			

Table C-7
Standards for Ground Water-Source and Ground-Source Heat Pumps

Appliance	*Rating Condition*	*Minimum Standard*
Ground water-source heat pumps (cooling)	59°F entering water temperature	16.2 EER
Ground water-source heat pumps (heating)	50°F entering water temperature	3.6 COP
Ground-source heat pumps (cooling)	77°F entering brine temperature	13.4 EER
Ground-source heat pumps (heating)	32°F entering brine temperature	3.1 COP

Table C-8
Standards for Evaporatively Cooled Computer Room Air Conditioners

Appliance	*Cooling Capacity (Btu/hr)*	*Minimum EER (Btu/watt-hour)*	
		Air-Cooled Effective January 1, 2006	*Water-Cooled, Glycol-Cooled, and Evaporatively-Cooled Effective October 29, 2006*
Computer room air conditioners	< 65,000	11.0	11.1
	≥ 65,000 and < 135,000	10.4	10.5
	≥ 135,000 and < 240,000	10.2	10.0

Table E-7
Standards for Boilers

Appliance	*Output (Btu/hr)*	*Standards*		
		Minimum AFUE %	*Minimum Combustion Efficiency % **	*Maximum Standby Loss (watts)*
Gas steam boilers with 3-phase electrical supply	< 300,000	75	—	—
All other boilers with 3-phase electrical supply	< 300,000	80	—	—
Natural gas, non-packaged boilers	≥ 300,000	—	80	147
LPG Non-packaged boilers	≥ 300,000	—	80	352
Oil, non-packaged boilers	≥ 300,000	—	83	—
*At both maximum and minimum rated capacity, as provided and allowed by the controls.				

Table E-8
Standards for Furnaces

Appliance	*Application*	*Minimum Efficiency %*
Central furnaces with 3-phase electrical supply < 225,000 Btu/hour	Mobile Home	75 AFUE
	All others	78 AFUE or 80 Thermal Efficiency (at manufacturer's option)

Table E-9
Standards for Duct Furnaces

Appliance	*Fuel*	*Standards*		
		Minimum Thermal Efficiency %[1]		*Maximum Energy Consumption during standby (watts)*
		At maximum rated capacity	*At minimum rated capacity*	
Duct furnaces	Natural gas	80	75	10
Duct furnaces	LPG[2]	80	75	147

[1] As provided and allowed by the controls.
[2] Designed expressly for use with LPG.

Table F-4
Standards for Small Water Heaters that are Not Federally-Regulated Consumer Products

Appliance	*Energy Source*	*Input Rating*	*Rated Storage Volume (gallons)*	*Minimum Energy Factor[1]*
Storage water heaters	Gas	≤ 75,000 Btu/hr	< 20	0.62 – (.0019 x V)
Storage water heaters	Gas	≤ 75,000 Btu/hr	> 100	0.62 – (.0019 x V)
Storage water heaters	Oil	≤ 105,000 Btu/hr	> 50	0.59 – (.0019 x V)
Storage water heaters	Electricity	≤ 12 kW	> 120	0.93 – (.00132 x V)
Instantaneous Water Heaters	Gas	≤ 50,000 Btu/hr	Any	0.62 – (.0019 x V)
Instantaneous Water Heaters	Gas	≤ 200,000 Btu/hr	≥ 2	0.62 – (.0019 x V)
Instantaneous Water Heaters	Oil	≤ 210,000 Btu/hr	Any	0.59 – (.0019 x V)
Instantaneous Water Heaters	Electricity	≤ 12 kW	Any	0.93 – (.00132 x V)

[1] Volume (V) = rated storage volume in gallons.

Table H-2
Standards for Tub Spout Diverters

Appliance	***Testing Conditions***	***Maximum Leakage Rate***
Tub spout diverters	When new	0.01 gpm
	After 15,000 cycles of diverting	0.05 gpm

Table K-9
Standards for State-Regulated Incandescent Reflector Lamps

Rated Lamp Wattage	**Minimum Average Lamp Efficacy (LPW)**
40-50	10.5
51-66	11.0
67-85	12.5
86-115	14.0
116-155	14.5
156-205	15.0

Table K-10
Standards for State-Regulated General Service Incandescent Lamps -Tier I

Rated Lumen Ranges	***Maximum Rated Wattage***	***Minimum Rated Lifetime***	***Effective Date***
1490-2600 Lumens	72 watts	1,000 Hours	Jan, 1, 2011
1050-1489 Lumens	53 watts	1,000 Hours	Jan 1, 2012
750-1049 Lumens	43 watts	1,000 Hours	Jan 1, 2013
310-749 Lumens	29 watts	1,000 Hours	Jan 1, 2013

Table K-11
Standards for State-Regulated General Service Lamps -Tier II

Lumen Ranges	***Minimum Lamp Efficacy***	***Minimum Rated Lifetime***	***Effective Date***
All	45 lumens per watt	1,000 Hours	Jan, 1, 2018

Table K-12
Standards for State-Regulated Modified Spectrum General Service Incandescent Lamps -Tier I

Rated Lumen Ranges	*Maximum Rated Wattage*	*Minimum Rated Lifetime*	*Effective Date*
1118-1950 Lumens	72 watts	1,000 Hours	Jan 1, 2011
788-1117 Lumens	53 watts	1,000 Hours	Jan 1, 2012
563-787 Lumens	43 watts	1,000 Hours	Jan 1, 2013
232-562 Lumens	29 watts	1,000 Hours	Jan 1, 2013

Table L-1
Ultrasound Maximum Decibel Values

Mid-frequency of Sound Pressure Third-Octave Band (in kHz)	*Maximum db Level within third-Octave Band (in dB reference 20 micropascals)*
Less than 20	80
20 or more to less than 25	105
25 or more to less than 31.5	110
31.5 or more	115

Table M-2
Standards for Traffic Signal Modules for Pedestrian Control Sold or Offered for Sale in California

Type	*at 25°C (77°F)*	*At 74°C (165.2°F)*
Hand or ‘Don’t Walk’ sign or countdown.	10 watts	12 watts
Walking Person or ‘Walk’ sign	9 watts	12 watts

Table N-1
Standards for Under-Cabinet Luminaires

Lamp Length (inches)	*Minimum Ballast Efficacy Factor (BEF) for one lamp*	*Minimum Ballast Efficacy Factor (BEF) for two lamps*
≤29	4.70	2.80
>29 and ≤35	3.95	2.30
>35 and ≤41	3.40	1.90
>41 and ≤47	3.05	1.65
>47	2.80	1.45

Table N-2
Minimum Requirements for Portable LED Luminaires, and Portable Luminaires with LED Light Engines with Integral Heat Sink

Criteria	***Requirement***
Light Output	≥ 200 lumens (initial)
Minimum LED Luminaire Efficacy	29 lumens/W
Minimum LED Light Engine Efficacy	40 lumens/W
Color Correlated Temperature (CCT)	2700 K through 5000 K
Minimum Color Rendering Index (CRI)	75
Power Factor (for luminaires labeled or sold for residential use)	≥ 0.70

Table U-2
Standards for State-Regulated External Power Supplies Effective January 1, 2007 for external power supplies used with laptop computers, mobile phones, printers, print servers, canners, personal digital assistants (PDAs), and digital cameras.
Effective July 1, 2007 for external power supplies used with wireline telephones and all other applications.

Nameplate Output	***Minimum Efficiency in Active Mode***
0 to < 1 watt	0.49 * Nameplate Output
≥ 1 and ≤ 49 watts	0.09 * Ln(Nameplate Output) + 0.49
> 49 watts	0.84
	Maximum Energy Consumption in No-Load Mode
0 to <10 watts	0.5 watts
≥ 10 to ≤ 250 watts	0.75 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

Table U-3
Standards for State-Regulated External Power Supplies
Effective July 1, 2008

Nameplate Output	*Minimum Efficiency in Active Mode*
<1 watt	0.5 * Nameplate Output
≥ 1 and ≤ 51 watts	0.09*Ln(Nameplate Output) + 0.5
> 51 watts	0.85
	Maximum Energy Consumption in No-Load Mode
Any output	0.5 watts
Where Ln (Nameplate Output) = Natural Logarithm of the nameplate output expressed in watts.	

Table V-1
Standards for Consumer Audio and Video Equipment

Appliance Type	*Effective Date*	*Maximum Power Usage (Watts)*
Compact Audio Products	January 1, 2007	2 W in Audio standby-passive mode for those without a permanently illuminated clock display 4 W in Audio standby-passive mode for those with a permanently illuminated clock display
Digital Versatile Disc Players and Digital Versatile Disc Recorders	January 1, 2006	3 W in Video standby-passive mode

Table V-2
Standards for Televisions

Effective Date	*Screen Size (area A in square inches)*	*Maximum TV Standby-passive Mode Power Usage (watts)*	*Maximum On Mode Power Usage (P in Watts)*	*Minimum Power Factor for (P ≥ 100W)*
January 1, 2006	All	3 W	No standard	No standard
January 1, 2011*	A < 1400	1 W	P ≤ 0.20 x A + 32	0.9
January 1, 2013	A < 1400	1 W	P ≤ 0.12 x A + 25	0.9

Table W-1
Standards for Large Battery Charger Systems

Performance Parameter		*Standard*
Charge Return Factor (CRF)	100 percent, 80 percent Depth of discharge	CRF≤ 1.10
	40 percent Depth of discharge	CRF ≤ 1.15
Power Conversion Efficiency		Greater than or equal to: 89 percent
Power Factor		Greater than or equal to: 0.90
Maintenance Mode Power (E_b = battery capacity of tested battery)		Less than or equal to: 10 + 0.0012E_b W
No Battery Mode Power		Less than or equal to: 10 W

Table W-2
Standards for Small Battery Charger Systems

Performance Parameter	***Standard***
Maximum 24 hour charge and maintenance energy (Wh) (E_b = capacity of all batteries in ports and N = number of charger ports)	For E_b of 2.5 Wh or less: 16 × N
	For E_b greater than 2.5 Wh and less than or equal to 100 Wh: 12 x N +1.6E_b
	For E_b greater than 100 Wh and less than or equal to 1000 Wh: 22 x N+1.5E_b
	For E_b greater than 1000 Wh: 36.4 x N +1.486E_b
Maintenance Mode Power and No Battery Mode Power (W) (E_b = capacity of all batteries in ports and N = number of charger ports)	The sum of maintenance mode power and no battery mode power must be less than or equal to: 1x N+0.0021xE_b