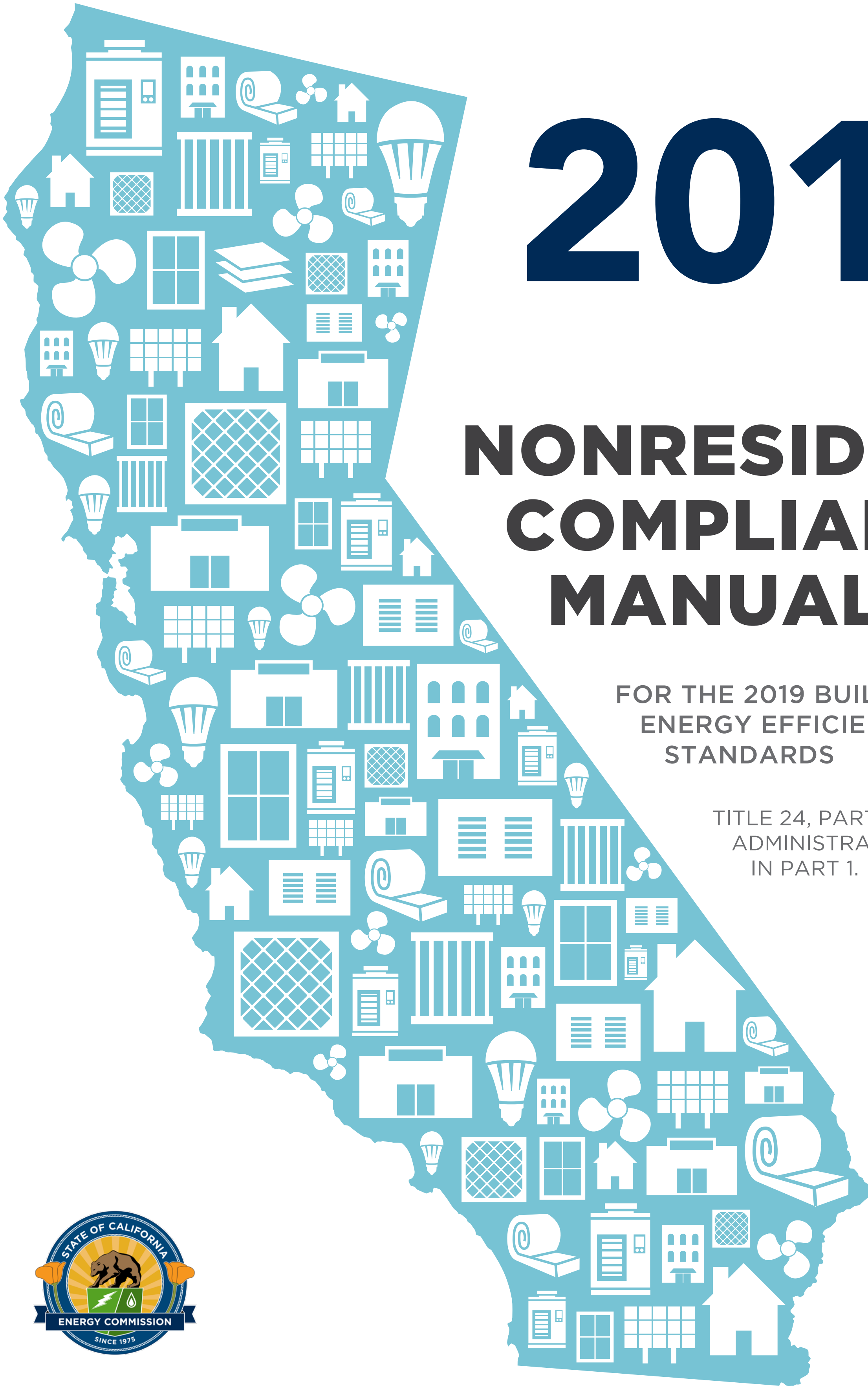

2019

NONRESIDENTIAL COMPLIANCE MANUAL

FOR THE 2019 BUILDING ENERGY EFFICIENCY STANDARDS

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

DECEMBER 2018
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CALIFORNIA ENERGY COMMISSION
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 2019 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.

2019 is a major step towards meeting the Zero Net Energy (ZNE) goal by the year 2020 and is the last of three updates to move California toward achieving that goal.

The 2019 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 1,300 formal public comments.

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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 2019 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 the introduction of photovoltaic into the prescriptive package, improvements for attics, walls, water heating, and lighting. The most significant efficiency improvements to the nonresidential Standards include alignment with the ASHRAE 90.1 2017 national standards. The 2019 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 conceptually 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, and provide flexibility in how energy efficiency in buildings can be achieved. Finally, the third set constitutes an alternative to the performance standards, which is a set of prescriptive packages that provide 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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Table of Contents

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 a reference and an instructional guide for anyone 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 Compliance and enforcement process, including design and the preparation of compliance documentation through acceptance testing.

Chapter 3 Building envelope.

Chapter 4 Heating, ventilation, and air-conditioning (HVAC) systems and water heating systems.

Chapter 5 Indoor lighting.

Chapter 6 Outdoor lighting.

Chapter 7 covers sign lighting for both indoor and outdoor applications.

Chapter 8 Electrical power distribution.

Chapter 9 Solar ready requirements.

Chapter 10 Covered processes energy requirements.

Chapter 11 Performance approach.

Chapter 12 Commissioning requirements.

Chapter 13 Acceptance test requirements.

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

1.2 Related Documents

This compliance manual supplements several other documents from the California Energy Commission (Energy Commission):

A. *The 2019 Building Energy Efficiency Standards, Title 24, Part 6 (Energy Standards)* - This manual supplements and explains the Energy Standards, the legal requirements for all covered buildings. This manual explains those requirements in simpler terms, but does not replace or supersede them. Readers should have a copy of the Energy Standards as a reference.

B. The 2019 Reference Appendices:

- Reference Joint Appendices contain information common to residential and nonresidential buildings.
- Reference Residential Appendices contain information for residential buildings only.
- Reference Nonresidential Appendices contain information for nonresidential buildings only.
- The 2019 Alternative Calculation Method (ACM) Approval and Nonresidential ACM Reference Manuals are specifications for compliance software.

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. Mechanical and lighting information is in the Reference Nonresidential Appendices. Residential water heating information is in the Reference Residential Appendices.*

Material from these documents is not always repeated in this manual. If you are using the electronic version of the manual, there may be hyperlinks to the reference document.

1.3 The Technical Chapters

Each of the 11 technical chapters (3 through 13) begins with an overview followed by 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 in each subsection or component. The prescriptive requirements establish the stringency of the Energy Standards because they are the basis of the energy budget when the performance compliance method is used.

1.4 Why California Needs Energy Standards

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

1.4.1 Electricity Reliability and Demand

Buildings are a major contributor to electricity demand. The 2000 to2001 California energy crisis and the East Coast blackout in the summer of 2003 illustrated the fragility of the electric distribution network. System overloads caused by excessive demand from buildings create unstable conditions. Blackouts disrupt business and cost the economy billions of dollars.

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

1.4.2 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 improve air circulation. Poorly designed building envelopes result in buildings that are less comfortable. Oversized heating and cooling systems do not ensure comfort in older, poorly insulated, or leaky buildings.

1.4.3 Economics

Energy efficiency helps create a more profitable operation for building owners. More broadly, the less California that depends on depletable resources such as natural gas, coal, and oil, the stronger and more stable the economy will remain as energy cost increases. investing in energy efficiency benefits everyone. It is more cost effective to invest in saving energy than build new power plants.

1.4.4 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 the 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.

1.4.5 Greenhouse Gas Emissions and Global Warming

Burning fossil fuel adds carbon dioxide (CO_2) to the atmosphere, a major contributor to global warming. Carbon dioxide and other greenhouse gases create an insulating layer that leads to global climate change. The Energy Commission's research shows that most sectors of California 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 to reducing greenhouse gases. 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 to adopt nationwide energy efficiency building codes.

The Energy Standards are expected to significantly reduce greenhouse gas and other air emissions.

1.5 What's New for 2019

1.5.1 Envelope

- Reduced the site-built fenestration requirement from a 1,000 square feet (sq ft) to 200 sq ft (NA6).

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1.5.2 Lighting

1. Changes to indoor and outdoor lighting power allowances with the lighting power allowances based on light-emitting diode (LED) lighting technologies (§140.6 and §140.7) Revisions to lighting power density (LPD) values in Table 140.6-B, 140.6-C, 140.6-D, 140.7-A, and 140.7-B.
2. Revision and streamlining luminaire classification and wattage requirements.
3. New lighting power adjustment for small aperture tunable white and dim-to-warm LED luminaires.

4. New power adjustment factors (PAFs) for daylighting devices including horizontal slats, light shelves and clerestory fenestrations. (§140.6(a)2L). New prescriptive measure and requirements of daylighting devices including horizontal slats, light shelves and clerestory fenestrations. (§140.3(d)).
5. Clarification and streamlining of manual area controls requirements, multi-level lighting controls requirements, automatic daylighting control requirements. Restrooms to comply with occupancy sensing control requirements. A new section for indoor lighting control interactions. (§130.1)
6. Revision and streamlining of outdoor lighting control requirements. (§130.2(c))
7. Revision and streamlining of alteration requirements, including the merging of three sections into a single "Altered Indoor Lighting Systems" section, the alignment of two reduced power options on controls, and trigger threshold of projects over 5000 sq ft. (§141.0(b)2I). Revised and consolidated Table 141.0-F.

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. Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) have to comply with the applicable requirements of Section 130.5 for electrical power distribution systems. There are exemptions added for healthcare facilities in order to avoid potentially conflicting requirements for healthcare facilities..

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 clarify §120.8.

1.6 Mandatory Measures and Compliance Approaches

1.6.1 Mandatory Measures

With either the prescriptive or performance compliance paths, there are mandatory measures that always must 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 requirements described in Chapters 3, 4, 5, 6, 7, and 10) requires each component of the proposed building to meet a prescribed minimum efficiency. The approach offers little flexibility but is easy to use. If the design fails to meet even one requirement, then the system does not comply with the prescriptive approach. In this case, the performance approach provides more 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 Chapter 3. The only flexibility is if portions of an envelope component do not meet a requirement, a weighted average of the component can be used to demonstrate compliance. The stringency of the envelope requirements vary according to climate zone and occupancy type.

B. **Mechanical.** The prescriptive mechanical requirements are described in Chapter 4. The prescriptive approach specifies equipment, features, and design procedures, but does not mandate the installation of a particular HVAC system.

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 approaches are described in Chapter 5. The allowed lighting varies according to the requirements of the building occupancy or task requirements

D. **Outdoor Lighting**. Outdoor lighting standards are described in Chapter 6, setting 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. Detailed information on the outdoor lighting power allowance calculations is in Section 6.4.

1.6.3 Performance Approach

The performance approach (Chapter 11) allows greater flexibility than the prescriptive approach. It is based on an energy simulation model of the building.

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

The performance approach may be used for:

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

Indoor lighting compliance must be combined with envelope compliance. The performance approach does not apply to outdoor lighting, sign lighting, exempt process load, some covered process loads (e.g., refrigerated warehouses), or solar ready applications.

Time-dependent valuation (TDV) energy is the "currency" for the performance approach. TDV energy considers the type of energy (electricity, gas, or propane) and when it is saved or used. Energy saved when California is likely to have a statewide system peak is worth more than when supply exceeds demand. Appendix JA3 of the Reference Appendices has more information on TDV energy.

See Chapter 11 if the performance approach will be used for additions and alterations.

1.6.3.1 **Compliance Options**

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

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 discusses the requirements for low-rise residential buildings.

1.7.1 Building Types Covered

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

The Energy Standards do not apply to CBC Group L. The standards also do not apply to buildings that fall outside the CBC's jurisdiction, such as mobile structures. If outdoor lighting is associated with a Group L occupancy, it is exempt. If the outdoor lighting is part of any other occupancy groups listed, it must comply.

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.

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 for interpreting the requirements of the CHBC and determining to what extent the requirements of the Energy Standards apply to new and replacement equipment and other alterations to qualified historic buildings. In enacting the CHBC legislation, the Legislature wants 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 percent 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, outdoor lighting systems, signs, or for modernization. The primary enforcement mechanism is 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 Energy Standards, it may withhold the building or occupancy permit.

The Energy Standards apply only to the construction subject to the building permit application. An existing spaces that is "conditioned" for the first time, is an addition and the all existing components , whether altered or not, must comply with the Energy Standards (see §100.1 addition or newly conditioned space).

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

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 was built on speculation, the owner would know the ultimate occupancy of the space, but might not know the specific tenant. For this 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.
2. Include envelope compliance as well as mechanical and/or lighting compliance, when those systems are to be installed prior to leasing.

A potential pitfall with delaying envelope compliance is that tenants may have a difficult time showing compliance. An energy code update between the time of shell construction and energy compliance for a tenant improvement could make compliance 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 retrofit costs). In most cases, delaying envelope increases construction costs. If a building is likely to be conditioned, some enforcement agencies require envelope compliance when the shell is constructed.

Section 1.7.12 has information about energy compliance for tenant improvements in existing buildings.

1.7.5.2 **Unknown Occupancy**

Speculative buildings may be built and the ultimate occupancy is determined only when the building is leased. The structure could be an office, a warehouse, a restaurant, or retail space. The Energy Standards treat these occupancies similarly. The major differences are the lighting and ventilation requirements. If, a tenant is not identified during the permitting time, the “All other areas” lighting power densities in Table 140.6-C are used.

Deferring compliance by calling the building unconditioned will cause problems when the first tenant installs mechanical space conditioning equipment.

1.7.6 Mixed and Multiple 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 depend on the percentages of conditioned floor **of** each occupancy type:

A. Minor Occupancy (Exception 1 to §100.0(f).) When a residential occupancy is 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 applicant may choose to treat the entire building as if it is the major occupancy for envelope, HVAC, and water heating compliance. Lighting requirements in §140.6 through §140.8 or §150.0(k) must be met for each occupancy separately. The mandatory measures that apply to the minor occupancy, if different from the major occupancy, would still apply.

B. Mixed Occupancy. When a residential occupancy is mixed with a nonresidential occupancy, and if neither occupancy is less than 20 percent of the total conditioned floor area, two compliance submittals are prepared, each using the calculations and documents of its respective standards. Separate compliance for each occupancy is an option when one of the occupancies is a minor occupancy.

1.7.6.2 **Different Nonresidential Occupancies.**

When **a building consists of** multiple **nonresidential** occupancies, they **are considered** separate occupancies. **Most** occupancies have the same envelope requirements. High-rise residential and hotel-motel guest rooms have different envelope requirements. Lighting and mechanical requirements vary among the various usage categories and **are** treated according to each **appropriate** occupancy type.

Example 1-1

Question

A 250,000 sq ft high-rise office building includes a small 900 sq ft apartment on the first floor that visiting executives use. Is the apartment required to meet the residential requirements of the Energy Standards, and if so, would it be high-rise residential or low-rise residential?

Answer

No. 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. Since it is on the first floor of the building, it is technically a low-rise residential building. All 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), comply with the nonresidential Energy Standards. Exit signs comply with the Appliance Efficiency Regulations.

1.7.7.1 **Mandatory Measures**

Special requirements for how mandatory measures apply to high-rise residential buildings include:

1. Living quarters meet the indoor lighting requirements for residential buildings.
2. Outdoor lighting meets 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 following summarizes how the requirements apply to 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. Economizer controls ae not required in high-rise residential living quarters.
3. High-rise residential living quarters are exempt from nonresidential lighting power density requirements. Occupancies other than living quarters must comply with the nonresidential lighting standards.
4. 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 ft² floor area. See Chapter 6 of the Residential Compliance Manual.
5. .
6. Water heating in living quarters must comply with the residential Energy Standards (§150.1(c)8).

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 software calculates an energy budget (standard design compared to proposed design).

1.7.8 Hotels and Motels

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

Hotels or motels are in unique in that their 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 arrival experience created through the main lobby's architectural features to the thermal comfort of the guest rooms. Other functions that designs must address include restaurants, kitchens, laundry, storage, light assembly, outdoor lighting, and sign lighting, these structures can range from simple guest rooms with a small office, to a structure encompassing a small city. (§100.1 "HOTEL/MOTEL").

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 Energy Standards. The guest room portions of hotels/motels must meet the envelope, mechanical, and lighting provisions applicable only to hotels/motel guest rooms. 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 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 describes any special requirements or exceptions:

- Hotel/motel guest rooms must meet the applicable residential lighting standards.
- Outdoor lighting must meet the applicable outdoor lighting standards.
- Indoor and outdoor signs (other than exit signs) must comply with nonresidential Energy Standards. Exit signs must comply with the Appliance Efficiency Regulations.
- Hotel and motel guest room thermostats shall have numeric temperature settings.
- 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.
- 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:

- Hotel/motel guest rooms must meet the prescriptive envelope criteria for high-rise residential buildings rather than the prescriptive criteria for nonresidential buildings.

- Hotel and motel guest rooms are not required to have economizer controls.
- Guest rooms in hotel/motels are exempt from the lighting power density requirements. However, lighting must meet the residential requirements of §150.0(k).
- Each occupancy (other than guest rooms) in the hotel/motel must comply with the Nonresidential Lighting Standards.
- For compliance with water heating requirements, use the residential compliance.

1.7.8.3 Performance Compliance

The rules for performance compliance are identical to those 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 calculates an energy budget (standard design compared to proposed design). 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 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

These 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 an addition and all the building's components must comply as if it were a new building.

This situation has potentially significant construction and cost implications. 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 conform with the current lighting requirements, including mandatory wiring and switching. If the envelope has large windows, some may have to be eliminated or replaced with more efficient windows. If the lighting system is inefficient, new and more efficient fixtures might have to be installed.

This requirement is a potential consequence of an owner 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 wants the tenants to handle conditioning and lighting improvements. If that owner claims unconditioned status for that building, the owner does not have to comply with the envelope requirements of the standards. The owner does have to demonstrate compliance with the lighting requirements. If a tenant is not identified for a multi-tenant space during the permitting time, the “All other areas” lighting power density allowances from Energy Standards Table 140.6-C shall be used. When the tenant applies for a permit to install the HVAC equipment, the envelope and any existing lighting to remain must fully comply 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 Energy Standards. If the building was initially designed in a way that makes 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 difficulties, the recommended practice is to demonstrate energy compliance when the envelope is built and comply with the lighting systems during installation.

1.7.12 New Construction in Existing Buildings

Tenant improvements, including alterations and repairs, are new construction in an existing building. For example, the base building was constructed, but the individual tenant spaces were not completed. Tenant improvements can include work on the envelope, mechanical, or lighting systems. The system or systems being installed are 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 time systems other than those subject to the current permit application are involved 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. An existing unconditioned building, where evaporative cooling is added to the existing unaltered envelope and lighting, does not need to comply with current standards.
6. Mechanical system alterations are governed primarily by the mandatory measures.

Beyond meeting all applicable mandatory requirements, alterations must also comply with applicable prescriptive requirements discussed in Chapters 3 through 8 or use the performance approach. Within the performance approach, the option to show changes to the existing building (existing and alteration) is explained in Chapter 11. Performance credit is given only for systems that are changing under the current permitted scope of work.

Example 1-2

Question

An owner wants to add less than 50 sq ft 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 sq ft of added windows from the relative solar heat gain coefficient (RSHGC) and visual transformation (VT) requirements in Table 141.0-A. 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. 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 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. There will be no changes to the building envelope or 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 the:

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

Mandatory measures and either prescriptive or 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 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

Using performance compliance, model the combination of the existing building with the addition (§141.0(a)2Bii). IN 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 by approved software 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 up for an inefficiencies of the addition depending on the nature and scope of 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 is the most stringent and is only practical if the existing building 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 Change of Occupancy

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

If no changes are proposed for the building, consider the ventilation requirements of the new occupancy. For example, if a residence is converted to a hair salon, with new sources of indoor pollution, existing residential ventilation rates would likely be inadequate. The Energy Standards requires no changes.

1.7.16 Repairs

A repair is reconstructing or renewing 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. The Energy Standards do not apply to repairs.

Example 1-9

Question

If a space were 1,000 sq ft, 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 British thermal units (Btu)/hour (hr)-sq ft =(hr-ft^2) x 1,000 sq ftft^2 = 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-sq ftft²) and operates to keep the space temperature from falling below 50 degrees °Fahrenheit (°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-sq ft?

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 in the building shell and its capacity exceeds 10 Btu/(hr-sq ft). 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 Btu/hr-sq ft 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 Btu/hr-sq ft and is controlled to a temperature of 75°F, does the space have to meet the envelope requirement of the Standards?

Answer

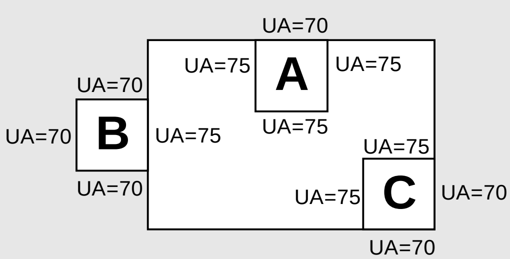
No. Computer rooms are a Covered Process. There are no envelope requirements in either §120.6 or §140.9.

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, each space is evaluated on the basis of heat transfer coefficients through the walls and roof. It is further assumed that the floors are adiabatic. 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, the first floor is retail, second and third floors are offices, and the fourth floor is residential. 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 (the Act) which created the Energy Resources and Conservation Development Commission (Energy Commission) in 1975 to deal with energy-related issues, and charged the Energy Commission to adopt and maintain Energy Efficiency Standards for new buildings. The first standards were adopted in 1978 in the aftermath 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."

The Energy Commission is required to periodically update the standards. Six months before the effective date of new standards, manuals must be published to support the Energy Standards. 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. That is 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. Major changes were made to lighting, building envelope, fenestration, and HVAC and mechanical requirements. Structural changes made in1992 led the way for national standards in other states.

The standards went through minor revisions in 1995. In 1998, lighting power limits were reduced significantly, because 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. This produced escalating energy prices at the wholesale market and in some areas in the retail market. The Legislature responded with Assembly Bill 970, which required the Energy Commission to update the Energy Standards through an emergency rulemaking.

This was achieved within the 120 days required by the Legislature. The2001 Standards (or the AB 970 Standards) took effect mid-2001. The 2001 Standards included requirements for high performance windows throughout California, 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 on the rich history of Nonresidential Energy Standards in California and the leadership and direction provided by the California Legislature over the years.

The 2008 Standards were expanded to include refrigerated warehouses and steep-sloped roofs.

The 2013 Energy Standards reflected many significant changes and 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

Does LEED-certified building still need to meet the 2016 Energy Standards?

Answer

Yes.

1.8.2 California Climate Zones

Since energy use depends partly upon weather conditions, the Energy Commission established 16 climate zones representing distinct climates within California. These 16 climate zones are used with both residential and the nonresidential standards. Information is available by zip code and in several formats (http://energy.ca.gov/maps/renewable/building_climate_zones.html).

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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Table of Contents

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 verification 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 and complies with all applicable codes and standards, they 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 is important, the compliance and enforcement process is significantly more involved and requires participation by other persons and organizations. This includes the architect or building designer, specialty engineers (mechanical, electrical, civil, and so forth), 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 Energy Commission's Executive Director of its determination.

2.1.1 Manufacturer Certification for Equipment, Products, and Devices

Certain equipment, products, and devices must be certified to the Energy Commission by the manufacturer that it meets requirements under Title 24, Part 6, and associated appendices. The Energy Commission makes no claim that the listed equipment, products, or devices meet the indicated requirements or, if tested, will confirm the indicated results.

Inclusion on these lists only confirms only that a manufacturer certification has been submitted to and accepted by the Energy Commission. See the Energy Commission's website for additional information about the required information for manufacturers to certify products and for lists of certified products:

http://www.energy.ca.gov/title24/equipment_cert/

In nonresidential buildings, the following are examples of products that must be certified by the manufacturer:

- Air economizers
- Airflow measurement apparatus - forced air systems
- Airflow measurement apparatus - ventilation systems
- Air-to-water heat pump systems
- Economizer fault detection and diagnostics
- Intermittent mechanical ventilation systems
- Low-leakage air-handling unit
- Occupant-controlled smart thermostats
- Demand-responsive control systems

2.1.2 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 a certificate 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).

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

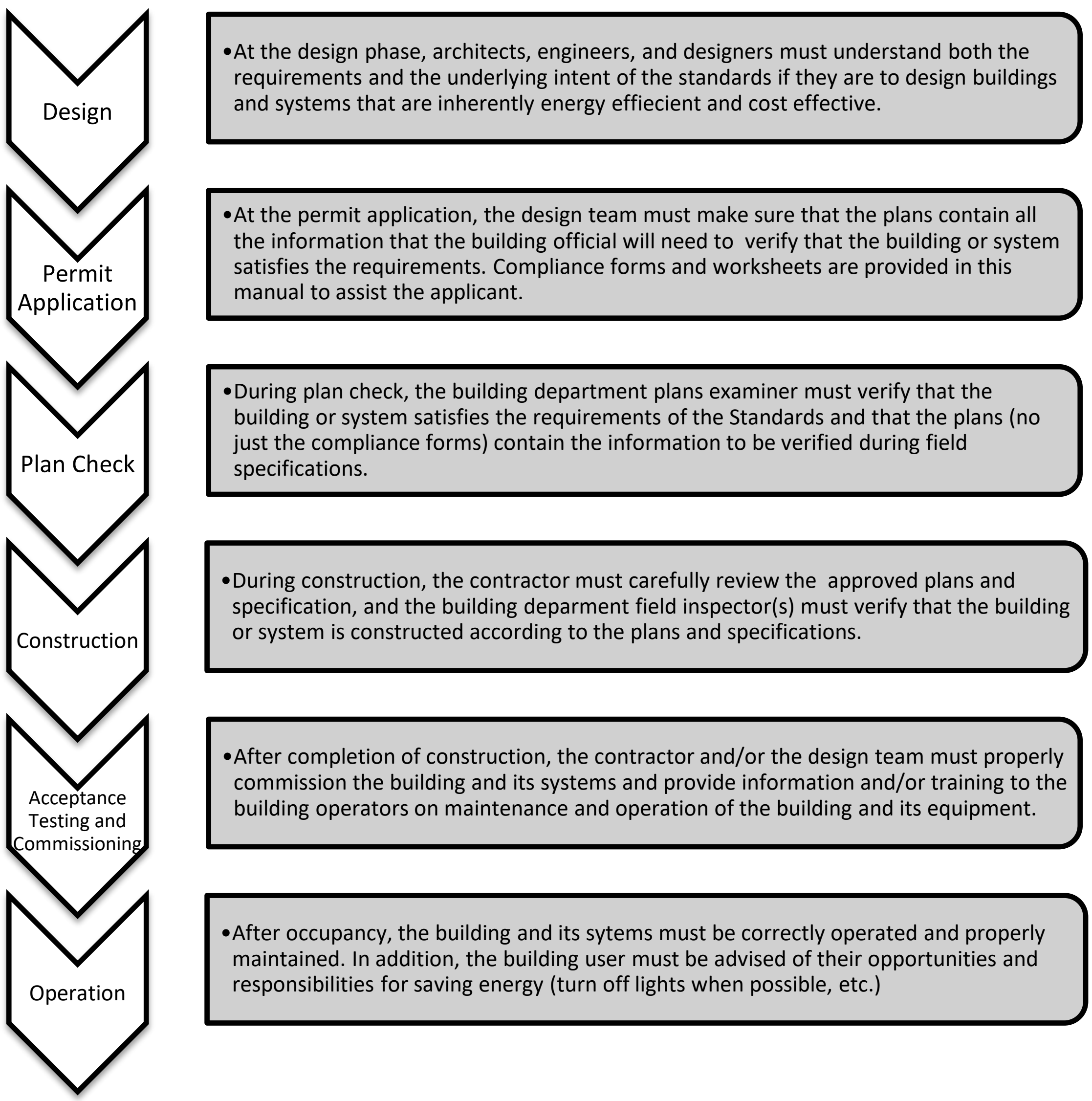
2.2 The Compliance and Enforcement Process

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 among 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 compliance and enforcement. (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 before 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 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 overall design of the building or system 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. Furthermore, 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 Energy 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.

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 overall design development. This coordination 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 the related recommendations as a whole. It recognizes that the recommendations for each discipline have an impact on other aspects of the building project. This approach allows for optimization of building performance and cost.

For example, often 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 nontypical 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 design components and systems. Though these 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. The permit application is generally the last step in the planning and design process. 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 preparing 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, lighting systems, etc. must all be submitted. New in 2019, there are only 10 prescriptive certificate of compliance documents that apply to new construction nonresidential buildings. They are organized by building component, and only one form has to be used to show compliance for each component (i.e., NRCC-LTI-E for indoor lighting). These documents are dynamic and expand based on the project scope. These were developed to greatly simplify the process of complying prescriptively. (See Table 2-1.)

If the performance method is used for the entire building, a compiled set of certificate(s) of compliance documentation pages is prepared (the NRCC-PRF-01 document) using one of the compliance software applications approved by the Energy Commission that summarizes the energy features for the building. The NRCC-PRF-01 will include the important details for the building envelope, mechanical systems, and lighting systems. 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.

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, as 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 document NRCC-CXR-E. The building owner, representative, design engineer and design reviewer must all sign and date the NRCC-CXR-E 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. See Chapter 12 of for more details regarding building commissioning.

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 used 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 the energy compliance documents be incorporated electronically onto the building plans. This incorporation 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 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 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
NRCC-CXR-E Building Commissioning	**NRCC-ELC-E** Electrical Power Distribution	**NRCC-ENV-E** Building Envelope	**NRCC-LTI-E** Indoor Lighting	**NRCC-LTO-E** Outdoor Lighting
Sign Lighting	**Mechanical**	**Plumbing**	**Covered Processes**	**Solar**
NRCC-LTS-E Sign Lighting	**NRCC-MCH-E** Mechanical Systems	**NRCC-PLB-01-E** Water Heating Systems	**NRCC-PRC-E** Covered Process	**NRCC-SRA-E** Solar Ready Areas
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 to determine whether the energy efficiency specifications for the design comply 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. When the permit applicant submits comprehensive, accurate, clearly defined building plans and specifications, it helps speed plan review.

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 for direction in performing their responsibilities.

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 must 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. The building design features represented on the approved building plans and specifications for the proposed building must comply with the Energy Standards requirements specified on the approved certificate(s) of compliance, and the actual construction/installation must be 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, the plans examiner must verify 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/title24/2019standards/2019_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, specifications, and energy compliance documentation for the project, the enforcement agency may issue a building permit at the builder's request. 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 noncompliance 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 construction, 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 the 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 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 before completion and submittal of the certificate(s) of installation.

2.2.5.3 Registration

Once a data registry has been established, all the certificate of installation documents must be registered 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 documents 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-E
Additional Videoconference Studio Lighting	NRCI-LTI-06-E
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, envelope features, and equipment that requires proper calibration at initial commissioning to ensure that operating conditions that could lead to premature system failure are prevented and that 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 before 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 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 to produce a completed, dated, and signed electronic certificate of acceptance that is retained by the registry for use by authorized registry users. 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 Under slab 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 the 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 before signing a certificate(s) of compliance for submittal to plan review and before 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 the following:

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

Since making changes on documents may be less costly compared to the cost of altering or replacing a completed but noncompliant building energy feature construction/installation, attention should be given to plan review early in the process. 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 before 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 does not comply 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 before proceeding with the acceptance tests and submitting or posting 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 comply with the Energy Standards.

The certified technician who conducts the applicable acceptance testing is responsible for documenting the results on the required certificate(s) of acceptance. 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 an 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 must 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 details.) Samples of the Energy Commission-approved documents are 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
	NRCA-ENV-03-F – Clerestories, horizontal slats, light shelves PAF	§140.3(d)1-3	NA7.4.4 – 7.4.6
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	§110.12(b)& §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	NA7.7.2
	NRCA-MCH-19-A – Occupancy Sensor	§120.2(e)3 §120.5(a)18	NA7.5.17
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	§110.12(c)	NA7.6.3
	NRCA-LTI-05-A Institutional Tuning Power Adjustment Factor	§140.6(a)2J	NA7.7.4.2

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
	NRCA-PRC-14-F – Lab Exhaust Ventilation	§140.9(c)3	NA7.16
	NRCA-PRC-15-F – Fume Hood Automatic sash Closure System	§140.9(c)4	NA7.17
	NRCA-PRC-16-F – Adiabatic Condensers	§120.6(a)4C §120.6(a)7	NA7.10.3.3
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 air distribution duct leakage of the system is within specifications required by the Energy Standards.

2.2.9 HERS Providers

http://www.energy.ca.gov/HERS/

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. In California, the certified HERS providers are:

1. ConSol Home Energy Efficiency Rating Services (CHEERS).

2. California Certified Energy Rating & Testing Services (CalCERTS).

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.

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 residential and nonresidential compliance documentation.

2.2.10 HERS Raters

An Energy Commission-approved HERS Provider certifies the HERS Rater 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 of compliance (NRCC-MCH-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 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. Before completing field verification and diagnostic testing, the HERS Rater shall confirm that the certificate(s) of installation and certificate(s) of acceptance have been completed as required and show 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 on the copy conforms to the registered document information 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 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 determine 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 result 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 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 before commencing 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 but do not have the authority to sign compliance documentation as a HERS Rater. Third Party Quality Control Programs:

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 are 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 performed by the participating TPQCP contractor. If group sampling is used 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 registered copies 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 *2019 Reference Nonresidential Appendices* and *2019 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 before 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 instructions 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[s] of compliance).
2. The construction phase (certificate[s] of installation).
3. The testing and verification phase (certificate[s] 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 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 preparing 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 used 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 requires 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.)

2.5 Roles and Responsibilities

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

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

- The design of the electrical and lighting system of the building 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.

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 **mechanical plans examiner** is responsible for reviewing the mechanical plans, and a **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 and 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 processes can be completed separately for each discipline. This enables each discipline to complete its work independently of others. To simplify this process, compliance documents have been grouped by discipline.

2.5.1 Designer

5537 and 6737.1 of California Business and Professions Code

The designer is responsible for the overall building design. The designer is also responsible for specifying the building features that determine compliance with the Energy Standards and other applicable building codes. They are 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 Energy Standards.

The designer may be an architect, engineer, or other California-licensed professional and may personally prepare the certificate(s) of compliance documents. This professional 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 demonstrate 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 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 construction, the builder or general contractor usually hires specialty subcontractors to provide specific services, such as installing insulation and 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, preparation and signature responsibility reside with the specialty subcontractor who provided the installation services. The certificate(s) of installation identifies the installed features, materials, components, or manufactured devices detailed in the building plans and the certificate(s) of compliance. 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. Also, 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 all applicable completed and signed compliance documents for the building owner at occupancy in the building. 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 building construction. The builder has ultimate responsibility for all aspects of building 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 completion of the installation work they have performed for the builder. The subcontractor's responsibility for certificate(s) of installation documentation includes providing a signed and registered copy of all applicable certificate of installation documents to the builder and posting the 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 the plan review of the certificate(s) of compliance documents and the building plans and specifications. During plan review, the certificate(s) of compliance documentation is compared to the plans and specifications for the building design to confirm that the building is specified consistently in all 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, the submitted documents must be revised 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 building construction, 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 it has received all applicable certificates 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 if the enforcement agency field inspector determines that the building conforms to the requirements of the building 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 it has 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), 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. It must confirm that these documents have been properly prepared and are consistent with the plans, 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 that 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 conditioned space of the building, 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 complies 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 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

3.1 Chapter Overview

This chapter covers the requirements for efficiency measures used for the building envelope of nonresidential, high-rise residential, hotel and motel occupancy buildings. Building energy use is affected by heating and cooling loads.

- **Heating loads** are affected by infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors.
- **Cooling loads** are dominated by solar gains through windows and skylights, internal gains due to lighting, plug loads, and occupant use, and from additional ventilation loads needed for indoor air quality.

3.1.1 What's New for 2019

The *2019 Building Energy Efficiency Standards* (Energy Standards) include two important changes to the building envelope component requirements as described below:

- The site-built fenestration requirement is reduced from a 1,000 square feet to 200 square feet (NA6).
- Daylighting design power adjustment factors (PAFs) are available for the following daylighting devices: clerestory fenestration, interior and exterior horizontal slats, and interior and exterior light shelves.

3.2 Opaque Envelope Assembly

This section addresses the requirements for thermal control of the opaque portion of the building shell or envelope. Fenestration, windows, skylights and glazed doors are addressed in Section 3.3.

3.2.1 Opaque Envelope Definitions

Opaque elements of the building envelope contribute significantly to the energy efficiency of the building and its design intent. Components of the building shell include the walls, floor, the roof or ceiling, doors, and fenestration. Definitions for fenestration are addressed in Section 3.3.

Envelope and other building components definitions are listed in §100.1(b) of the Energy Standards and the Reference Joint Appendices JA1.

A. **Conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1(b) for full definition.) Indirectly conditioned space is influenced more by directly adjacent conditioned space than it is by ambient (outdoor) conditions.

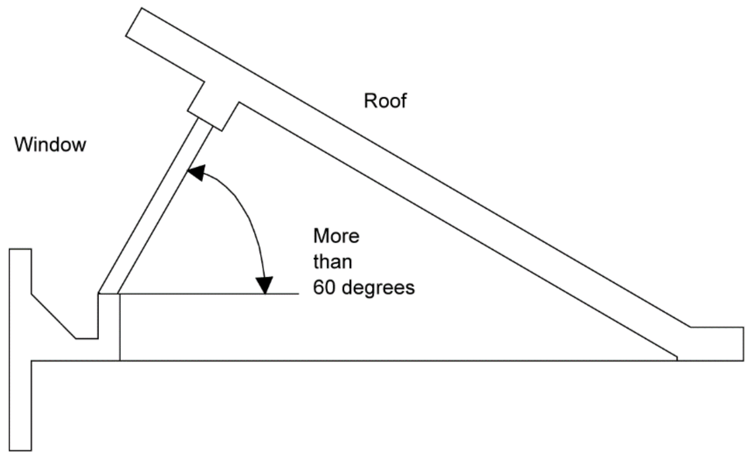
B. **Unconditioned space** is an enclosed space within a building that is not directly conditioned or indirectly conditioned.

C. **Air Leakage.** Infiltration is the *unintentional* replacement of conditioned air with unconditioned air through leaks or cracks in the building envelope. It is a major component of heating and cooling loads. Infiltration can occur through holes and cracks in the building envelope and around doors and fenestration framing areas

D. **Ventilation** is the *intentional* replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems.

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 degrees from horizontal, it is considered a roof; a slope of 60 degrees or more is a wall. This definition extends to fenestration products, including windows in walls and any skylights in roofs.

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



F. **Exterior partition or wall** is an envelope component (roof, wall, floor, window, etc.) that separates conditioned space from ambient (outdoor) conditions. An exterior wall is considered separate from a demising wall or demising partition and has more stringent thermal requirements

G. **Demising partition or wall** is an envelope component that separates conditioned space from an enclosed unconditioned space.

H. **Exterior floor** is a horizontal exterior element under conditioned space and above ambient (outdoor) conditions.

I. **Soffit** is a horizontal demising element, under conditioned space and above an unconditioned space.

J. **Attic** is a space below an uninsulated roof that has insulation on the attic floor, and is an unconditioned space because there is less thermal resistance to the outside than across the insulated ceiling to the conditioned space below.

K. **Plenum** is an air compartment or chamber, including uninhabited crawl space, 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.

L. **Exterior roof** has a slope less than 60 degrees from horizontal and has conditioned or indirectly conditioned space below with ambient (outdoor) conditions space above.

M. **Ceiling** is a demising element that has a slope less than 60 degrees from horizontal and has conditioned space below with unconditioned space above.

N. **Roof deck** is the surface of an exterior roof that is directly above the roof rafter and below exterior roofing materials.

O. **Roofing Products (Cool Roofs).** Roofing products with a high solar reflectance and thermal emittance are referred to as "*cool roofs*." These roofing types absorb less solar heat and give off more heat to the surroundings than traditional roofing materials. These roofs are cooler and thus help reduce air conditioning loads by reflecting and emitting energy from the sun.
P. **Solar reflectance**—the fraction of solar energy that is reflected by the roof surface
Q. **Thermal emittance**—the fraction of thermal energy that is emitted from the roof surface
R. **Low-sloped roof** is a surface with a pitch less than 2:12 (less than 9.5 degrees from the horizon)
S. **Steep-sloped roof** is a surface with a pitch greater than or equal to 2:12 (9.5 degrees from the horizontal or more)
T. **Air barrier** is combination of interconnected materials and assemblies joined and sealed together to provide a continuous barrier to air leakage through the building envelope that separates conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses
U. **Vapor retarder or barrier** is a special covering over framing and insulation or covering the ground of a crawl space that protects the assembly components from possible damage due to moisture condensation.

3.2.2 Thermal Properties of Opaque Envelope Components

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 Joint Appendices JA4, "U-factor, C-factor, and Thermal Mass Data," provide detailed thermal data for many wall, roof/ceiling, and floor assemblies. However, JA4 cannot cover every possible combination of materials and thickness that might be used in a building. For this reason, the Energy Commission has incorporated into the public domain software CBECC-COM, a program for calculating material properties of typical envelope assemblies which are not found in JA4.

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 ^{o}F/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.

$$U\text{-factor} = Btu/(hr \times ft^2 \times °F)$$

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.

$$k = Btu \times in/(hr \times ft^2 \times °F)$$

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.

$$C = Btu/(hr. \times ft^2 \times °F) \text{ or } C = k/\text{inches of thickness}$$

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.

3.2.3 General Envelope Requirements

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

3.2.3.1 Mandatory Requirements

A. Certification of Insulation Materials

§110.8(a)

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: bear.enf@dca.ca.gov.

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 Index and Smoke Development Index of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* requires 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 index of 25 and a smoke development index 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 index and smoke density index 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, weather stripped, or otherwise sealed to limit air leakage. This applies to penetrations for pipes and conduits, ducts, vents, and other openings. 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).

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.

See the sections on roof, walls, doors and floors

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, the building should have a design computer room process load of 750 kW or greater.

3.2.3.2 Prescriptive Requirements

A. Air Barrier

§140.3(a)9, TABLE 140.3-B

Energy Standards Table 140.3-B specifies requirements for air barriers in nonresidential buildings. Air barrier requirements apply to nonresidential buildings, but not relocatable public school buildings, and 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/ft^2 (see Table 3-1).
2. Assemblies of materials and components having an average air leakage not exceeding 0.04 cfm/ft^2.
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 of 0.04 cfm/ft^2 or the whole-building air leakage of 0.4 cfm/ft^2 is not exceeded.

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. ½ inches thickness	15	Sheet steel or sheet aluminum
8	Cement board – min. ½ inches thickness	_____	________________________

3.2.4 Roofing Products and Insulation

3.2.4.1 Mandatory Measures

A. Roof/Ceiling Insulation

§120.7(a)

Metal Building: Weighted average U-factor of U-0.098 (R-19 screw down roof, no thermal blocks).

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 Joint Appendix JA4 for determining assembly U-factor. See the footnotes in JA4 for Tables 4.2.1 through 4.2.7.

D. Roofing Products: Solar Reflectance (SR) and Thermal Emittance (TE)

§10-113, §110.8(i)

In general, light-colored, high-reflectance surfaces reflect solar energy (visible light, invisible infrared and ultraviolet radiation) and stay cooler than darker surfaces that absorb the sun's energy and become heated. The Energy Standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky.

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. When installing cool roofs, the solar reflectance and thermal emittance of the roofing product must be tested and certified according to CRRC procedures. The solar reflectance and thermal emittance properties are rated and listed by the Cool Roof Rating Council at www.coolroofs.org. When a CRRC rating is not obtained for the roofing products, the Energy Standards default values for solar reflectance and thermal 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.

Source: Cool Roof Rating Council

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

§110.8(i)1-3

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 wide range of colors that have adequate cool roof properties. Excess heat can increase the air-conditioning load of a building, resulting in increased air-conditioning energy needed for maintaining occupant comfort. High-emitting roof surfaces reject absorbed heat quickly (upward and out of the building) than roof surfaces with low-emitting properties.

Solar Reflectance (SR). There are three measurements of solar reflectance:

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

All requirements of the Energy Standards are based on the three-year aged solar reflectance. 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, or a new method of testing is used to find the accelerated solar reflectance, the equation below can be used to calculate the aged rated 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

Thermal Emittance. 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.

Default Values. 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.

Solar Reflective Index (SRI). The temperature of a surface depends on the solar radiation incidence, 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 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/title24/2019standards . To calculate the SRI, the three-year aged solar reflectance value of the roofing product must be used. By using the SRI calculator, a cool roof may comply with a lower emittance, as long as the aged solar reflectance is higher and vice versa.

3. Field-Applied Liquid Coatings

§110.8(i)4, Table 110.8-C

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 depending on the type of coating. 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.

4. 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 D3805[2], Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings.

a. 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 D822[3], ASTM C1583, and ASTM D5870.

b. 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

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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.
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.

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.

3.2.4.2 Prescriptive Measures

A. Thermal Emittance and Solar Reflectance

§140.3(a)1A, TABLES 140.3-B,C,D

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 3-2 below. Table 3-3 is for high-rise residential buildings and hotel/motel guest rooms, and Table 3-4 is for relocatable public school buildings where the manufacturer certifies use in all climate zones.

Table 3-2: 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 3-3: Prescriptive Criteria for Roofing Products for High-Rise Residential Buildings and Guest Rooms of Hotel/Motel 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	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 3-4: 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	

Energy Standards Table 140.3-D

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 3-5 for nonresidential buildings based on roof type, climate zone and aged reflectance of at least 0.25.

Table 3-5: 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

B. Insulation Requirements − Exterior Roofs and Ceilings

§140.3(a)1B, TABLES 140.3-B,C,D

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 3-6.) The U-factor values for exterior roofs and ceilings from Reference Joint 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, can be used to determine U-factors for assemblies and/or components not listed in JA4 tables.

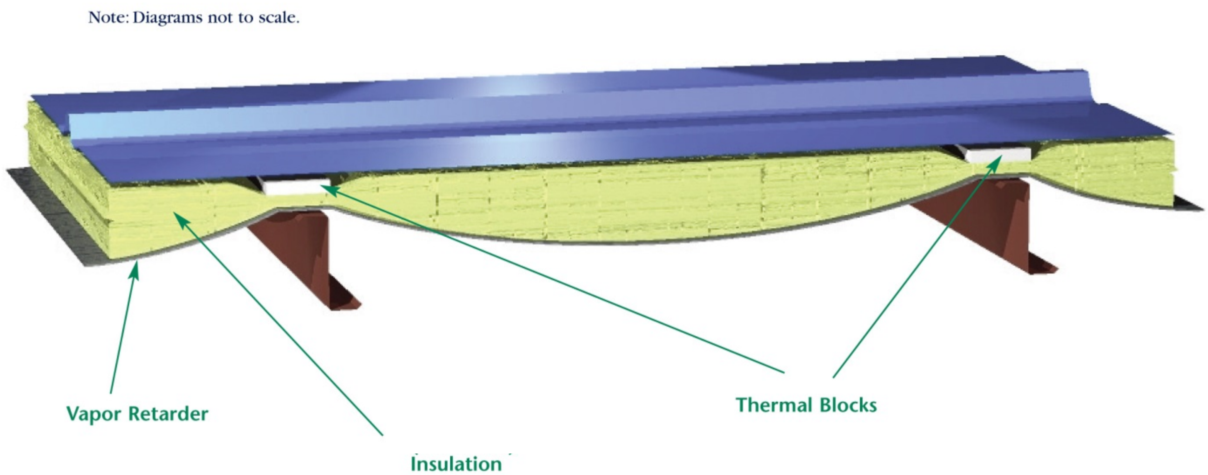
The prescriptive requirement for metal building roofs require the entire cavity be filled with insulation. A common technique for standing seam metal roofs is to drape a layer of insulation over the purlins, using thermal blocks where the insulation is compressed at the supports. (See Figure 3-3A.) Either approach on insulation may be used in the Performance approach. However, there are significant benefits to using the “filled cavity” approach as shown in Figure 3-3B.

Table 3-6: Roof/Ceiling U-Factor Requirements

Building Type		Climate Zones							
		1	2	3	4	5	6	7	8
Nonresidential	Metal Building	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 Building	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 Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Building	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 Building	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 Building	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 Building	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041
	Non-Metal Building	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034

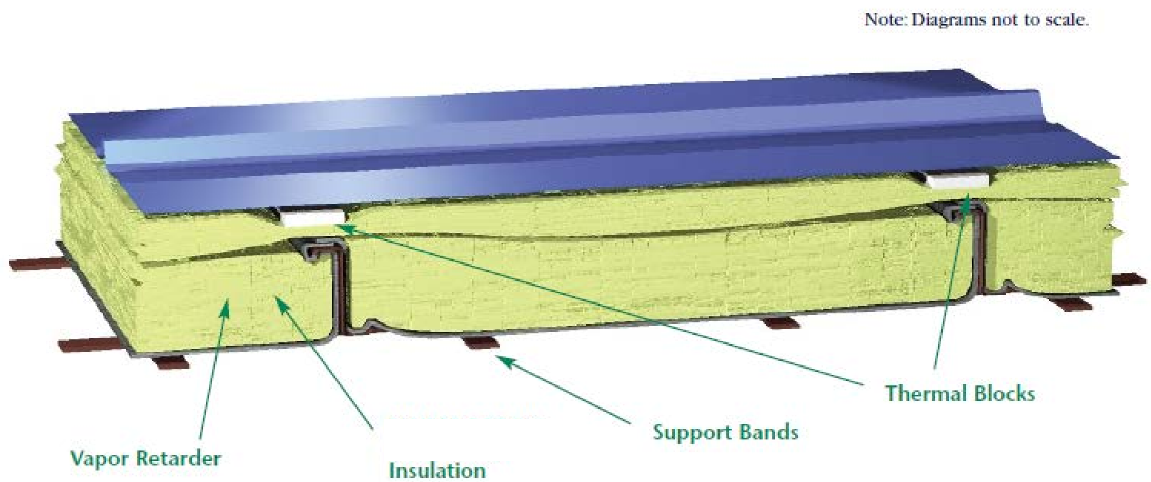
Summary of Tables 140.3-B, 140.3-C, and 140.3-D of the Energy Standards

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



Source: North American Insulation Manufacturers Association (NAIMA)

Figure 3-3B – 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.

3.2.4.3 Performance Approach

§10-113, §140.1, TABLE 140.3

Compliance options for roofing products and insulation. See Section 3.5 and Chapter 11 for more on the performance approach.

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 Standards stipulate 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 per Table 140.3.

Table 3-7: Default SR and TE 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 mandatory for nonresidential buildings or high-rise residential buildings?

Answer:

No. Cool roofs are not mandatory. The prescriptive compliance requirements depend on the climate zone, building type and roof slope. Compliance with solar reflectance and thermal emittance, or SRI is required per 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. A roof repair, such as for a leak, or replacement of 50 percent or 2,000ft², whichever is more, does not require the roofing product to be cool roof or certified by the CRRC.

Yes, when altering your roof, such as a new reroof or replacement of 50 percent or 2,000ft², whichever is less, then, either the prescriptive envelope component approach or the performance approach can be used for compliance. In these cases, 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 solar reflectance for asphalt shingles is 0.08.

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. 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/ft^2, then the garden roof is equivalent to cool roof.

3.2.5 Exterior Walls

The U-factor criteria for walls depend on the class of construction. U-factors used for compliance must be selected from Reference Joint 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.

There are five common classes of wall constructions: wood-framed, metal-framed, metal building walls, light mass, and heavy mass. Figure 3-5. The following provides information about these wall systems, as well as furred walls and spandrel walls:

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 Joint 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 Joint Appendix JA4, Table 4.3.3, has data for metal-framed walls.
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 Joint 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 a HC equal to or greater than 15.0 Btu/°F-ft². See Reference Joint 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/ft^3), 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 8.4 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 Joint Appendix JA4 Table 4.3.5, 4.3.6, or other masonry tables list alternative walls. Additional continuous insulation layers are selected from JA4 Table 4.3.13 and calculated using either Equation 4-1 or 4-4 from 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 **opaque 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 Joint Appendix JA4, Table 4.3.8 for U-factor data.

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 Joint Appendix JA4.

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

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.

Example 3-10

Question :

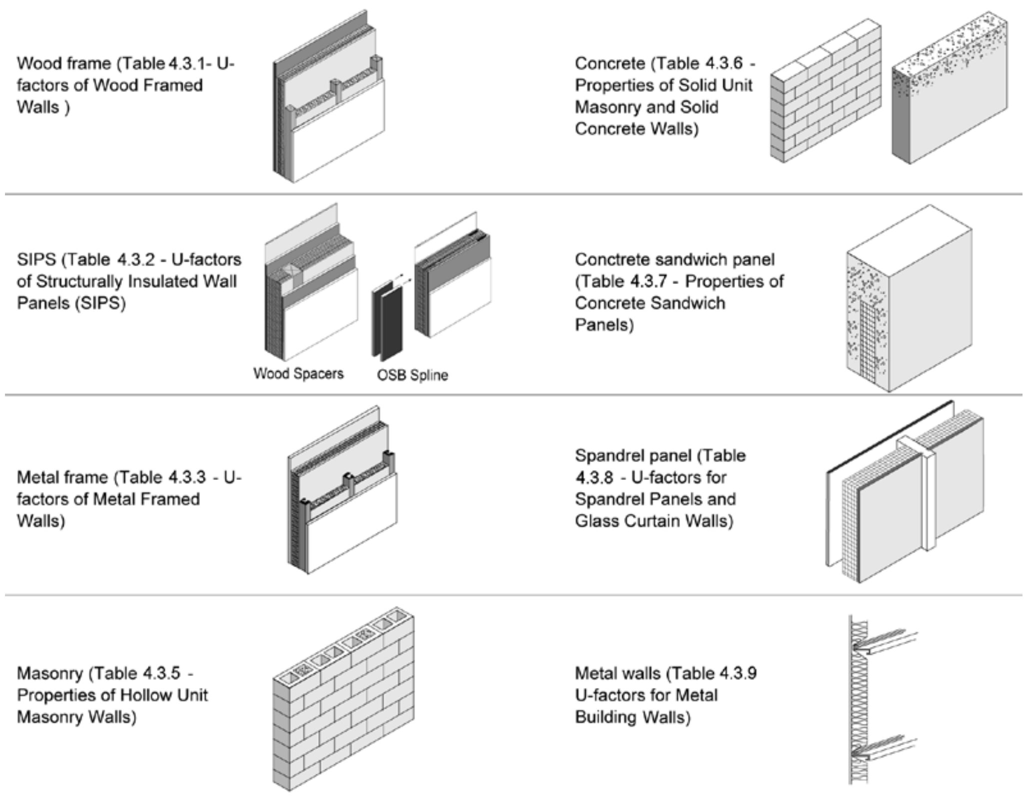
An 8-inch (20 cm) medium-weight concrete block wall with uninsulated cores has a layer of 1 inch (25 mm) thick exterior polystyrene continuous insulation with an R-value of R-5. What is the U-factor for this assembly?

Answer:

From Reference Joint 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

3.2.5.1 Mandatory Requirements

A. Wall Insulation

§ 110.8, § 120.7(b)

In addition to the mandatory requirements in § 110.8 for all buildings, Nonresidential, high–rise residential, hotels and motels must also meet the requirements in § 120.7

The opaque portions of walls that separate conditioned spaces from unconditioned spaces or ambient air shall meet these applicable requirements.

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/ft^3).
5. Wood-Framed and Others: Weighted average U-factor of U-0.110 (R-11 batt insulation).

6. Spandrel Panels and Opaque Curtain Wall: Weighted average U-factor of U-0.280.

Exception to Section 120.7: 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.

3.2.5.2 Prescriptive Requirements

§140.3(a)2, TABLES 140.3-B,C,D

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 Tables 140.3-B,C,D (see Table 3-8).

The U-factor for exterior walls from Reference Joint Appendix JA4 must be used to determine compliance with the assembly U-factor requirements. The Energy Standards does not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of Reference Joint 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		Climate Zones 1	2	3	4	5	6	7	8
Nonresidential	Metal Building	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 building	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		Climate Zones 9	10	11	12	13	14	15	16
Nonresidential	Metal Building	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 Building	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

3.2.6 Demising Walls

3.2.6.1 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.

EXCEPTION to Section 140.3(a)5A: Window area in demising walls is not counted as part of the window area for this requirement. Demising wall area is not counted as part of the gross exterior wall area or display perimeter for this requirement.

3.2.7 Exterior Doors

When an exterior door has 25 percent or more glazed area it is considered fenestration. See more on fenestration in Section 3.3.

3.2.7.1 Mandatory Requirements

§110.6(a)1

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

- 0.3 cfm/ft^2 of door area for nonresidential single doors (swinging and sliding).
- 1.0 cfm/ft^2 of door area for nonresidential double doors (swinging).

3.2.7.2 Prescriptive Requirements

§140.3(a)7, TABLES 140.3-B,C,D

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 non-swinging 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 is 25 percent or more 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. If the glazing area is less than 25 percent of the door area, the glazing must be modeled as the glass area plus two 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 to wall ratio.

Table 3-9: Exterior Door U-factor Requirements

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

3.2.8 Floors

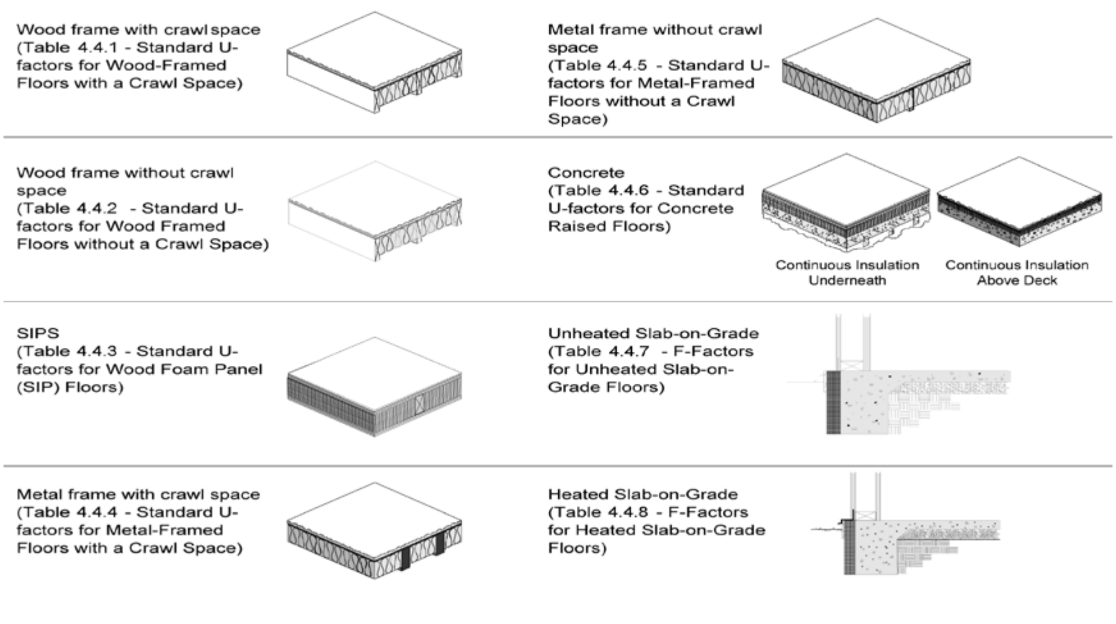
The U-factor criteria for concrete raised floors depend on whether the floor is a mass floor or not. A mass floor is one constructed of concrete with a heat capacity (HC) greater than or equal to 7.0 Btu/°F-ft².

Insulation levels for nonresidential concrete raised floors with HC ≥ 7.0 using U-factor for compliance, from Reference Joint 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 climate zones 1, 2, 14 and 16.

Table 4.4.6 from Reference Joint Appendix JA4 is used with mass floors while Tables 4.4.1 through 4.4.5 are used for non-mass floors. (See Figure 3-6.)

Figure 3-6: Classes of Floor Constructions



Source: Reference Appendix JA4.4

3.2.8.1 Mandatory Requirements

A. Insulation Requirements for Heated Slab Floors

§ 110.8(g), TABLE 110.8-A

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 feet 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.

Note: The California Mechanical Code should be consulted when constructing a heated slab.

Figure 3-7: Perimeter Slab Insulation

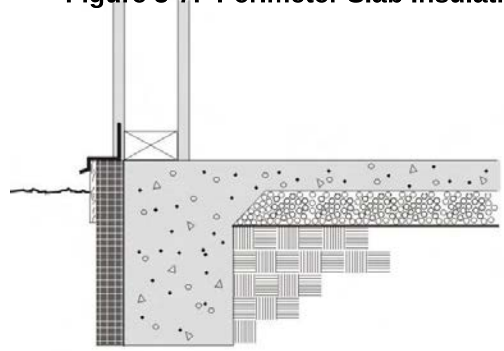


Table 3-10: Slab Insulation Requirements for Heated Slab Floors

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

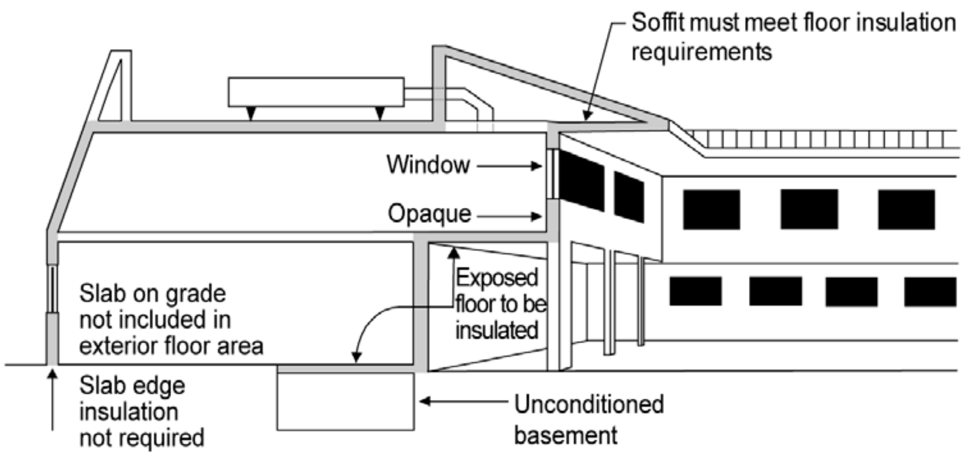
Energy Standards Table 110.8-A

B. Floor and Soffit Insulation

§ 110.8(g), § 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).

Figure 3-8: Requirements for Floor/Soffit Surfaces



3.2.8.2 Prescriptive Requirements

A. Exterior Floors and Soffits

§140.3(a)4, TABLES 140.3-B,C,D

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 Tables 140.3-B,C,D (Table 3-11). The U-factor for exterior floors and soffits from Reference Joint Appendix JA4 shall be used to determine compliance with the maximum assembly U-factor requirements. The Energy Standards do not allow using the R-value of the cavity or continuous insulation alone to demonstrate compliance with the insulation values of 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 and 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

3.3 Fenestration (Window/Skylight/Glazed Door)

Choosing energy efficient 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.

The Energy Standards 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 Fenestration Definitions

Windows. A window is a vertical fenestration product that is an assembled unit consisting of a frame and sash component holding one or more pieces of glazing. Window performance is measured with the U-factor, Solar Heat Gain Coefficient (SHGC), and Visible Transmittance (VT).

Windows are considered part of an exterior wall when the slope is 60° or more. When the slope of fenestration is less than 60°, the glazing is considered a skylight and part of the roof.

Skylights and Tubular Daylight Devices. Skylights and tubular daylight devices (TDD) are an exceptional source of daylight and passive solar heating, illuminating rooms with direct and indirect sunlight. In addition, when used appropriately, daylighting can increase the quality of light in a room and reduce dependence upon electrical lighting. Skylights and TDDs don't typically have the same thermal properties as vertical fenestration and can be prone to greater heat loss in winter and solar heat gain during the summer. When a building designer optimizes the whole envelope glazing arrangement for daylight and thermal control, significant heating and cooling energy savings can be realized, especially when skylights and TDDs are energy efficient.

Glazed Doors. Glazed door is an exterior door having a glazed area of 25 percent or more of the area of the door. When the door has less than 25 percent glazing material, it is no longer considered a glazed door. (See exterior doors in previous section). All glazed areas, will be counted toward the overall glazed area of the conditioned space in any calculations.

There are two options for measuring the glazed area of a door: Count the entire door area for glazed doors or count the area of the glazing in the door plus a 2" frame around the glass (i.e., if you have 1' by 1' glazing in a door you would measure the area as 1'4" by 1'4").

Fenestration Categories

A. **Manufactured fenestration** is a fenestration product constructed of materials that are factory-cut or otherwise factory-formed with the specific intention of being used to fabricate a fenestration product. Knocked down or partially assembled products may be sold as a fenestration product when provided with temporary and permanent labels, as described in §10-111, or as a site-built fenestration product when not provided with temporary and permanent labels, as described in §10-111.

B. **Site-built fenestration** is designed to be field-glazed or field-assembled units, using specific factory-cut or other factory-formed framing, and glazing units that are manufactured with the intention of being assembled at the construction site. These include storefront systems, curtain walls or large-track sliding glass walls, and atrium roof systems.

C. **Field-fabricated fenestration** is when the windows are fabricated at the building site from elements that are not sold together as a fenestration product (that is, separate glazing, framing, and weather stripping elements). Field-fabricated does not include site-assembled frame components that were manufactured elsewhere with the intention of being assembled on site (such as knocked-down products, sunspace kits, and curtain walls).

Additional Fenestration Definitions

Reference Joint Appendix JA1 lists additional terms that relate to fenestration.

A. **Center of Glass.** U-factor, SHGC, and VT are measured only through glass at least 2.5 inches from the edge of the glass or dividers.

B. **Clear glass** has little, if any, observable tint.

C. **Chromogenic** is a class of switchable glazing which includes active materials (e.g. electrochromic) and passive materials (e.g. photochromic and thermochromic) permanently integrated into the glazing assembly

D. **Divider (Muntin)**. An element that actually or visually divides different lites of glass. It may be a true divided lite, between the panes, and/or applied to the exterior or interior of the glazing.

E. **Double Pane Window.** Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by space (generally 1/4" [6 mm] to 3/4" [18 mm]) filled with air or other gas. Two panes of glazing laminated together do not constitute double-pane glazing

F. **Dynamic Glazing.** Glazing systems that have the ability to reversibly change their performance properties, including U-factor, solar heat gain coefficient (SHGC), and/or visible transmittance (VT) between well-defined end points. Includes active materials (electrochromic) and passive materials (photochromic and thermochromic) permanently integrated into the glazing assembly. Electrochromatic glass darkens by demand or lightens up when more free daylight or solar heat is desired. Improved glazing decreases the SHGC in the summer and reduces heat loss in the winter and has the ability to reversibly change their performance properties, including U-factor, SHGC, and/or VT between well-defined end points.

G. **Integrated shading systems.** A class of fenestration products including an active layer: for example, shades, louvers, blinds, or other materials permanently integrated between two or more glazing layers and that has the ability to reversibly change performance properties, including U-factor, SHGC, and/or VT between well-defined end points.

H. **Fixed glass.** The fenestration product cannot be opened.

I. **Gap Width.** The distance between glazing in multi-glazed systems (e.g., double-or triple-glazing). This dimension is measured from inside surface to inside surface. Some manufacturers may report "overall" IG unit thickness which is measured from outside surface to outside surface.

J. **Insulating glass unit (IG Unit)**. An IG unit includes the glazing, spacer(s), films (if any), gas infills, and edge caulking.

K. **Hard Coat.** A pyrolytic low-e coating that is generally more durable but less effective than a soft coat. See separate glossary term for low-e coating.

L. **Light or Lite**. A layer of glazing material, especially in a multi-layered IG unit. Referred to as panes in §110.6 when the lites are separated by a spacer from inside to outside of the fenestration.

M. **Low-e Coatings.** Low-emissivity coatings are special coatings applied to the second, third or fourth surfaces in double-glazed windows or skylights. As the name implies the surface has a low emittance. This means that radiation from that surface to the surface it “looks at” is reduced. Since radiation transfer from the hot side of the window to the cool side of the window is a major component of heat transfer in glazing, low-e coatings are very effective in reducing the U-factor. They do nothing, however, to reduce losses through the frame.

Low-e coatings can be engineered to have different levels of solar heat gain. Generally, there are two kinds of low-e coatings:

1. Low solar gain low-e coatings are formulated to reduce air conditioning loads. Fenestration products with low solar gain low-e coatings typically have an SHGC of 0.40 or less. Low-solar gain low-e coatings are sometimes called spectrally selective coatings because they filter much of the infrared and ultra-violet portions of the sun’s radiation while allowing visible light to pass through.
2. High solar gain low-e coatings, by contrast, are formulated to maximize solar gains. Such coatings would be preferable in passive solar applications or where there is little air conditioning.

Another advantage of low-e coatings, especially low solar gain low-e coatings, is that when they filter the sun’s energy, they generally remove between 80 percent and 85 percent of the ultraviolet light that would otherwise pass through the window and damage fabrics and other interior furnishings.

N. **Mullion**. A frame member that is used to join two individual windows into one fenestration unit.

O. **Nonmetal Frame**. Includes vinyl, wood, or fiberglass. Vinyl is a polyvinyl chloride (PVC) compound used for frame and divider elements with a significantly lower conductivity than metal and a similar conductivity to wood. Fiberglass has similar thermal characteristics. Non-metal frames may have metal strengthening bars entirely inside the frame extrusions or metal-cladding only on the surface.

P. **Operable**. The fenestration product can be opened for ventilation.

Q. **Soft Coat**. A low-e coating applied through a sputter process. See separate glossary term for low-e coating.

R. **Solar Heat Gain Coefficient (SHGC).** A measure of the relative amount of heat gain from sunlight that passes through a fenestration product. SHGC is a number between zero and one that represents the ratio of solar heat that passes through the fenestration product to the total solar heat that is incident on the outside of the window. A low SHGC number (closer to 0) means that the fenestration product keeps out most solar heat. A higher SHGC number (closer to 1) means that the fenestration product lets in most of the solar heat. SHGC or SHGCt is the SHGC for the total fenestration product and is the value used for compliance with the Standards.

S. **Spacer or Gap Space.** A material that separates multiple panes of glass in an insulating glass unit.

T. **Thermal Break Frame.** Includes metal frames that are not solid metal from the inside to the outside, but are separated in the middle by a material, usually vinyl or urethane, with a significantly lower conductivity.

U. **Tinted**. Darker gray, brown or green visible tint. Also, low-e or IG unit with a VT less than 0.5.

V. **U-factor.** A measure of how much heat can pass through a construction assembly or a fenestration product. The lower the U-factor, the more energy efficient the product is. The units for U-factor are Btu of heat loss each hour per square foot (ft^2) of window area per degree °F of temperature difference (Btu/hr-ft^2-°F). U-factor is the inverse of R-value. The U-factor considers the entire product, including losses through the center of glass, at the edge of glass where a metal spacer typically separates the double-glazing panes, losses through the frame, and through the mullions. For metal-framed fenestration products, the frame losses can be significant.

W. **Visible Transmittance (VT)** is the ratio of visible light transmitted through the fenestration. The higher the VT rating, the more light is allowed through a window.

X. **Window Films** are composed of a polyester substrate to which a special scratch resistant coating is applied on one side, with a mounting adhesive layer and protective release liner applied to the other side.

Example 3-11

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 Mandatory Requirements

§ 10-111, § 10-112, § 110.6(a)

The mandatory measures for windows, glazed doors, and skylights address product certification and labeling, the air-tightness of the units (air leakage), how to determine the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT).

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

3.3.2.1 Certification and Labeling

§10-111 § 10.112 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 (Figure 3-9), which is not to be removed before inspection by the enforcement agency. The manufacturer rates and labels its fenestrations products for U-factor, SHGC and VT.

Figure 3-9: NFRC Manufactured Label

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). If the manufactured fenestration product is rated using the NFRC rating procedure, it must also be permanently labeled in accordance with NFRC procedures.

B. Default Temporary Label

Fenestration product manufacturers can choose to use default performance values for U-factors in Table 110.6-A and SHGC in Table 110.6-B. (Table 3-14 and Table 3-15) For fenestration products requiring a VT value, assume a value of 1.0 as specified in the Reference Nonresidential Appendix NA6. 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.

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 for the enforcement agency field inspector to read easily. 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 following words at the bottom of the label.

> *"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 3-10:
Sample Default Temporary Label

2019 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 2019 Energy Standards for Residential and Nonresidential Buildings.		

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.

C. **Component Modeling Approach (CMA)**

NFRC has developed a performance base calculation, the *component modeling approach* (CMA), to make the rating process quick and simple. This serves as an energy ratings certification program for fenestration products used in nonresidential projects. The CMA allows users to assemble fenestration products in a virtual environment. CMA 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. This tool helps users to:

1. 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, they create a bid report containing the data for all fenestration products to be reviewed. 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) and a license agreement is signed with NFRC. Then the NFRC issues a CMA label certificate for the project. This label certificate 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 variation of glazing and framing. This is significantly less expensive than building sample wall sections and testing them in a large test enclosure. 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 Standard'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 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.

Figure 3-11: 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): __________.

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 percent in energy compliance margins. This means that compared to other available options, CMA provides the most accurate values on window energy and visible performance."*

Figure 3-11A: 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	Name	Framing Ref	Glazing Ref	Spacer Ref	U**	SHGC**	VT**
	ft^2					Btu/ hr•ft²•°F	-	-
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

D. 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.

E. Site-Built Label Certificates

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.

1. For site-built fenestration totaling 200 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 200 ft^2 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.

Site-built certificates should be filed at the contractor's project office during construction or in the building manager's office. Site-built fenestration has multiple responsible parties. 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 and to coordinate the certification and labeling process. The design team may 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 the NFRC.

It is not necessary to complete the NFRC testing and labeling prior to completing the building permit application. Designers should specify the type of glass and whether the frame has a thermal break or is thermally improved. Plans examiners should verify that the fenestration performance shown in the plans and used in the compliance calculations is reasonable and achievable, by consulting the default values for U-factor and SHGC in Reference Nonresidential Appendix NA6.

F. Field-Fabricated Fenestration and Field-Fabricated 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.

No attached labeling is required for field-fabricated fenestration products; only the NRCC-ENV-05-E with the default values is required. Field-fabricated fenestration and field-fabricated exterior doors may be installed only if the documentation has demonstrated compliance with the Energy Standards.

For field-fabricated fenestration, the U-factor and SHGC default values can be found in Table 3-12 and Table 3-13, respectively, below. Values are determined by frame type, fenestration type, and glazing composition.

Exterior doors with glazing for 25 percent or more 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 25 percent 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.

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.

Table 3-12: 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 3-13: 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

3.3.2.2 Determining Fenestration Performance

§110.6, TABLES 110.6-A,B

A. U-Factor

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 must be used when a NFRC label for the U-factor is not available (Table 3-14). The U-factors in Table 110.6-A represent the least efficient possible values, thereby encouraging designers to obtain ratings through NFRC test procedures, when they are available.

B. Solar Heat Gain Coefficient (SHGC)

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 3-14) must be used for default values.

Table 3-14: Methods for Determining U-Factor and SHGC

U-factor and SHGC	Fenestration Category				
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-100	✓	✓	✓	N/A	N/A
Default Tables 110.6-A (U-factor) 110.6-B (SHGC)	✓	✓	✓	✓	✓
NA6[2]	N/A	N/A	✓	N/A	N/A

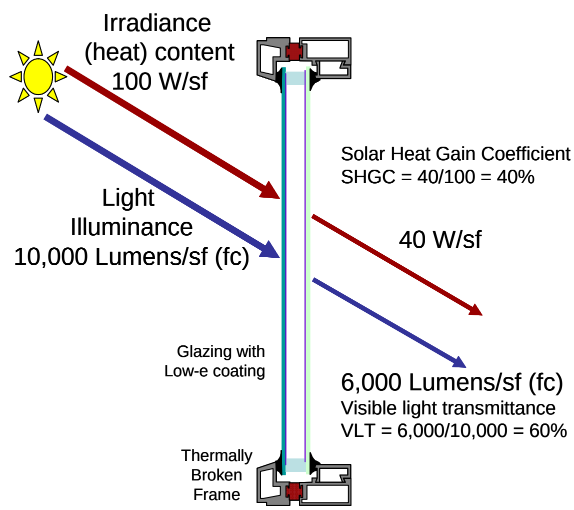
[1]*The NFRC Residential CMA method is an option that may be available in the Energy Standards.*
[2]*The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may only be used for site-built vertical and skylights having less than 200 ft^2.*

C. Visible Transmittance (VT)

The visible transmittance (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.

VT is a property of glazing materials that has a varying relationship to SHGC (Figure 3-12). The ideal glazing material for most hot 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 3-12: Solar Heat Gain Coefficient and Visible Transmittance



3.3.2.3 Air Leakage

§110.6(a)1, §110.7

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 3-15. For field-fabricated products or exterior doors, the Energy Standards require that the unit be caulked, gasketed, weather stripped, or otherwise sealed. Unframed glass doors and fire doors are the two exceptions to these air leakage requirements.

Table 3-15: 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 3-12

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 200 ft² then one of the following three methods may be used:

1. Rate the fenestration using the component modeling approach (CMA), which will yield the most efficient values possible.

2. Use the default U-factor and SHGC values from equations in Reference Nonresidential Appendix NA6:

- U-factor may be calculated from NA6, Equation NA6-1, $U_T = C_1 + C_2 X U_C$. 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.
- SHGC is determined from NA6, Equation NA6-2, $SHGC_T$ = 0.08 + 0.86 x $SHGC_C$. The SHGC is calculated to be 0.08 + 0.86 x 0.70 = 0.68.
- VT from NA6, the visible transmittance of the frame is 0.88 for a curtain wall, so the $VT_T = VT_{F X} VT_C$ = 0.88 X 0.75 = 0.66.

2. Select from default Tables 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. A Fenestration Certificate Label, NRCC-ENV-05-E, should be completed for each fenestration product. Or the responsible party may attach a default temporary label to each fenestration unit throughout the building.

3.3.3 Vertical Fenestration (Windows and Doors)

3.3.3.1 Prescriptive Measures

§140.3(a)5

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 by 6 feet in height and use the larger of the product of that multiplication or 40 percent of gross exterior wall area.

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.

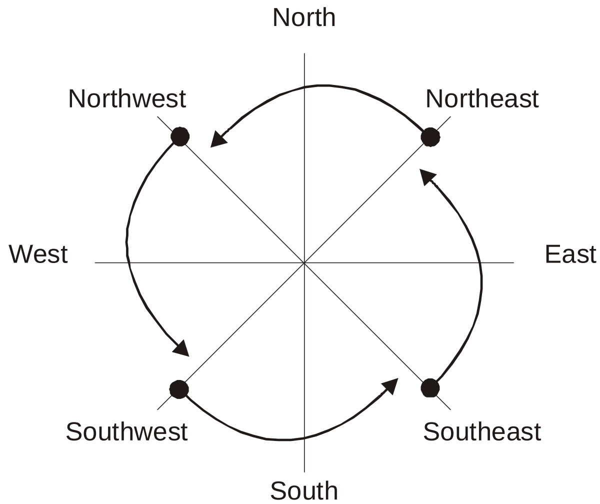
Glazing in a demising wall does not count toward the total building allowance. There is no limit to the amount of glazing allowed in demising walls, but it must meet the prescriptive U-factorrequirements for the climate zone.

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.

Glazed doors, 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.

The orientation can be determined from an accurate site plan. Any orientation within 45 degrees of true north, east, south, or west will be assigned to that orientation. Figure 3-13 demonstrates how surface orientations are determined and what to do if the surface is oriented exactly at 45 degrees 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, TABLES 140.3-B,C

Fenestration products must meet the prescriptively required maximum U-factor criteria in Tables 140.3-B and 140.3-C of the Energy Standards (Table 3-16) for each climate zone. Most NFRC-rated multi-glazed windows with a low-e coating and a thermally broken frame will comply with the U-factor criterion. See http://www.nfrc.org, Certified Product Directory database, or use Equation NA6-1 found in Reference Nonresidential Appendix NA6.

Table 3-16: 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

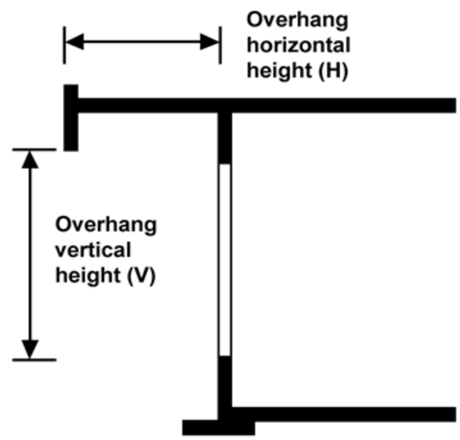
C. SHGC and Overhang Factor

§140.3(a)5C

Relative solar heat gain (RSHGC) allows for an 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 specify the maximum area-weighted average RSHGC, excluding the effects of interior shading. (Table 3-16)

Overhang factors may either be calculated or taken from Table 3-17 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), see 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 comply.

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 feet, but no greater than V

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

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

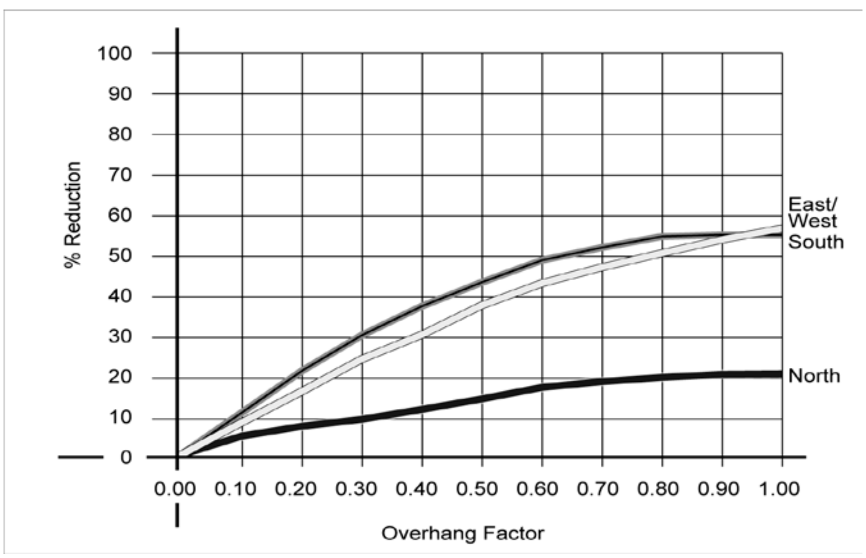
Table 3-17: Overhang Factors

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

Any value of H/V greater than 1 has the same overhang factor (for a given orientation) shown in the last row of Table 3-17.

Figure 3-15 illustrates the benefits of overhang factors of the various orientations as a function of H/V. The graph 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.

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 feet out from the plane of the glass (H = 3) and is 6 feet above the bottom of the glass (V = 6). The overhang extends more than 3 feet beyond each side of the glass, and the top of the window is less than 2 feet 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 3-16) 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. The performance method is discussed in more detail in Chapter 5.

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 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*

$$VT \geq 0.11 / WWR$$

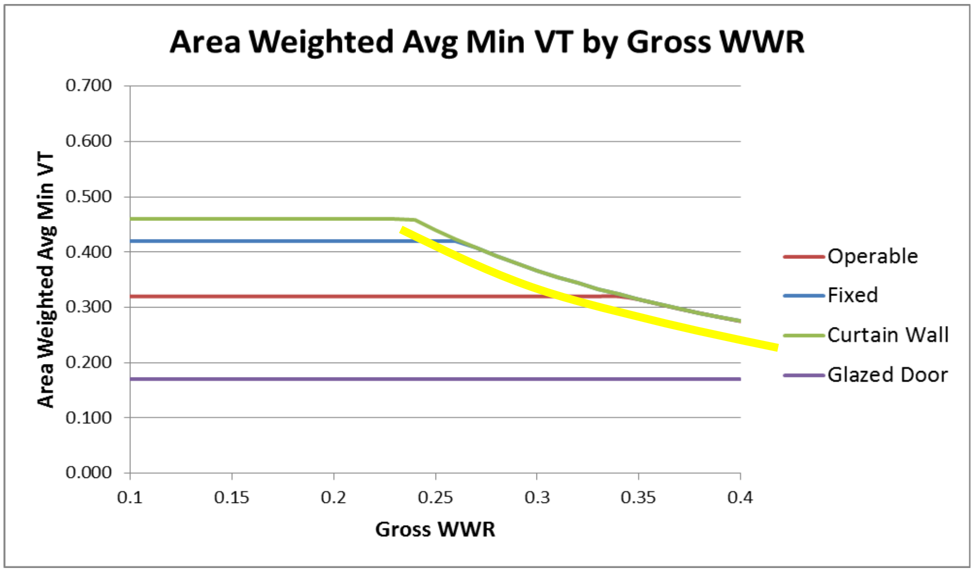
Where:

VT = the visible transmittance of the framed window

WWR = the gross window-to-wall ratio

The graph in Figure 3-16 shows the allowed area weighted average minimum VT’s by gross WWR for four types of windows. 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. All glazing that is not chromatic must separately meet the area-weighted VT prescriptive requirements.

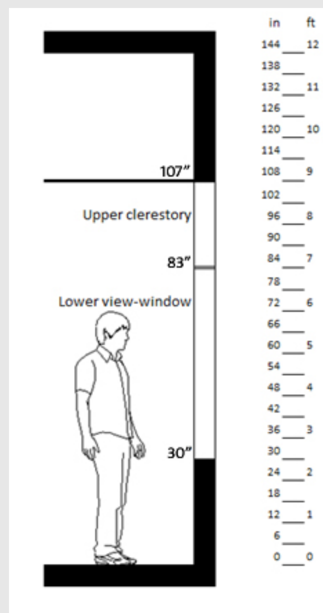
Figure 3-16: Area Weighted Average Minimum VT by Gross Window-to-Wall Ratio



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:

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

VT ≥ 0.11 / 0.3 = 0.367. The area weighted minimum VT we need for this window is 0.367.

(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.

Using 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.

Solve the equation for Clerestory VT: Clerestory VT = 0.515

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

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

Example 3-15

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:

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

3.3.3.2 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.

Look for NFRC Dynamic Glazing Labels to compare and contrast the energy performance for these products. See Figure 3-17. 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

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

1. Optional prescriptive U-factor and SHGC from Tables 140.3-B and 140.3-C
2. Performance approach compliance gives 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

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 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. 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 security films and to reduce ultraviolet (UV) light, which contributes to fading. These 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 secondary.
3. **Metalized** (reflective) films can be metalized though vacuum coating, sputtering, or reactive deposition and may be clear or colored. Metalized films are preferred for 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.

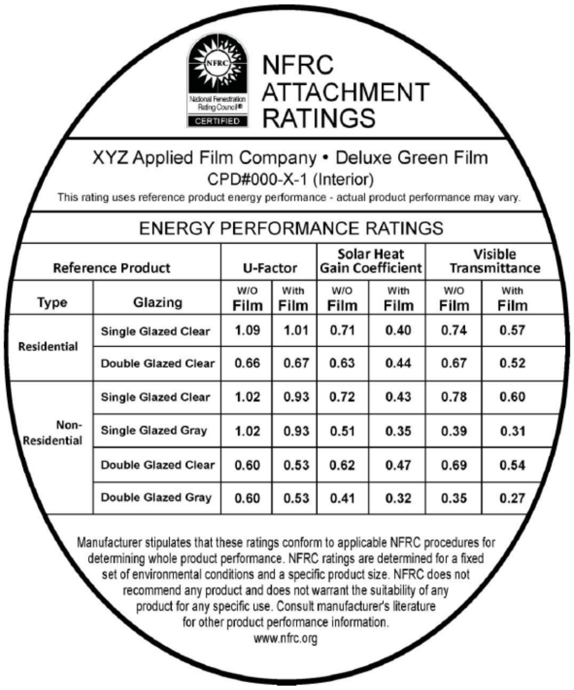
Look for the NFRC–certified attachment ratings energy-performance label, which helps consumers understand the contrast in energy performance of window films. An example of a window film energy performance label is shown on Figure 3-18.

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 15-year or longer warranty.

Figure 3-18: Window Film Energy Performance Label



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

3.3.4 Skylights

Skylights can be either flush-mounted or curb-mounted into a roof system. 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.

3.3.4.1 Skylight Mandatory Measures

§10-111, § 110.6, § 110.7

Skylights must meet all mandatory requirements for fenestration in §10-111, §110.6 and §110.7. Either the prescriptive or performance approach may be used.

When skylights are specified, the designer must show the skylit daylight zones on the building plans. There are mandatory requirements for lighting controls related to daylighting. See Section 3.3.3. 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.

3.3.4.2 Skylight Prescriptive Requirements

140.3(a)6

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 3-18: 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

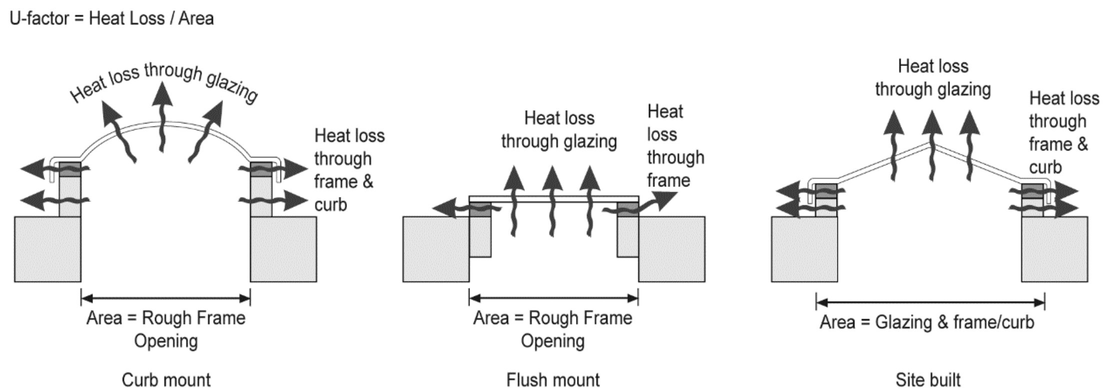
§140.3(a)6A

Skylight area is defined in Reference Joint Appendix 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, 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 the threshold at which the California Building Code requires a mechanical smoke-control system for atriums (CBC Sec. 909). This means that the 10 percent SRR is not allowed for atriums unless they also meet the smoke control requirement.

Site-built monumental or architectural skylights equipped with integral built-in or site-built curbs (not part of the roof construction) are often used for atrium roofs, malls, and other applications that need large skylights. In these cases, the skylight area is the surface area of the glazing and frame/curb, *not the area of the rough-framed opening*. Regardless of the geometry of the skylight (flat pyramid, bubble, barrel vault, or other three-dimensional shape), what matters is the anticipated heat exchanged through the glazing area. For special cases such as clerestory, rooftop monitor or tubular skylights, see Chapter 5.

§140.3(c)4 requires that the skylight area be at least 3 percent of the floor area (not accounting for obstructions), or that the total of the skylight area multiplied by 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 skylit 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 use 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. (Table 3-18)

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 3-18). The designer can use 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 200 ft^2.

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 Tables 140.3-B, C, and D (Table 3-18). There are exceptions for chromogenic glazing.

E. Daylighting

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.

Mandatory Daylighting Controls

§130.1(d)

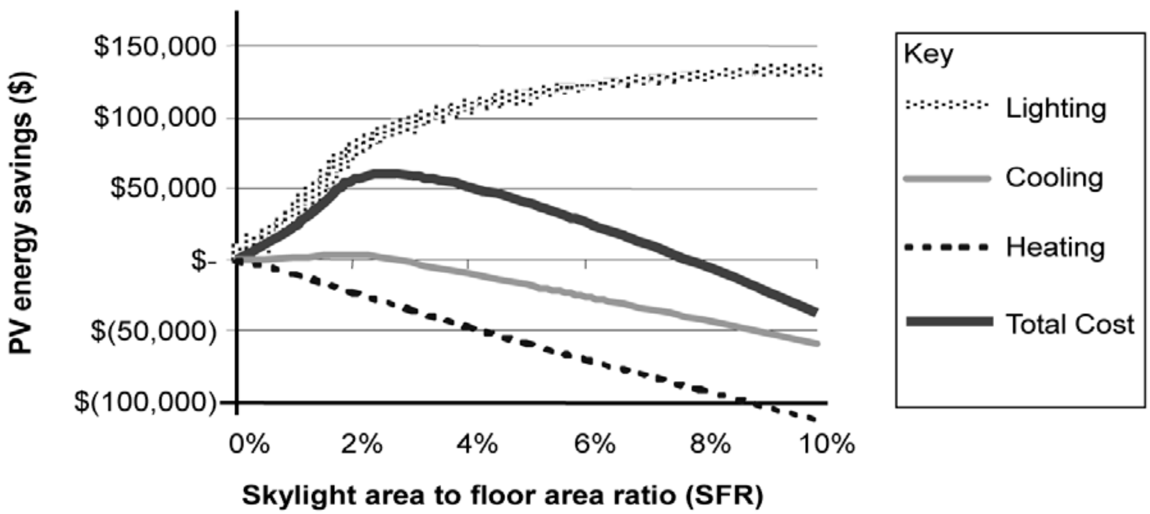
Electric lighting in skylight daylit zones shall meet the mandatory control requirements in §130.1(d). Obstructions are ignored for evaluating the architectural area served by skylights. For controlling lighting, consider the area shaded that is behind permanent obstructions that are greater than half the ceiling height. Those luminaires behind tall obstructions are not part of the skylit daylit area and not controlled by automatic daylighting controls.

Minimum Daylighting Prescriptive Requirements in Large Enclosed Spaces

§140.3(c)

Sizing is important; since too little skylight area has insufficient light available to turn off electric lighting; where 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 Climate Zone 12



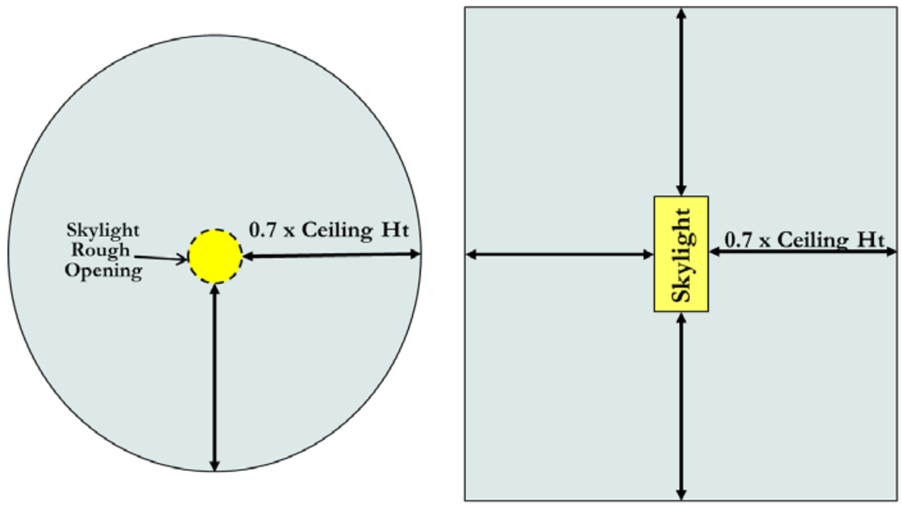
Skylights and automatic daylighting controls are most cost-effective in large open spaces and are prescriptively required in enclosed spaces (rooms):

- Larger than 5,000 ft².
- Directly under a roof.
- Ceiling heights greater than 15 ft.
- 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, an area in plain 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 3-20), or
2. A primary sidelit daylit zone, an area in plain 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 3-20: Area Within 0.7 Times Ceiling Height of Rough Opening of Circular Skylight and Rectangular Skylight

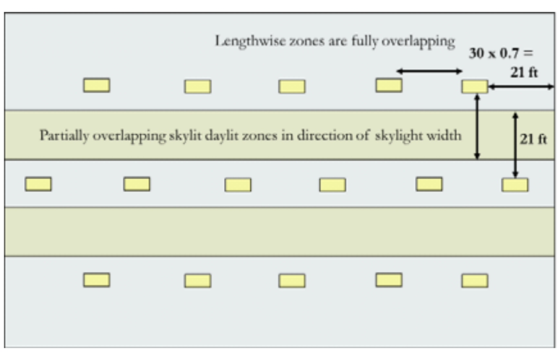


The shape of the skylit daylit zone will be similar in shape to the rough opening of the skylight (Figure 3-20).

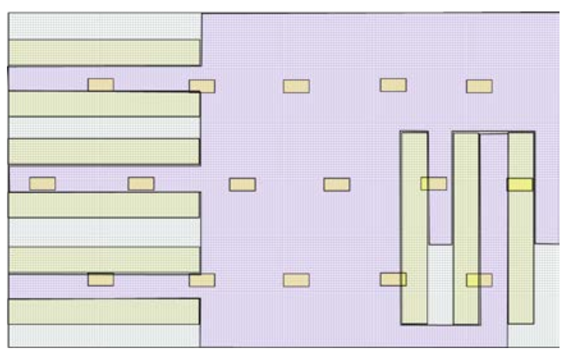
Examples: If the skylight is circular, the area that is within a horizontal distance 0.7 times the average ceiling height from the edge of the rough opening, is also a circle, with the radius of the circle being the radius of the skylight + 0.7 x the ceiling height.

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

Figure 3-21: 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 3-21, 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.*

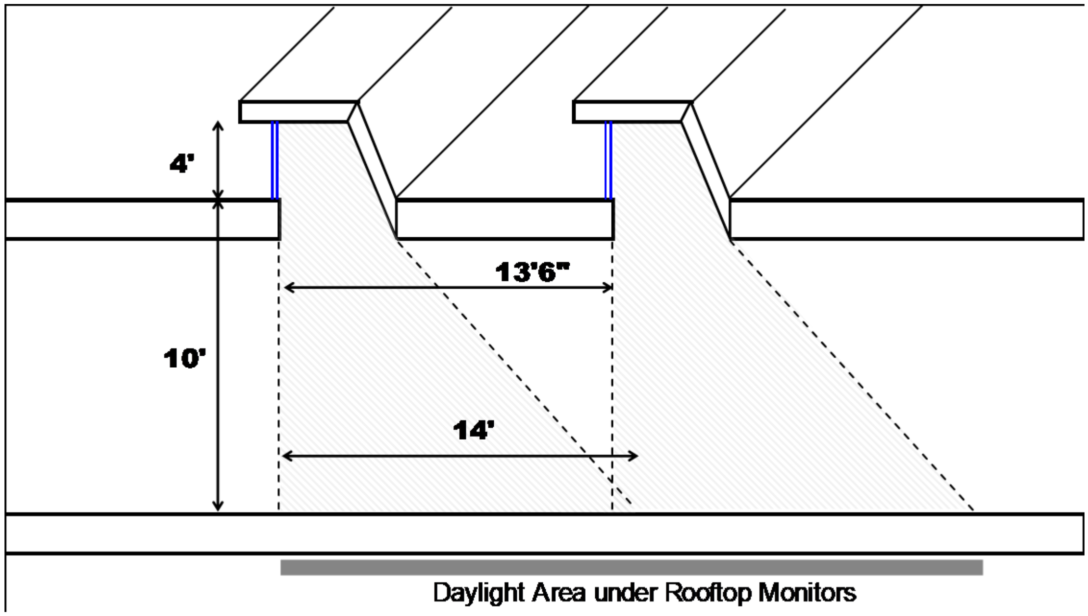
Since skylights paired with daylighting controls can significantly reduce energy demands from lighting, they are mandatory on all nonresidential occupancies that meet the above criteria *whether the space is conditioned or unconditioned*. Further information can be found in Section 3.3.3.1.

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 3-22: Daylight Area Under Rooftop Monitors (Primary Sidelit Daylit Zone)



G. Exceptions for Shading

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.

3.3.4.3 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.

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

Example 3-16

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.

3.3.4.4 Glazing Material and Diffusers

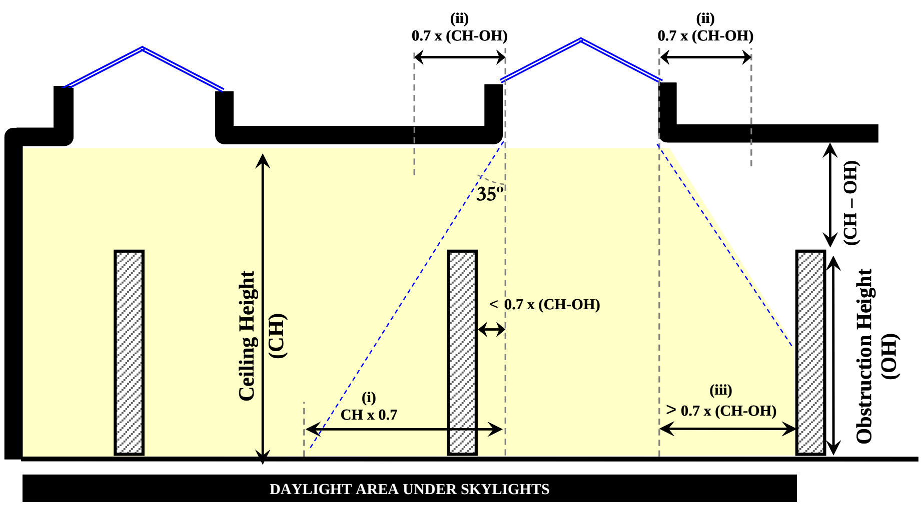
§140.3(a)6E, TABLE 140.3-B,C

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 Energy Standards require 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 the glazing or diffuser material has a haze rating greater 90 percent and the visible transmittance meets 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 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 need to be documented by the designer and approved by the code authority in your jurisdiction.

Figure 3-23: Daylit Area Under Skylights



3.3.5 Daylighting Design Power Adjustment Factors (PAFs)

Certain design features and technologies have the capacity to increase the daylighting potential of spaces. Some of these design features and technologies may be used in conjunction with automatic daylighting controls to receive PAFs from Table 140.6-A, or as a performance compliance option (PCO) in the performance method.

A thorough daylighting analysis should be performed to ensure the avoidance of glare issues when including daylighting features in the design. An example where caution should be taken is specularly reflective (e.g. polished or mirror-finished) horizontal slats. These slats may redirect direct beam sunlight causing uncomfortable glare. This is not the only consideration when designing daylighting features. Daylighting analysis should be performed on a space-by-space, project-by-project basis.

Throughout all phases of the project, the envelope and lighting designers will need to coordinate closely to ensure that the requirements are met for their respective disciplines. Even if the envelope (e.g. horizontal slats) portion of the requirements meets all the envelope requirements, installing daylighting controls that do not meet the daylighting controls requirements will result in a loss of the PAF or PCO. Chapter 5, Section 5.5.1 gives guidance on the daylighting controls requirements.

3.3.5.1 Clerestory Fenestration

§140.3(d)1

Clerestory windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF. Clerestory windows increase the head height of windows and therefore increase the depth and width of the primary and secondary daylit zones for a space.

As with all vertical fenestration installed in a building, clerestory windows must meet the vertical fenestration requirements.

A. Qualifying Fenestration Area

Any portion of vertical fenestration area 8 feet or higher above the finished floor of a space is considered a clerestory window. Note that a rooftop monitor (see Figure 3-22) qualifies as a clerestory window.

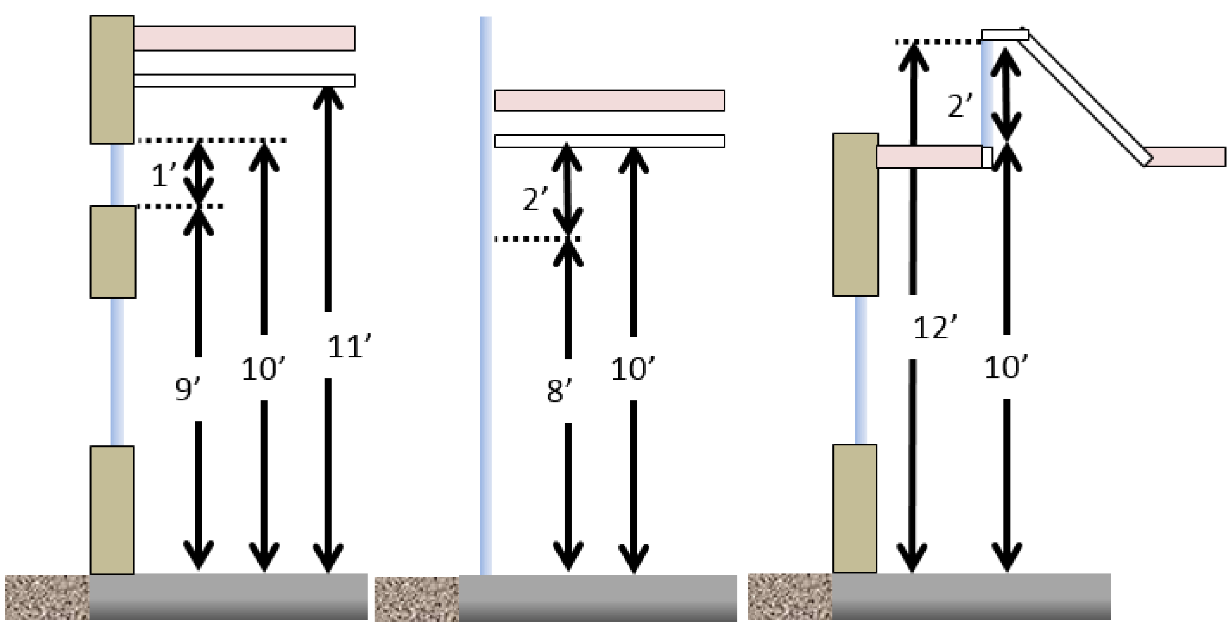
B. Orientation

For the PAF, the clerestory windows must be installed on east-, west- or south-facing facades.

C. Head Height and Window Height

For the PAF, clerestory windows must have a head height at least 10 feet above the finished floor of the space onto which the clerestory window is installed. The clerestory window height must be at least 10 percent of its head height. Examples are given in Figure 3-24.

Figure 3-24: Prescriptive PAF Clerestory Window Examples



D. Shading

Blinds or shading may not be installed at the time of inspection. However, if blinds or shading are installed at the time of inspection, then the blinds or shading which covers the clerestory window must be shown to be controlled separately from shading serving other vertical fenestration.

3.3.5.2 Interior and Exterior Horizontal Slats

§140.3(d)2

Horizontal slats on exterior or interior of windows may be used in conjunction with automatic daylighting controls to receive a prescriptive PAF or as a PCO in the performance method. Exterior horizontal slats may be preferable in a design to reduce solar gains whereas interior horizontal slats may be preferable considering wind loads, thermal bridging, passive solar heating, or vandalism.

A. Adjacency and Window-to-Wall Ratio (WWR)

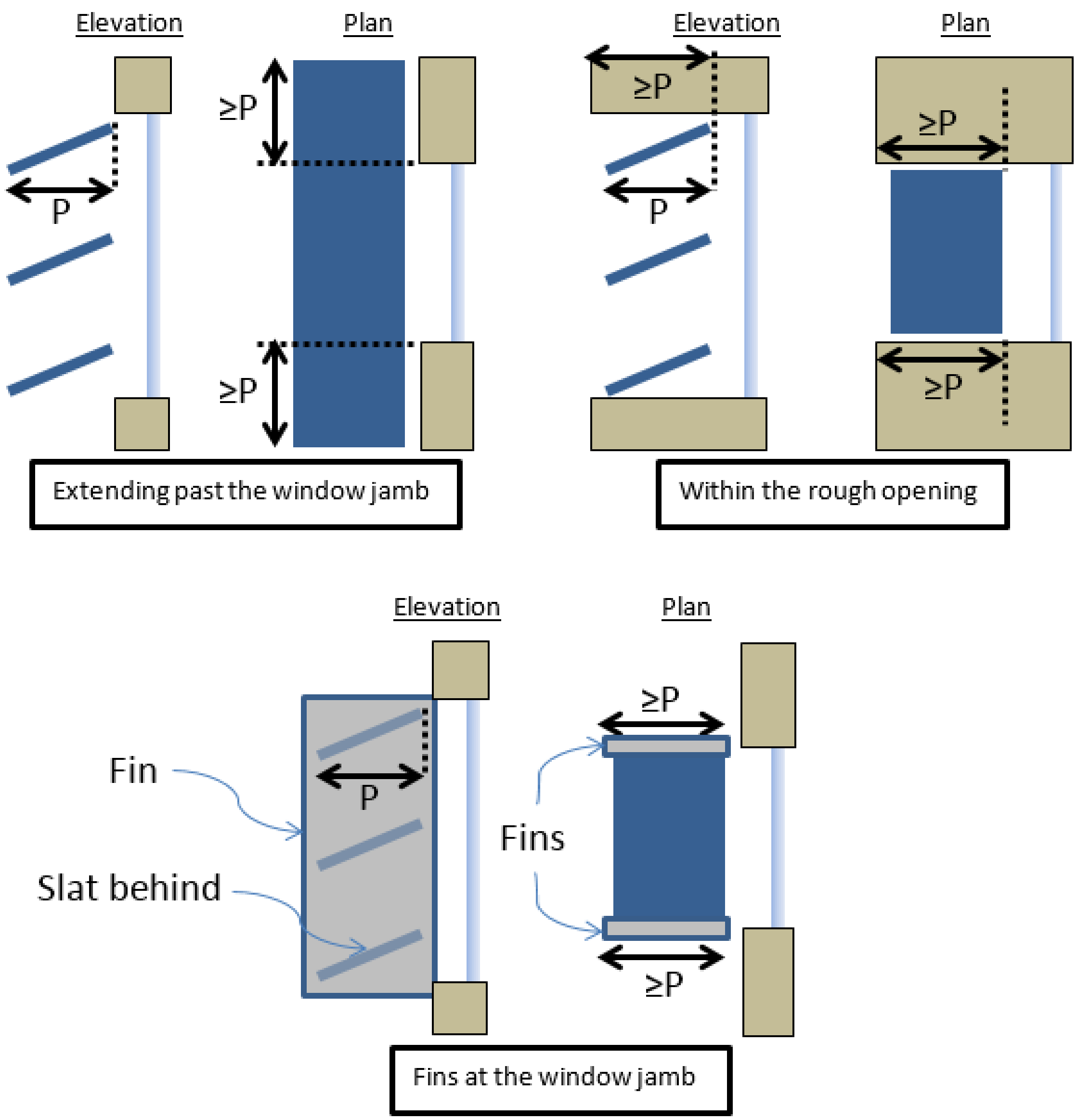
For the PAF, horizontal slats must be installed adjacent to (in front or behind) vertical fenestration. They must also extend the entire height of the window, and the WWR must be between 20 percent and 30 percent. The horizontal slats must be mounted on windows on east- and west-facing facades.

B. Side-Shading

Horizontal slats must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e. high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, slats must extend on either side of the window at least as far as their horizontal projection.

Alternatively, the horizontal slats can be located entirely within the reveal for the window or have fins on either side from top to bottom. Diagrams of qualifying side-shading configurations are given in Figure 3-25.

Figure 3-25 Qualifying Horizontal Side-Shading



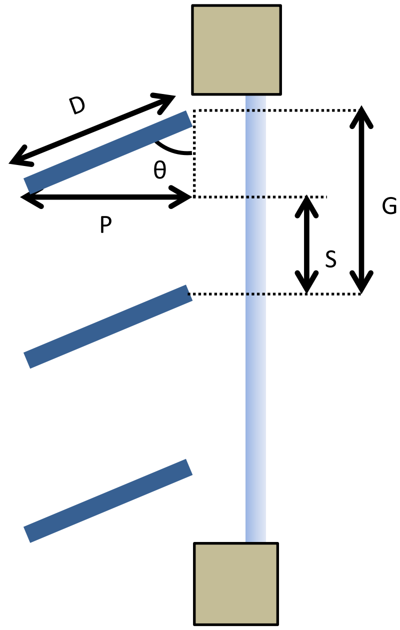
C. Projection Factor

Horizontal slats must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e. exterior horizontal slats slope downwards from fenestration while interior horizontal slats slope upwards from fenestration).

Projection factor is the ratio of the effective horizontal depth to the effective vertical spacing of a shading surface.

For the PAF, the projection factor must be at least 2.0 and no greater than 3.0. The projection factor is calculated per Equation 140.3-D. Horizontal slat angle, depth, gap and corresponding spacing and horizontal projection are illustrated in Figure 3-26. The spacing and horizontal projection must be documented in the construction documents.

Figure 3-27 Projection Factor for Horizontal Slats



$$Projection\ Factor = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, Θ = Angle, G = Gap, D = Depth

D. Distance Factor

If objects exterior to the building are tall enough, they will shade the building's fenestration. In some cases, they may shade enough such that adding horizontal slats to the project adds no benefit. For this reason, horizontal slat installations must also have a minimum distance factor to ensure that any nearby tall objects are far away enough to not cast a substantial shadow on the fenestration. An object casting a shadow can be all or part of an existing structure or natural object such as a chimney on an otherwise flat roof, a decorative feature of a roofline, or even any particular point along a flat roofline, a place on a hilly landscape, a tree on that landscape, or a particular brand on that tree. All of these objects must be evaluated to see if they meet the minimum distance factor requirement.

Distance factor is calculated using the projection factor, the elevation of the window sill, and the distance and elevation of the top of obstructions within view of the window. To determine the lowest distance factor for the window, all obstructions within view of the window must be considered. This includes building self-shading from walls within view of the window. Distance factor is calculated using Equation 140.3-D. For the PAF, the distance factor must be at least 0.3. Example 3-17 shows how to calculate distance factor.

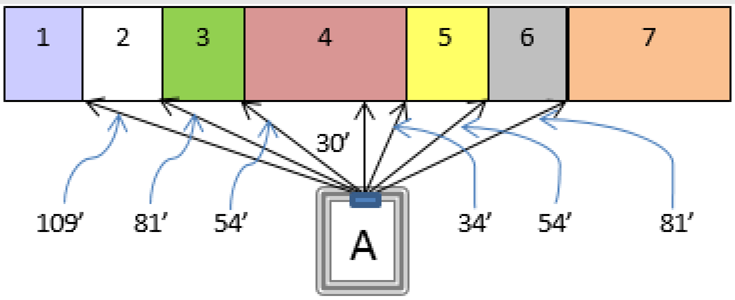
Note that for calculating distance factor, the shape of the obstruction is not accounted for. This is accurate for a situation where the relative heights of obstructions are similar, such as a street with an ordinance on height limit, but it actually may not be relevant if the obstruction does not cast much of a shadow (e.g. a radio tower on a hill).

In these cases, the project may instead demonstrate to the enforcement agency that the fenestration is shaded for less than a certain number of daytime hours between 8 am and 5 pm. For the PAF, the minimum number of shaded hours is 500. Section 3.3.3.2.2Q gives an example of how to demonstrate shaded hours.

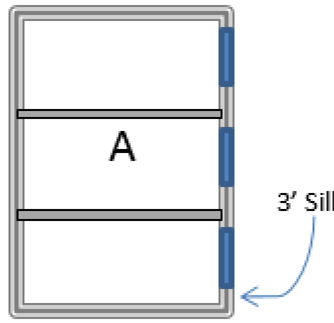
Example 3-17

Question

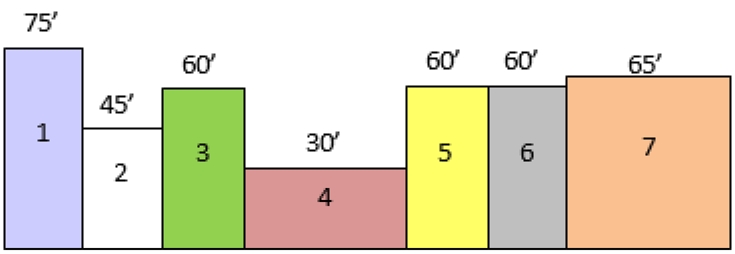
Building "A" in the diagram below faces east and has a window on the first floor with a sill height of three feet. There are seven buildings within view of this window with the distances and elevations as given in the figures. Can the designer use horizontal slats with a projection factor of 3.0 on this window to receive a PAF?



Site Plan



Building Section



View through Window

Building	Distance [ft]	Elevation [ft]	Distance Factor
1	109	75	0.50
2	81	45	0.64
3	54	60	0.32
4	30	30	0.37
5	34	60	0.20
6	54	60	0.32
7	81	65	0.44

Answer:

No. Building 5 is too close compared to its height.

Equation 140.3-D for distance factor is applied to each of the seven buildings within view of building A. For these buildings, the elevations are the same all along their flat rooftops. So, the objects which might not comply with the minimum distance factor requirement correspond to each of the buildings' rooflines. If we examine the closest point for the rooflines, we will be assured that they will not shade as much or more than the horizontal slats are intended to. The closest point for these rooflines are the sides of the buildings to the side of building A's view (namely, buildings 1-3 and 5-7) and the distance directly across for buildings in front of building A (i.e., building 4). In the case of building 5, this distance factor is

$$Distance\ Factor = \frac{D}{H_{AS} * Projection\ Factor} = \frac{34}{(60-3)*3.0} = 0.2 < 0.3\ (Minimum\ Distance\ Factor)$$

This is lower than the minimum distance factor, so horizontal slats with a projection factor of 3.0 can't be used for the PAF credit.

What can the designer do? The designer may select a lower projection factor or may choose to only use horizontal slats on the 2nd and higher floors of the building which have higher sill elevations.

E. Reflectance and Transmittance

The visible reflectance of horizontal slats must be tested as specified in ASTM E903. Certain coatings for horizontal slats have already been tested per ASTM E903 and can be researched to avoid re-testing. For the PAF, the visible reflectance must be at least 0.50.

If slats are opaque, then they do not require visible transmittance testing. But if they are not opaque, they must be tested as specified in ASTM E1175 and have a visible transmittance of 0.03 or less.

F. Mounting and Adjustability

Horizontal slats must be permanently mounted and not adjustable by occupants or facilities personnel. Horizontal slats are intended to be fixed and unmoving. Venetian blinds do not qualify for the PAF or a performance compliance option. Fasteners such as bolts, welds, and rivets are examples of fasteners that may be used to meet this requirement as long as they impede the movement of the horizontal slats and the horizontal slat assembly as a whole.

G. Labeling

A factory installed label must be permanently affixed and prominently located on an attachment point of the device to the building envelope. This label spells out that removal of the horizontal slats will trigger re-submittal of compliance documentation to the enforcement agency. If the horizontal slat assembly is removed, the building owners will again need to prove that the building still meets the requirements of Title 24, Part 6 with the slats removed.

Specifically, the label must state:

"NOTICE: Removal of this device will require re-submittal of compliance documentation to the enforcement agency responsible for compliance with California Title 24, Part 6."

3.3.5.3 Interior and Exterior Light Shelves

§140.3(d)3

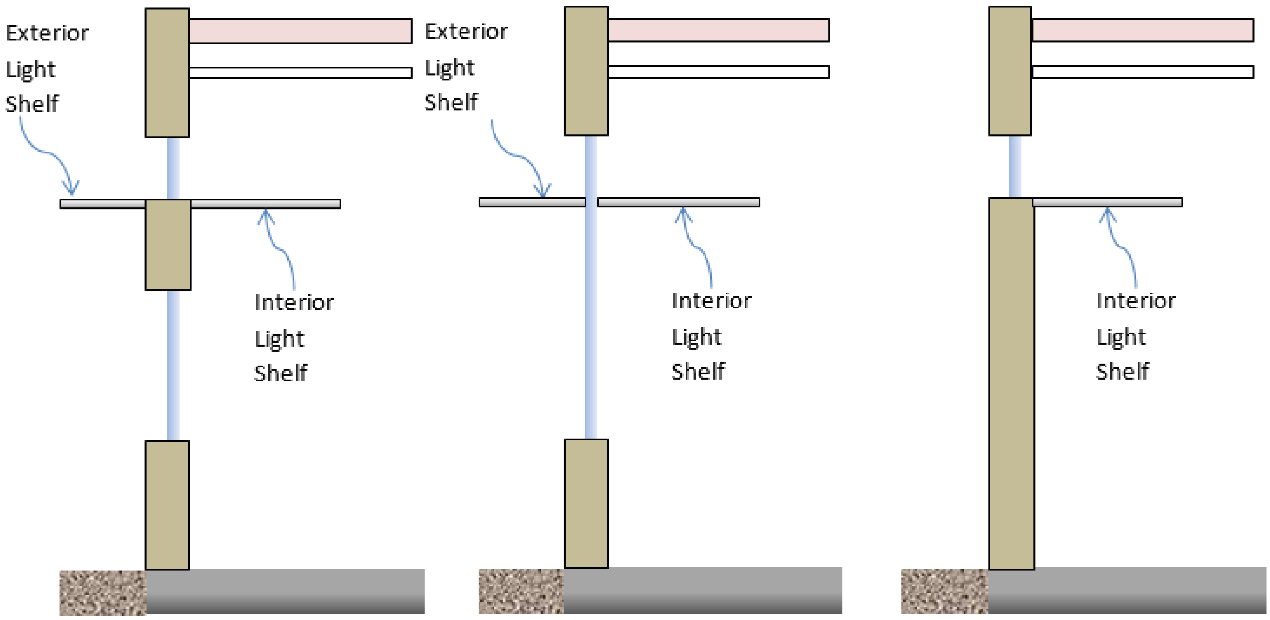
Interior light shelves combined with exterior light shelves on clerestory windows can be used in conjunction with automatic daylighting controls to receive a PAF. Light shelves block and redirect direct sun beam onto the ceiling of a space then reflect it downward into the space.

One pitfall of interior light shelves is the tendency for occupants to place objects on top of them, effectively using them as shelving. Thoughts should be put into the design of interior light shelves so as to discourage their use in this manner.

A. Exterior Light Shelf Exception and RHSGC

An exterior light shelf also acts as an overhang, blocking direct sun beam through any window area below the clerestory window (the "view window" area). Thus, it may take the overhang SHGC credit. If there is no view window area below the light shelf, then an exterior light shelf may still be installed but it is not required. Diagrams of qualifying interior and exterior light shelf configurations are given in Figure 3-27.

Figure 3-27 Qualifying Interior and Exterior Light Shelves Combinations



B. Clerestory

Light shelves must be installed adjacent to a clerestory window that meets the requirements discussed in the Clerestory Fenestration section. In addition, interior light shelves depend on a ceiling to reflect daylight. So, the clerestory window's head must be no greater than one foot below a finished ceiling.

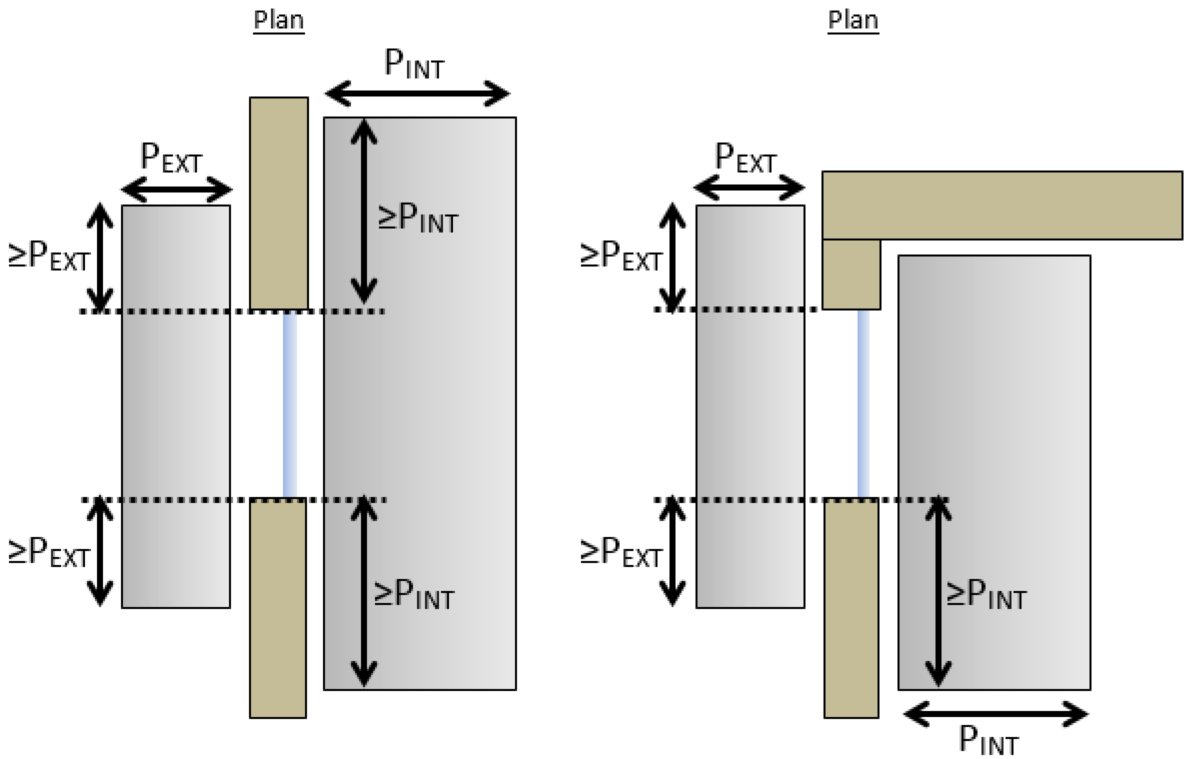
C. Window-to-Wall Ratio (WWR) and Orientation

For the PAF, the WWR must be greater than 30 percent. The light shelves must be mounted on windows on south-facing facades.

D. Side-Shading

Light shelves must block direct beam sunlight at their side edges. At sharp horizontal angles to the window (i.e. high and low relative azimuths), direct beam sunlight still passes through horizontal slats if they are only as wide as the window. Similar to overhangs, light shelves must extend on either side of the window at least as far as their horizontal projection. An example of a qualifying side-shading configuration is given in Figure 3-28.

Figure 3-28 Qualifying Light Shelf Side-Shading Example



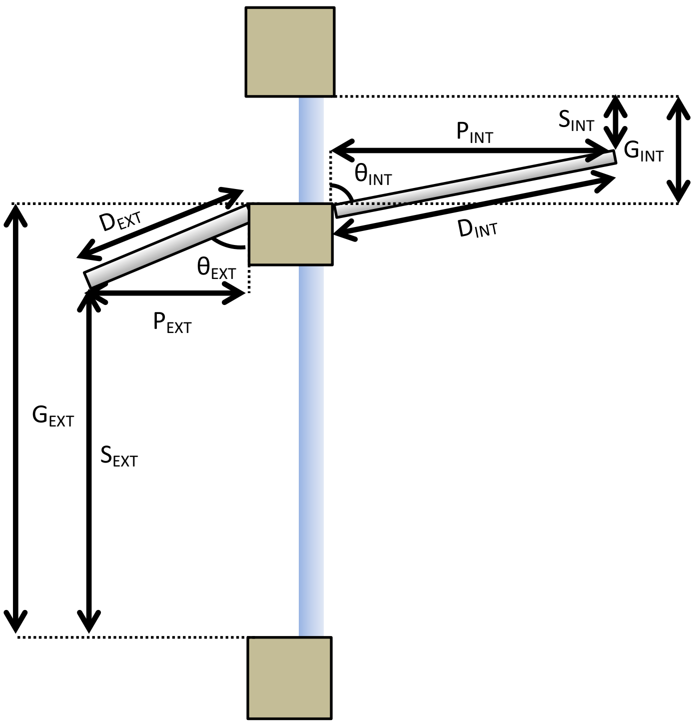
E. Projection Factor

Light shelves must shade direct beam sunlight from above. They may be level or slope downwards when looking out the window (i.e. exterior light shelves slope downwards from fenestration while interior light shelves slope upwards from fenestration). The slopes of interior light shelves should not be too steeply or they may block the daylight reflected off of the ceiling, thus reducing the daylighting benefits.

Projection factor is the ratio of the effective horizontal depth to effective vertical spacing of a shading surface. The projection factor is calculated per Equation 140.3-D. For a PAF, the interior light shelf projection factor must be at least 1.0 and not greater than 2.0. The exterior light shelf projection factor must be at least 0.25 and not greater than 1.25.

Light shelf angle, depth, gap, and corresponding spacing and horizontal projection are illustrated in Figure 3-29. The light shelf spacing and horizontal projections must be documented in the construction documents.

Figure 3-29 Projection Factor for Light Shelves



$$Projection\ Factor = \frac{P}{S} = \frac{D \times \sin(\theta)}{G - D \times \cos(\theta)}$$

P = Projection, S = Spacing, Θ = Angle, G = Gap, D = Depth

F. Distance Factor

The requirements and procedures for distance factor are the same as those for horizontal slats as given in the Horizontal Slats section. For the light shelf PAF, the minimum shaded hours are 750.

G. Reflectance

The visible reflectance of the top surface of light shelves must be tested as specified in ASTM E903. If the exterior light shelf is greater than two feet below the clerestory sill, then the top surface of the exterior light shelf needs not be reflective. Certain coatings for light shelves have already been tested per ASTM E903 and can be researched to avoid re-testing.

For the PAF, the visible reflectance must be at least 0.50.

3.4 Relocatable Public School Buildings

§140.3, Table 140.3-D, *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 eight different orientations either in climate zones 14, 15 or 16, or the specific climate zones in which the relocatable building is installed.. Also see §140.3(a)8 and §141.0(b)2.

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.

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.

3.5 Performance Approach

§140.1

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. A discussion on the performance approach, and fixed and restricted inputs, is included in Chapter 11. 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 Compliance Modeling

3.5.1.1 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 Joint 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.

3.5.1.2 Opaque Surfaces

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:

- Surface areas by opaque surface type.
- Surface orientation and slope.
- 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 represents insulation, framing, homogenous construction material, or a combination of framing and cavity insulation.
- 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 3.2.4.

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.

3.5.1.3 Fenestration

Heat transfer through all fenestration surfaces of the building envelope are modeled using the following inputs:

- 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.
- 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 60º 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.
- 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 200 ft^2.
- 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 200 ft^2. 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.
- Visual Transmittance

3.5.1.4 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).

3.5.1.5 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 Joint 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

§141.0

The Energy Standards offer prescriptive approaches and a performance approach to additions and alterations, but they do not apply to repairs. See §141.0(a) and §100.1(b) for detailed definitions.

A. **Addition** is a change to an existing building that increases conditioned floor area and volume. 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. 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 performance 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.

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 using 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 of § 110.6, § 110.7, and § 110.8 as well.

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 per Table 3-19:

Table 3-19 Wall Insulation for Alterations

Wall Assembly Type	Minimum R-value	Maximum U-factor
Metal buildings	R-13	0.113
Metal-framed walls	R-13	0.217
Wood-framed walls and others	R-11	0.110
Spandrel panel and curtain walls	R-4	0.280

Light mass and heavy mass walls do not have mandatory requirements for minimum R-value and maximum U-factor.

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.

Table 3-20 Floor Insulation for Alterations

Floor Assembly Type	Minimum R-value	Maximum U-factor
Raised framed floors	R-11	0.071
Raised mass floors in high rise, hotel and motel	R-6	0.111

Raised mass floors in all other occupancies - No minimum U-factor is required.

3.6.2 Prescriptive Requirements

For more details on the prescriptive requirements, see Section 3.2 for envelope requirements and Section 3.3 for fenestration 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.

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, §110.7 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 3-21) 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 3-21: 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

<table>
<tr><th colspan="2"></th><th>Fixed Window</th><th>Operable Window</th><th>Curtain Wall/ Storefront</th><th>Glazed Doors</th></tr>
<tr><td rowspan="3">VT</td><td>Vertical</td><td>0.42</td><td>0.32</td><td>0.46</td><td>0.17</td></tr>
<tr><td></td><td>Glass, Curb-Mounted</td><td>Glass, Deck-Mounted</td><td colspan="2">Plastic, Curb-Mounted</td></tr>
<tr><td>Skylights</td><td>0.49</td><td>0.49</td><td colspan="2">0.64</td></tr>
</table>

Energy Standards Table 141.0-A

Example 3-18

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 to fenestration products removed and reinstalled as part of a building alteration or addition.

3. Use either NFRC label certificate or use Tables 110.6-A and 110.6-B default values; applies in this case as 24,000 ft² of new fenestration is being installed.

4. Since the site-built fenestration area is less than 200 ft², use either the NFRC label certificate, the applicable default U-factor or SHGC set forth in Reference Nonresidential Appendix NA6, or default values from Tables 110.6-A and 110.6-B.

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 50 percent or more of the existing roof area or when more than 2,000 ft^2 of the roof is being altered, (whichever is less) the requirements apply. When a small repair is made, these requirements do not apply. For example, the requirements for roof insulation would not be triggered if the existing roof surface were overlaid instead of replaced.

These requirements 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 insulation recover boards.

Roof Insulation

When a roof is exposed to the roof deck or recover boards, and the 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 3-22).

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 Joint 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 3-22: 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.

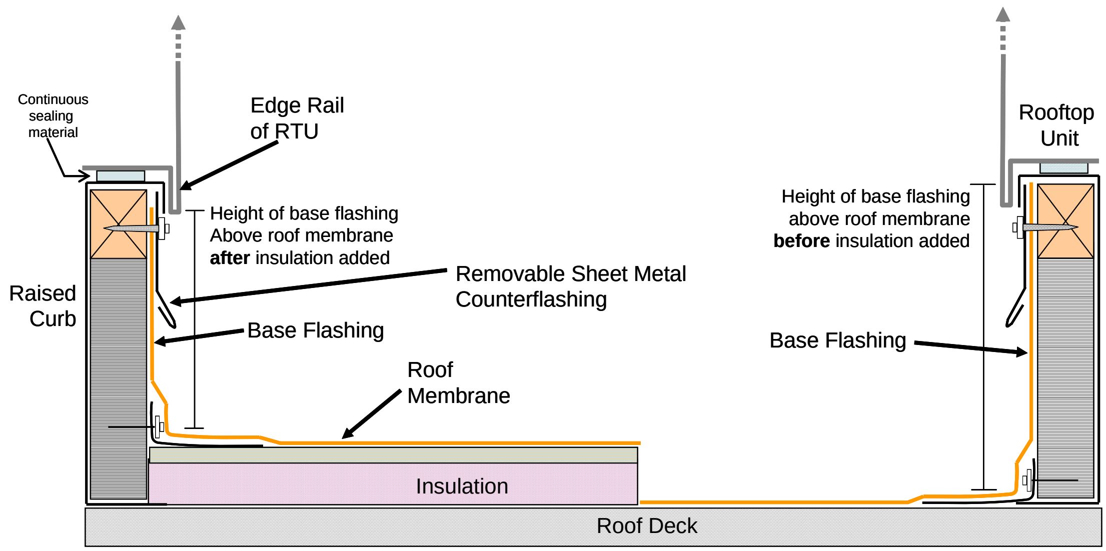
Exceptions to 141.0(b)2Biii:

- No additional insulation is required if the roof is already insulated to a minimum level of R-7.
- If mechanical equipment is located on the roof will not be disconnected and lifted as part of the roof replacement, insulation added may be limited to the maximum insulation thickness that will allow a height of 8 inches (203 mm) from the roof membrane surface to the top of the base flashing.
- 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. These conditions must be met:
  - The penthouse or parapet walls are finished with an exterior cladding material other than the roofing covering membrane material.
  - 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.
  - 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.
  - 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.
  - 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.

When insulation is added on top of a roof, the elevation of the roof membrane is increased. When insulation is added to a roof and the curb height (counterflashing for walls) is unchanged (Figure 3-30), 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.

When adding insulation on top of a formerly uninsulated or underinsulated roof, 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, 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 3-30: Base Flashing on Rooftop Unit Curb Detail



Roof Products

§141.0(b)2B

1. *Thermal Emittance and Solar Reflectance Prescriptive Requirements*

For nonresidential buildings, the prescriptive requirements for roofing products are:

- 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.

Exception for nonresidential buildings: an aged solar reflectance less than 0.63 is allowed, provided that additional insulation is installed. (Table 3-23)

For high-rise residential buildings and hotels and motels, the prescriptive requirements for roofing products are:

- 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.

Exceptions for high-rise residential buildings and hotels and motels:

- 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.
- 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.

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. Table 141.0-B (Table 3-23) shows the overall roof U-factors trade-off requirements, by climate zones.

Table 3-23: 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

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 3-19

Question:

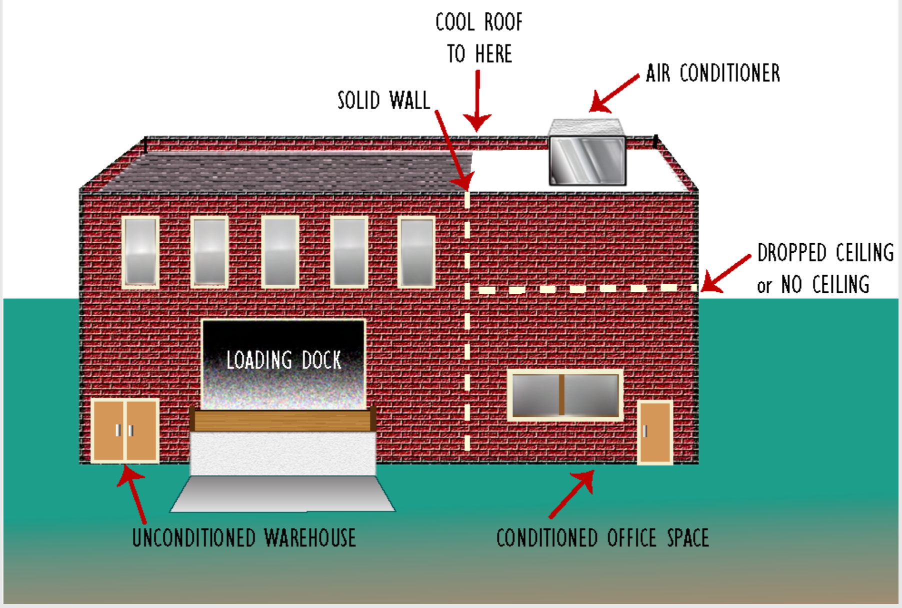
What are the Energy Standards requirements for cool roofs when reroofing a low-sloped roof on an unconditioned warehouse containing conditioned office space?

Answer:

Scenario 1.

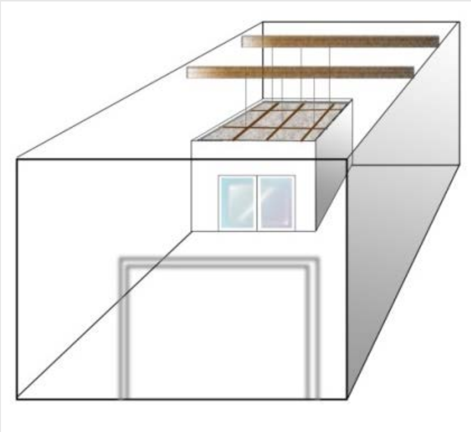
There is either directly or indirectly conditioned space under the roof. The cool roof requirements apply to just the portion(s) of the warehouse roof over the conditioned space(s). The rest of the roof (over unconditioned warehouse space) is not required to be a cool roof.

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. 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 3-20

Question:

I have a barrel roof on nonresidential conditioned building that needs to be reroofed. Must I follow the Energy Standards roofing product requirement?

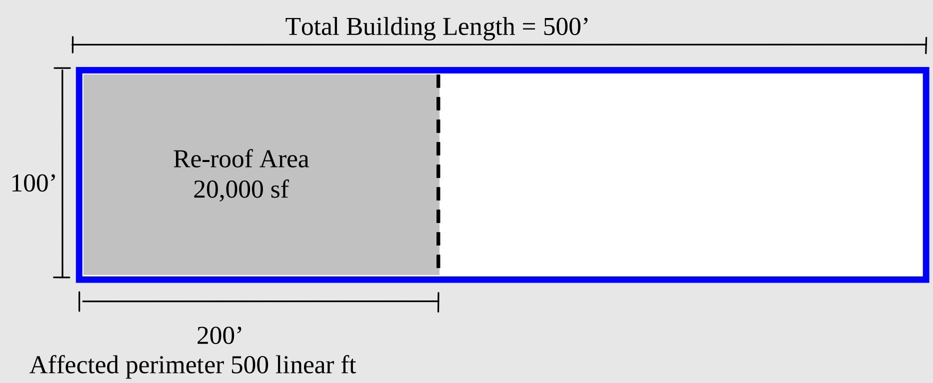
Answer:

Yes, the roof would need to meet the aged solar reflectance and thermal emittance for a steep-sloped roof. Although a barrel roof has both low-sloped and steep-sloped roofing areas, the continuous gradual slope change allows the steep-sloped section of the roof to be seen from ground level. Barrel roofs only need to meet the steep-sloped requirement for the entire roof area.

Example 3-21

Question 1:

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?



Answer 1:

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. The roof does not have any insulation and, therefore, is required to add insulation. 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.

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 higher up on the wall. Alternatively, the installer may ask for the roofing manufacturer to provide a variance in the warranty 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 meet the U-factor.

Question 2:

If the building was located in San Francisco, would the insulation requirements be different on the building?

Answer 2:

Yes. San Francisco (as shown in Reference Joint Appendix JA2) is in Climate Zone 3. Per 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.

For nonresidential buildings in Climate Zone 3, the ratio is 100:1. 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.

Example 3-22

Question 1:

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?

Answer 1:

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.

Question 2:

What if the rooftop air conditioner is lifted temporarily during reroofing to remove and replace the roofing membrane? Is added insulation required?

Answer 2:

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 3-23

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. There are no exceptions for skylights. Removing a unit skylight and increasing its curb height is substantially less effort than that for space-conditioning equipment.

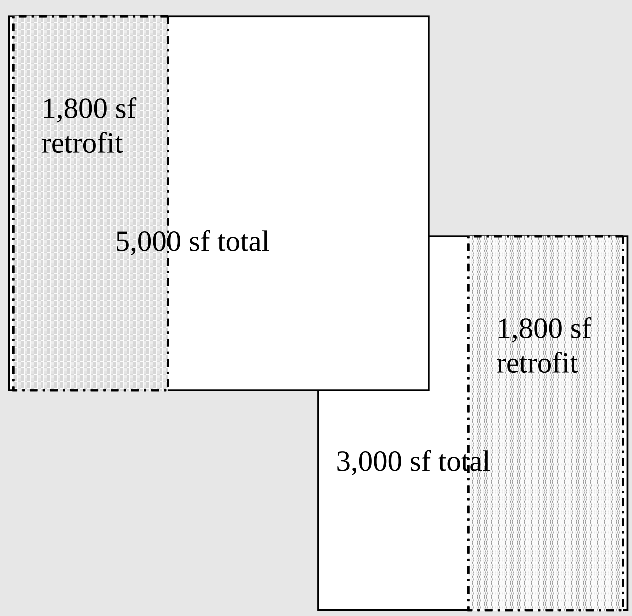
Example 3-24

Question 1:

A building has low-sloped roofs at two elevations. 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 1:

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.



Question 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 be a cool roof and have insulation installed?

Answer 2:

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 3-25

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:

Question 1: 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?

Answer 1:

No. The unit with the 9-inch base flashing was disconnected and lifted and thus it does not qualify for the exception to §141.0(b)2Biii. As much as 6 inches or more of insulation can be added 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. The full R-14 insulation would be required.

Question 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 2:

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. Only 1 inch (2.5 cm) of insulation can be added 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). Only 1 inch (2.5cm) of additional insulation is required since 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.

Question 3:

In Question 2, does this reduced amount of required insulation apply only to the area immediately surrounding the unlifted unit or to the entire roof?

Answer 3:

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 3-26

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 exceptions in 140.3(a)Ai?

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 3-27

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 3-28

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 3-29

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.

1. To make an insulation/reflectance trade-off under the prescriptive approach, using Table 141.0-B. 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. Consult Section 4.2 (Roofs and Ceilings) of Reference Joint 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/title24/2019standards/. 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 3-30

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

3.6.3.1 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.

3.6.3.2 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 one of these:

- 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).

- 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 3-24: 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

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Table of Contents

4 Mechanical Systems

4.1 Overview

The objective of the Building Energy Efficiency Standards (Energy Standards) for mechanical systems is to reduce energy consumption while maintaining occupant comfort by:

1. Maximizing equipment efficiency 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

An important function of the Energy Standards is indoor air quality for occupant comfort and health. The 2019 Standards incorporate requirements for outdoor air ventilation that must be met during normally occupied hours.

This chapter summarizes the requirements for space conditioning, ventilation, 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 overview of the chapter and the scope of the mechanical systems requirement in the Energy Standards

Section 4.2 requirements for heating, ventilation, and air conditioning (HVAC) and service water heating equipment efficiency and equipment mounted controls

Section 4.3 mechanical ventilation, natural ventilation, and demand controlled ventilation

Section 4.4 construction and insulation of ducts and pipes and duct sealing to reduce leakage

Section 4.5 control requirements for HVAC systems including zone controls and controls to limit reheating and recooling

Section 4.6 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 remaining requirements for service water heating

Section 4.8 performance method of compliance

Section 4.9 compliance requirements for additions and alterations.

Section 4.10 glossary, reference, and definitions.

Section 4.11 mechanical plan check documents, including information that must be provided in the building plans and specifications to show compliance with the Energy Standards

Acceptance requirements apply to all covered systems regardless of whether the prescriptive or performance compliance approach is used.

Chapter 12 lays out the 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 2019 Reference Appendix NA7.

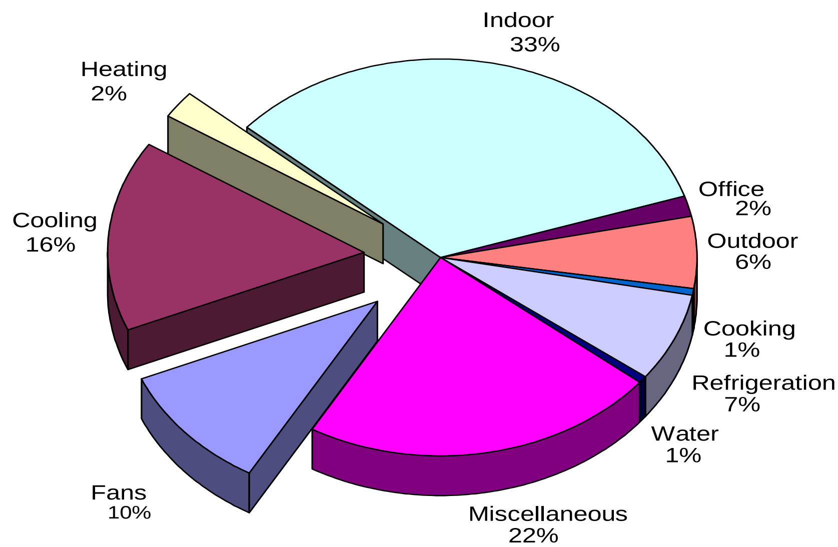
4.1.1 What's New for 2019

- Demand response HVAC controls
  - Open ADR 2.0
  - Occupancy sensors
- Air filtration requirements
  - Efficiency
  - Pressure Drop
  - Labeling
- Ventilation and indoor air quality
  - Kitchen range hoods
  - Natural ventilation criteria
  - Minimum ventilation rates
  - Exhaust ventilation
  - Zone air distribution effectiveness
  - Air classification and recirculation limits
- Demand control ventilation updates
- Healthcare facilities
- Fan power limitation changes
  - Pressure drop adjustment
- Variable air volume zone controls
- Passive waterside economizer requirements
  - Integrated waterside economizer
- Cooling tower efficiency
- Exhaust system transfer air
- Expanded economizer fault detection diagnostics
- Adiabatic condenser requirements

4.1.2 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. Fans and cooling equipment are the largest components of energy consumed for HVAC purposes in most building in lower elevation climates. 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 percent of commercial building electricity use in California.

Source IEQ RFP, December 2002, California Energy Commission No. 500-02-501.

4.1.3 Mandatory Measures

Mandatory measures, covered in §110.0-110.12 and §120.0-120.9, apply to all nonresidential buildings, whether the designer chooses the prescriptive or performance approach for compliance. The following sections are applicable to mechanical systems:

1. Equipment certification and equipment efficiency - §110.1 and §110.2
2. Service water heating systems and equipment - §110.3
3. Pool and spa heating systems and equipment - §110.4
4. Restrictions on pilot lights for natural gas appliances and equipment - §110.5
5. Demand responsive controls - §110.12
6. Ventilation and indoor air quality requirements - §120.1
7. Control requirements - §120.2
8. Pipe insulation - §120.3
9. Duct construction and insulation - §120.4
10. Acceptance tests in §120.5 and the 2019 Reference Appendices NA7
11. Commissioning - §120.8
12. Commercial Boilers - §120.9

4.1.4 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.

4.1.4.1 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. §140.4(a) and (b) -Load calculations, sizing, system type and equipment selection
2. §140.4(c) - Fan power consumption
3. §140.4(d) - Controls to reduce reheating, recooling and mixing of conditioned air streams
4. §140.4(e) - Economizers
5. §140.4(f) - Supply temperature reset
6. §140.4(g) - Restrictions on electric-resistance heating
7. §140.4(h) - Fan speed controls for heat rejection equipment
8. §140.4(h) - Limitation on centrifugal fan cooling towers
9. §140.4(i) - Minimum chiller efficiency
10. §140.4(j) - Limitation on air-cooled chillers
11. §140.4(k) - Hydronic system design
12. §140.4(l) - Duct sealing
13. §140.4(m) - Supply fan control
14. §140.4(n) - Mechanical system shut-off control
15. §140.4(o) - Exhaust system transfer air

4.1.4.2 Performance Compliance Approach

The performance compliance approach, §140.1, allows the designer to trade off energy use between 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 mandatory requirements.

1. Performance approach trade-offs can be applied to the following disciplines: mechanical, lighting, envelope, and covered processes. The performance approach requires creating a proposed energy model using approved Energy Commission compliance software. The software will automatically create a standard design model based on the features of the proposed model and compare the energy use of the two: Standard design energy model that meets mandatory and prescriptive requirements (per the Alternative Calculation Method Reference Manual).
2. Proposed design energy model that reflects the feature of the proposed building.

The proposed model complies if it results in lower time dependent valuation (TDV) energy use than the standard design 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

All of the equipment efficiency requirements are mandatory measures.

The mandatory requirements for mechanical equipment must be included in the system design, whether the overall building compliance is the prescriptive or performance approach. These features are cost effective over a wide range of building types and mechanical systems.

Most mandatory features for equipment efficiency are requirements for the manufacturer. It is the responsibility of the designer to specify products in the building design that meet these requirements. Manufacturers of central air conditioners and heat pumps, room air conditioners, package terminal air conditioners, 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 Commission maintains a database which lists the certified equipment 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 Appendices JA9.

4.2.1 Mandatory Requirements

Mechanical equipment must be certified by the manufacturer as complying with the mandatory requirements in the following sections:

1. §110.0 - Mandatory Requirements for Systems and Equipment Certification
2. §110.1 - Mandatory Requirements for Appliances.
3. §110.2 - Mandatory Requirements for Space-Conditioning Equipment
    a. Efficiency
    b. Gas- and Oil-Fired Furnace Standby Loss Controls
    c. Low Leakage Air-Handling Units
4. §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
    a. Certification by Manufactures
    b. Efficiency
5. §110.4 - Mandatory Requirements for Pool and Spa Systems and Equipment
    a. Certification by Manufactures
6. §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:

1. §110.2 - Mandatory Requirements for Space Conditioning Equipment
    a. Controls for Heat Pumps with Supplementary Electric Resistance Heaters
    b. Thermostats
    c. Open and Closed Circuit Cooling Towers (blowdown control)

2. §110.3 - Mandatory Requirements for Service Water Heating Systems and Equipment
3. §110.12 – Mandatory Requirements for Demand Management
4. §120.1 - Requirements for Ventilation and Indoor Air Quality
5. §120.2 - Required Controls for Space Conditioning Systems (see Section 4.5)
    a. Occupant Controlled Smart Thermostats (OCST)
    b. Direct Digital Controls (DDC)
    c. Optimum Start/Stop Controls
    d. Economizer Fault Detection and Diagnostics
6. §120.3 - Requirements for Pipe Insulation
7. §120.4 - Requirements for Air Distribution Ducts and Plenums
8. §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 and vary based on the type and capacity of the equipment. Tables 110.2-A through 110.2-K list the minimum equipment efficiency requirements for the 2019 Energy Standards.

Table 4-1: Unitary Air Conditioners and Condensing Units Minimum Efficiency Requirements

For equipment <65,000 Btu/hr see Nonresidential Appendix B

Equipment Type	Size Category	Efficiency [a,b]	Test Procedure[c]
Air conditioners, air cooled both split and single packaged	≥65,000 Btu/h and < 135,000 Btu/h	11.2 EER 12.9 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	11.0 EER 12.4 IEER	
	≥240,000 Btu/h and < 760,000 Btu/h	10.0 EER 11.6 IEER	
	≥760,000 Btu/h	9.7 EER 11.2 IEER	
Air conditioners, water cooled	≥65,000 Btu/h and < 135,000 Btu/h	12.1 EER 13.9 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	12.5 EER 13.9 IEER	ANSI/AHRI 340/360
	≥240,000 Btu/h and < 760,000 Btu/h	12.4 EER 13.6 IEER	ANSI/AHRI 340/360
	≥760,000 Btu/h	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

Source: California Energy Commission, 2019 Building Energy Efficiency Standards, Table 110.2-A

Table 4-2: Heat Pumps Minimum Efficiency Requirements

Equipment Type	Size Category	Efficiency[a,b]		Test Procedure[c]
Air cooled (cooling mode), both split system and single package	≥65,000 Btu/h and < 135,000 Btu/h	11.0 EER 12.2 IEER		ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	10.6 EER 11.6 IEER		
	≥240,000 Btu/h	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: Heat Pumps Minimum Efficiency Requirements

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

Source: California Energy Commission, 2019 Building Energy Efficiency 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° F db Outdoor air	0.60 COP	ANSI Z21.40.4A
Air-cooled gas-engine heat pump (heating mode)	All Capacities	47° F 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

Source: California Energy Commission, 2019 Building Energy Efficiency 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 requirement for:

- Centrifugal chillers with design leaving evaporator temperature less than 36 degrees F; or
- Positive displacement chillers with design leaving fluid temperatures less than or equal to 32 degrees F
- Absorption chillers with design leaving fluid temperature less than 40 degrees 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

Source; California Energy Commission, Building Energy Efficiency Standards, Table 110.2-D

Table 4-5: Packaged Terminal Air Conditioners (PTAC) and Heat Pumps Minimum Efficiency Requirements

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^{0}F 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^{0}F 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^{0}F db Outdoor air	14.0-(0.300 x Cap/1000) [a] EER	
PTHP (Cooling mode) replacements[b]	All capacities	95^{0}F 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^{0}F db/75^{0}F wb Outdoor air	11.0 EER	ANSI/AHRI 390
	≥ 65,000 Btu/h and < 135,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	10.0 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	10.0 EER	
SPVAC (cooling mode) nonweatherized space constrained	≤ 30,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	9.20 EER	
	> 30,000 Btu/h and ≤36,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	9.00 EER	
SPVHP (cooling mode)	< 65,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	11.0 EER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	10.0EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	10.0 EER	
SPVHP (cooling mode) nonweatherized space constrained	≤ 30,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	9.20 EER	
	> 30,000 Btu/h and ≤36,000 Btu/h	95^{0}F db/75^{0}F wb Outdoor air	9.00 EER	
SPVHP (heating mode)	< 65,000 Btu/h	47^{0}F db/43^{0}F wb Outdoor air	3.3 COP	
	≥ 65,000 Btu/h and < 135,000 Btu/h	47^{0}F db/43^{0}F wb Outdoor air	3.0 COP	
	≥ 135,000 Btu/h and < 240,000 Btu/h	47^{0}F db/43^{0}F wb Outdoor air	3.0 COP	

SPVHP (heating mode)	≤ 30,000 Btu/h	47⁰F db/43⁰F wb Outdoor air	3.00 COP	
nonweatherized space constrained	> 30,000 Btu/h and ≤36,000 Btu/h	47⁰F db/43⁰F 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 sq inches.
[c] Applicable test procedure and reference year are provided under the definitions

Source: California Energy Commission, Building Energy Efficiency 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

Source: California Energy Commission, Building Energy Efficiency 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	95⁰F entering water 85⁰F leaving water 75⁰F entering air wb	≥ 42.1 gpm/hp	CTI ATC-105 and CTI STD-201 RS
Centrifugal fan open-circuit cooling towers	All	95⁰F entering water 85⁰F leaving water 75⁰F entering air wb	≥ 20.0 gpm/hp	
Propeller or axial fan closed-circuit cooling towers	All	102⁰F entering water 90⁰F leaving water 75⁰F entering air wb	≥ 16.1 gpm/hp	
Centrifugal fan closed-circuit cooling towers	All	102⁰F entering water 90⁰F leaving water 75⁰F 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)

Source: California Energy Commission, Building Energy Efficiency Standards, Table 110.2-G

Table 4-8: Electrically Operated Variable Refrigerant Flow Air Conditioners Minimum Efficiency Requirements

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 15.5 IEER[b]	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	11.0 EER 14.9 IEER[b]	
	≥ 240,000 Btu/h	Electric Resistance (or none)	VRF Multi-Split System	10.0 EER 13.9 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.

Source: California Energy Commission, Building Energy Efficiency Standards Table 110.2-H

Table 4-9: Electrically Operated VRF Air-to-Air and Applied Heat Pumps Minimum Efficiency Requirements

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 14.6 IEER[c]	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)	VRF multi-split system[a]	10.6 EER 13.9 IEER[c]	
	≥ 240,000 Btu/h	Electric resistance (or none)	VRF multi-split System[a]	9.5 EER 12.7 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 15.8 IEER	
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	VRF multi-split system[a] 86^{0}F entering water	12.0 EER 15.8 IEER	
	≥ 135,000 Btu/h and < 240,000 BTU/h	All	VRF multi-split system[a] 86^{0}F entering water	10.0 EER 13.8 IEER	
	≥ 240,000 Btu/h	All	VRF multi-split system[a] 59^{0}F entering water	10.0 EER 12.0 IEER	

(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] 59⁰F entering water	16.2 EER	AHRI 1230
	≥ 135,000 Btu/h	All	VRF multi-split system[a] 59⁰F entering water	13.8 EER	
VRF ground source (cooling mode)	< 135,000 Btu/h	All	VRF multi-split system[a] 77⁰F entering water	13.4 EER	
	≥ 135,000 Btu/h	All	VRF multi-split system[a] 77⁰F 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 47ºF db/ 43ºF wb outdoor air	3.3 COP	
			VRF Multi-split system 17ºF db/15ºF wb outdoor air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	--	VRF multi-split system 47⁰F db/ 43⁰F wb outdoor air	3.2 COP	
			VRF multi-split system 17⁰F db/ 15⁰F wb outdoor air	2.05 COP	
VRF water source (heating mode)	< 65,000 Btu/h (cooling capacity)	--	VRF multi-split system 68 ⁰F entering water	4.3 COP	
	≥ 65,000 Btu/h and <135,000 Btu/h (cooling capacity	--	VRF multi-split system 68 ⁰F entering water	4.3 COP	
	≥135,000 Btu/h and <240,000 Btu/h (cooling capacity)	--	VRF multi-split system 68 ⁰F entering water	4.0 COP	
	≥ 240,000 Btu/h (cooling capacity)	--	VRF multi-split System 68 ⁰F entering water	3.9 COP	
VRF groundwater source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-Split System 50ºF entering water	3.6 COP	
	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-Split System 50ºF entering water	3.3 COP	
VRF ground source (heating mode)	<135,000 Btu/h (cooling capacity)	---	VRF Multi-Split System 32ºF entering water	3.1 COP	

	≥135,000 Btu/h (cooling capacity)	---	VRF Multi-Split System 32ºF entering water	2.8 COP	AHRI 1230 AHRI 1230
[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.					

Source: California Energy Commission, Building Energy Efficiency 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				
	≥ 225,00 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]	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 percent 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 IID and have either power venting or an automatic flue damper.
Combustion units not covered by the U.S. Department of Energy Code of Federal Regulations 10 CFR 430 (3-phase power or cooling capacity greater than or equal to 19 kW) may comply with either rating.

Source: California Energy Commission, Building Energy Efficiency 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).

Source: California Energy Commission, Building Energy Efficiency 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, 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. Where equipment serves more than one function, it must comply with the efficiency standards applicable to each function.

When there is a requirement for equipment rated at its "maximum rated capacity" or "minimum rated capacity," the proper capacity shall be maintained 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 not designed for operation at ANSI/AHRI Standard 550/590 test conditions, which are:

a. 44 degrees Fahrenheit (F) leaving chilled water temperature

b. 85 degrees F entering condenser water temperature

c. Three 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, which 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 by 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

$$A = (1.4592 \times 10^{-7})(LIFT^4) - (3.46496 \times 10^{-5})(LIFT^3) + (3.14196 \times 10^{-3})(LIFT^2) - (0.147199)(LIFT) + 3.9302$$

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 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 degrees F
2. Maximum leaving condenser fluid temperature: 115 degrees F
3. LIFT greater than or equal to 20 degrees F and less than or equal to 80 degrees 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 are for positive displacement (air-cooled and water-cooled) chillers with a leaving evaporator fluid temperature higher than 32 degrees F. These equipment shall comply instead with Table 4-4 (Table 110.2-D in the Energy Standard) 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.

Manufacturers of any appliance or equipment regulated by Section 1601 of the Appliance Efficiency Regulations are required to comply with the certification and testing requirements of Section 1608(a) of those regulations. This includes being listed in the Modernized Appliance Efficiency Database System.

Equipment not covered by the Appliance Efficiency Regulations, for which there is a minimum efficiency requirement in the Energy Standards, cannot be installed unless the required efficiency data is listed and verifiable in one of the following:

1. The Energy Commission's database of certified appliances available at: www.energy.ca.gov/appliances/.
2. An equivalent directory published by a federal agency.
3. An approved trade association directory as defined in Title 20 California Code of Regulations, Section 1606(h) such as the Air Conditioning, Heating and Refrigeration Institute (AHRI) Directory of Certified Products. This information is available at www.ahridirectory.org.
4. The Home Ventilating Institute (HVI) certified products directory available at www.hvi.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. Heat pumps may contain electric resistance heat strips which act as a supplemental heating source. If this type of system is used, then controls must be put in place to prevent the use of the electric resistance supplementary heating when the heating load can be satisfied with the heat pump alone. tThe controls must set a cut-on temperature for compressor heating higher than the cut-on temperature for electric resistance heating. The cut-off temperature for compression heating must also be set higher than the cut-off temperature for electric resistance heating.

Exceptions exist for these control requirements if one of the following applies:

1. 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. The heat pump is a room air-conditioner heat pump.

4.2.5 Thermostats

§110.2(c) and §120.2(b)4

All heating or cooling systems are required to have a thermostat with setback capability and is capable of at least four 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 single zone air conditioners and heat pumps must comply with the demand responsive control requirements of Section 110.12(a), also known as the Occupant controlled Smart Thermostat (OCST). See Appendix D of this compliance manual for guidance on compliance with demand responsive control requirements.

Exceptions to §120.2(b)4, setback thermostat and OCST requirements:

1. Systems serving zones that must have constant temperatures to protect a process or product (e.g. a laboratory or a museum).
2. The following HVAC systems are exempt:
    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

In most cases setup and setback are based on time of day only. However, see Section 4.5.1.3, Shut-off and Temperature Setup/Setback which describes those applications where occupancy sensing is also required to trigger setup and setback periods and shutting off ventilation air.

4.2.6 Furnace Standby Loss Controls

§110.2(d)

Forced air gas- and oil-fired furnaces with input ratings greater than or equal to 225,000 Btu/h are required to have controls and designs that limit their standby losses:

1. Either an intermittent ignition or interrupted device (IID) is required. Standing pilot lights are not allowed.
2. Either a power venting or a flue damper is required. 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 greater than or equal to 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 and 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. 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 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, and recirculating pump run time (or bleed time).

The makeup water line must be equipped with an analog flow meter and an 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 energy management control system (EMCS).

Drift eliminators are louvered or comb-like devices that are installed at the top of the cooling tower to capture air stream water particles. 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 calculated with an Energy Commission approved calculator based on local water quality conditions (which is reported annually by the local utility) and a Langelier Saturation Index (LSI) of 2.5 or less. The maximum cycles of concentration must be catloged in the mechanical compliance documentation and reviewed and approved by the Professional Engineer (P.E.) of record. Energy Commission compliance document NRCC-MCH-E has a built in calculator. An approved excel file LSIcalculator is located on the Energy Commission's website.

The website address for the excel calculator is:
http://www.energy.ca.gov/title24/2013standards/documents/maximum_cycles_calculator.xls

The website address for the NRCC-MCH-06 is:

http://www.energy.ca.gov/2015publications/CEC-400-2015-033/appendices/forms/NRCC/

4.2.8 Pilot Lights

§110.5

Pilot lights are prohibited in the following circumstances:

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.
4. Indoor and outdoor fireplaces §110.5(e).

Example 4-1

Question

If a 15 ton (180,000 Btu/h) 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 12.3, and a heating thermal efficiency of 78 percent, does it comply?

Answer

No. While the cooling side appears to not comply because both the EER and IEER are less than the values listed in Table 4-1, the EER and IEER values in the 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. Since this unit has gas heat, the EER requirement is actually 10.8 and the IEER requirement is 12.2 , this unit complies with the cooling requirements. The 0.2 deduction provided in Table 4-1 and Table 4-2 compensates for the higher fan power required to move air through the heat exchanger.

From Table 4-10, the heating efficiency must be at least 80 percent thermal efficiency. This unit has a 78 percent thermal efficiency and does not comply with the heating requirements, therefore, the entire unit does not comply since it's a packaged unit.

Example 4-2

Question

A 500,000 Btu/h gas-fired hot water 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 78 percent (less than 80 percent) so it doesn't comply.

Example 4-3

Question

A 300 ton water-cooled centrifugal chiller is designed to operate at 44 degrees F chilled water supply, 90 degrees 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 (44 degrees F chilled water supply, 85 degrees F condenser water return, 3 gpm/ton condenser water flow), 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 is required to have a maximum full load efficiency of 0.560 kW/ton and a maximum IPLV of 0.520 kW/ton for Path A and a maximum full load efficiency of 0.595 kW/ton and a maximum IPLV of 0.390 kW/ton for Path B.

The Kadj is calculated as follows:

LIFT = LvgCond – LvgEvap = 90F-44F = 46F

A = (0.00000014592 x $(46)^4$) – (0.0000346496 x $(46)^3$)+ (0.00314196 x $(46)^2$) – (0.147199 x (46)) + 3.9302=1.08813

B = (0.0015 x 44) + 0.934 = 1.000

Kadj=A x B=1.08813

For compliance with Path A, the maximum Full load kW/ton = 0.560 / 1.08813 = 0.515 kW/ton and the maximum NPLV= 0.520 / 1.08813 = 0.478 kW/ton

For compliance with Path B the maximum Full load kW/ton = 0.595 / 1.08813 = 0.547 kW/ton and the maximum NPLV= 0.390 / 1.08813 = 0.358 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 degrees F chilled water supply, 82 degrees F condenser water supply and 94 degrees 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 degrees 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 is required to have a maximum full load efficiency of 0.610 kW/ton and a maximum IPLV of 0.520 kW/ton for Path A and a maximum full load efficiency of 0.625 kW/ton and a maximum IPLV of 0.410 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 = 0.610 / 0.80388 = 0.759 kW/ton and the maximum NPLV= 0.520 / 0.80388 = 0.647 kW/ton. For compliance with Path B the maximum Full load kW/ton = 0.625 / 0.80388 = 0.777 kW/ton and the maximum NPLV= 0.410 / 0.80388 = 0.510 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/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, 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.

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
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 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 of 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. The drawbacks of excess air are increased stack heat loss and reduced combustion efficiency.

Parallel positioning controls optimize the combustion excess air based on the firing rate of the boiler 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. It is 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 the type of burner, a more consistent level of excess oxygen can be achieved with parallel position compared to single-point positioning control with parallel positioning, 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.

The other method of control of combustion air volume is by measuring the flue gas oxygen concentration to optimize combustion efficiency. This method of control commonly called is oxygen trim control and can provide higher levels of efficiency than parallel positioning controls as it can also account for relative humidity of the combustion air. 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 proportional-integral-derivative (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.

4.3 Ventilation and Indoor Air Quality Requirements

§120.1

All of the ventilation and indoor air quality requirements are mandatory measures. Some measures require acceptance testing, which is addressed in Chapter 13.

Within a building, all occupied space that is normally used by humans must be continuously ventilated during occupied hours with outdoor air, using either natural or mechanical ventilation as specified in §120.1(c). Ventilation requirements for healthcare facilities should conform to the requirements in Chapter 4 of the California Mechanical Code.

Attached dwelling units in high-rise residential buildings are subject to the requirements of §120.1(b) while all other occupied spaces in a high-rise residential building are subject to the requirements of §120.1(c). The requirements of §120.1(b)2 are based on ASHRAE Standard 62.2, "Ventilation and Acceptable Indoor Air Quality in Residential Buildings" with certain amendments.

"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 that do not have any unusual sources of air contaminants do not need to be directly ventilated. For example:

- A closet, provided it is not normally occupied
- A storeroom that is only infrequently or briefly occupied. 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 minimum ventilation must be provided throughout the entire occupied period. Meaning variable air volume (VAV) systems must provide the code-required ventilation over the full range of operating supply airflow. Some means of dynamically controlling the minimum ventilation air must be provided.

For dwelling units' subject to ASHRAE 62.2 requirements, the mechanical ventilation system must operate as designed in order for the dwelling to be in compliance. The ventilation system must be verified in accordance with the applicable procedures in NA2.2. When supply or exhaust systems are used, the dwelling unit enclosure leakage must be verified in accordance with the procedures in NA2.3.

4.3.1 Air Filtration

§120.1(b)1 and (c)1

Occupied spaces may be subjected to poor indoor air quality if poor quality outdoor air is brought in without first being cleaned. Particles less than 2.5 µm are referred to as "fine" particles, and because of their small size, can lodge deeply into the lungs. There is a strong correlation between exposure to fine particles and premature mortality. Other effects of particulate matter exposure include respiratory and cardiovascular disease. Because of these adverse health effects, advances in filtration technology and market availability, removal of fine particulate contaminants by use of filtration is reasonable and achievable. The Energy Standards require that filters have a particle removal efficiency equal to or greater than the minimum efficiency reporting value (MERV) 13 when tested in accordance with ASHRAE Standard 52.2, or a particle size efficiency rating equal to or greater than 50 percent in the 0.3-1.0 µm and 85 percent in the 1.0-3.0 µm range when tested in accordance with AHRI Standard 680.

The following system types are required to provide air filtration:

a. Mechanical space conditioning (heating or cooling) systems that utilize forced air ducts greater than 10 feet in length to supply air to an occupied space. The total is determined by summing the lengths of all the supply and return ducts for the force air system.
b. Mechanical supply-only ventilation systems that provide outside air to an occupied space.
c. The supply side of mechanical balanced ventilation systems, including heat recovery ventilator and energy recovery ventilators that provide outside air to an occupied space.

4.3.1.1 Air Filter Requirements for Space Conditioning Systems in High-Rise Residential Dwelling Units

Space conditioning systems in high-rise residential dwelling units may use either of the two following compliance approaches:

a. Install a filter grille or accessible filter rack that accommodates a minimum 2 inch depth filter, and install the appropriate filter.

b. Install a filter grille or accessible filter rack that accommodates a minimum 1 inch depth filter, and install the appropriate filter. The filter/grille must be sized for a velocity of less than or equal to 150 feet (ft) per minute. The installed filter must be labeled to indicate the pressure drop across the filter at the design airflow rate for that return is less than or equal to 0.1 inch water column (w.c.) (25 PA).

   Use the following method to calculate the 1 inch depth filter face area required: Divide the design airflow rate (ft^3/ min) for the filter grille/rack by the maximum allowed face velocity 150 ft per min. This yields a value for the face area in square feet (sq ft). Since air filters are sold using nominal sizes in terms of inches, convert the face area to sq inches by multiplying the face area (sq ft) by a conversion factor of 144 sq inches by sq ft. Summarizing:

Equation 4-7

$$\text{Filter Nominal Face Area (sq inch)} = \text{airflow (cu ft per minute [CFM])} \div 150 \times 144$$

Air Filter Requirements for Ventilation Systems in High-Rise Residential Dwelling Units

Ventilation system filters in high-rise residential dwelling units must conform to the following requirements:

a. Filters with a depth of 1 inch or greater are allowed

b. The design airflow rate and maximum allowable clean-filter pressure drop at the design airflow rate applicable to each air filter device must be determined by the system designer or installer.

c. The ventilation systems must deliver the volume of air specified by §120.1(b) with filters in place as verified by field verification and diagnostic testing in accordance with the procedures in NA1, and NA2.2.

4.3.1.2 Air Filter Requirements for Space Conditioning Systems and Ventilation Systems in Nonresidential and Hotel/Motel Buildings

Space conditioning systems and ventilation systems in nonresidential and hotel/motel occupancies may use either of the two following compliance approaches:

a. Install a filter grille or accessible filter rack sized by the system designer that accommodates a minimum 2 inch depth filter, and install the appropriate filter.

b. Install a filter grille or accessible filter rack that accommodates a minimum 1 inch depth filter, and install the appropriate filter. The filter/grille must be sized for a velocity of less than or equal to 150 ft per minute. The installed filter must be labeled to indicate the pressure drop across the filter at the design airflow rate for that return is less than or equal to 0.1 inch w.c. (25 PA).

   Use the following method to calculate the 1 inch per min. This yields a value for the face area in sq ft. Since air filters are sold using nominal sizes in terms of inches, convert the face area to sq in by multiplying the face area (sq ft) by a conversion factor of 144 sq inch/sq ft. Refer also to Equation 4-7 above.

Field verification and diagnostic testing of system airflow in accordance with the procedures in NA1 (HERS verification) is not required for nonresidential and hotel/motel occupancies.

4.3.1.3 Air Filter Compliance for High-Rise Residential Dwelling Units

§120.1(b)1

Standards Section 120.1(b)1D requires all systems to be designed to accommodate the clean-filter pressure drop imposed by the system air filter device(s). This applies to space conditioning systems and to the ventilation system types described in Section 4.3.1.1 and 4.3.1.2 above. A designer or installer must determine the design airflow rate and maximum allowable clean-filter pressure drop. It must then be posted by the installer on a sticker or label inside the filter grille or near the filter rack, according to Section 4.3.1.3.2 below.

Designers of space conditioning systems must determine the total of the system external static pressure losses from filters, coils, ducts, and grilles, such that the sum is not greater than the air handling unit's available static pressure at the design airflow rate. Therefore, air filters should be sized to minimize static pressure drop across the filter during system operation.

4.3.1.3.1 Factors that Affect Air Filter Pressure Drop

Air filter pressure drop can be reduced by increasing the amount of air filter media surface area available to the system’s airflow. Increased media surface area can be accomplished by adjusting one, two, or three of the following factors:

a. **Adjust the number of pleats of media per inch inside the air filter frame.** The number of pleats per inch inside the filter frame is determined by the manufacturer’s filter model design, and is held constant for all filter sizes of the same manufacturer’s model. For example, all 3M Filtrete 1900 filters will have the same media type, the same MERV rating, and the same number of pleats of media per inch inside the filter frame, regardless of the nominal filter size (20 inches by 30 inches or 24 inches by 24 inches, etc.). Generally, as the number of pleats per inch is increased, the pressure drop is reduced, if all other factors remain constant. The pressure drop characteristics of air filters vary widely between air filter manufacturers and between air filter models, largely due to the number of pleats per inch in the manufacturer’s air filter model design. System designers and system owners cannot change the manufacturer's filter model characteristics. They can select a superior air filter model from a manufacturer that provides greater airflow at a lower pressure drop by comparing the filter pressure drop performance shown on the air filter manufacturer's product label (see example label in Figure 4-3).

b. **Adjust the face area of the air filter and filter grille.** Face area is the nominal cross-sectional area of the air filter, perpendicular to the direction of the airflow through the filter. Face area is also the area of the filter grille opening in the ceiling or wall. The face area is determined by multiplying the length times width of the filter face (or filter grille opening). The nominal face area for a filter corresponds to the nominal face area of the filter grille in which the filter is installed. For example, a nominal 20 inch by 30 inch filter has a face area of 600 sq inches and would be installed in a nominal 20 inch by 30 inch filter grille. Generally, as the total system air filter face area increases, the pressure drop is reduced if all other factors remain constant. Total system air filter face area can be increased by specifying a larger area filter/grille, or by using additional/multiple return filters/grilles, summing the face areas. The filter face area is specified by the system designer or installer.

c. **Adjust the depth of the filter and filter grille.** Air filter depth is the nominal filter dimension parallel to the direction of the airflow through the filter. Nominal filter depths readily available for purchase include one, two, four, and six inches. Generally, as the system air filter depth increases, the pressure drop is reduced if all other factors remain constant. For example, increasing filter depth from one inch to two inches nominally doubles the filter media surface area without increasing the filter face area. The filter depth is specified by the system designer or installer.

4.3.1.3.2 Filter Access and Filter Grille Sticker - Design Airflow and Pressure Drop

All filters must be accessible to facilitate replacement.

a. **Air filter grille sticker**. A designer or installer must determine the design airflow rate and maximum allowable clean-filter pressure drop. It must then be posted by the installer on a sticker inside or near the filter grille/rack. The design airflow and initial resistance posted on this sticker should correspond to the conditions used in the system design calculations. This requirement applies to space conditioning systems and also to the ventilation system types described in Sections 4.3.1.1 and 4.3.1.2 above.

   An example of an air filter grille sticker showing the design airflow and pressure drop for the filter grille/rack is shown in Figure 4-2.

b. **Air filter manufacturer label.** Space conditioning system filters are required to be labelled by the manufacturer to indicate the pressure drop across the filter at several airflow rates. The manufacturer's air filter label (see Figure 4-3) must display information that indicates the filter can meet the design airflow rate for that return grille/rack at a pressure drop less than or equal to the value shown on the installer's

Figure 4-2: Example of Installer's Filter Grille Sticker

Air Filter Performance Requirement		Maintenance Instructions
Airflow Rate (CFM) Must be greater than or equal to the value shown	**Initial Resistance (IWC)** Must be less than or equal to the value shown	Use only replacement filters that are rated to simultaneously meet both of the performance requirements specified on this sticker.
750	0.1	

Source: California Energy Commission

Figure 4-3: Example Manufacturer's Filter Label

MERV	(µm)	0.30-1.0	1.0-3.0	3.0-10	Airflow Rate (CFM)	615	925	1230	1540	2085*	*Max Rated Airflow
13	PSE (%)	62	87	95	Initial Resistance (IWC)	0.07	0.13	0.18	0.25	0.38	

Source: California Energy Commission

4.3.1.3.3 Air Filter Selection

In order for a filter to meet the system's specifications for airflow and pressure drop, it must be rated by the manufacturer to simultaneously provide more than the specified airflow at less than the specified pressure drop. It is unlikely that a filter will be available that is rated to have the exact airflow and pressure drop ratings specified, so filters should be selected that are rated to have less than the specified pressure drop at the specified airflow rate, otherwise select filters that are rated to have greater than the specified airflow rate at the specified pressure drop. See Figure 4-4 for an example of an installer's filter grille sticker that provides an air filter rating specification for minimum airflow of 750 cfm at maximum pressure drop 0.1 inch w.c..

Air filter manufacturers may make supplementary product information available to consumers to assist with selecting the proper replacement filters. This product information may provide more detailed information about their filter model airflow and pressure drop performance - details such as airflow and pressure drop values that are intermediate values that lie between the values shown on their product label. The information may be published in tables, graphs, or presented in software applications available on the internet or at the point of sale.

Figure 4-4 below shows a graphical representation of the initial resistance (pressure drop) and airflow rate ordered pairs given on the example air filter manufacturer's label shown in Figure 4-3 above. The graph in Figure 4-4 makes it possible to visually determine the airflow rate at 0.1 inch w.c. pressure drop for which the values are not shown on the manufacturer's filter label.

If there is no supplementary manufacturer information available and it is necessary to determine a filter model's performance at an airflow rate or pressure drop, linear interpolation may be used. Example formulas for are shown below.

This method may be used to determine an unknown pressure drop corresponding to a known airflow rate by use of Equation 4-8a, or it may also be used to determine an unknown airflow rate corresponding to a known pressure drop by use of Equation 4-8b.

$$p = p_1 + [(f-f_1) \div (f_2-f_1)] \times (p_2 - p_1)$$ Equation 4-8a

where:

f = a known flow value between f_1 and f_2

p = the unknown pressure drop value corresponding to f

p_1 and p_2 = known values that are less than and greater than p respectively

f_1 and f_2 are the known values corresponding to p_1 and p_2

$$f = f_1 + [(p-p_1) \div (p_2-p_1)] \times (f_2 - f_1)$$ Equation 4-8b

where:

p = a known pressure drop value between p_1 and p_2

f = the unknown flow value corresponding to p

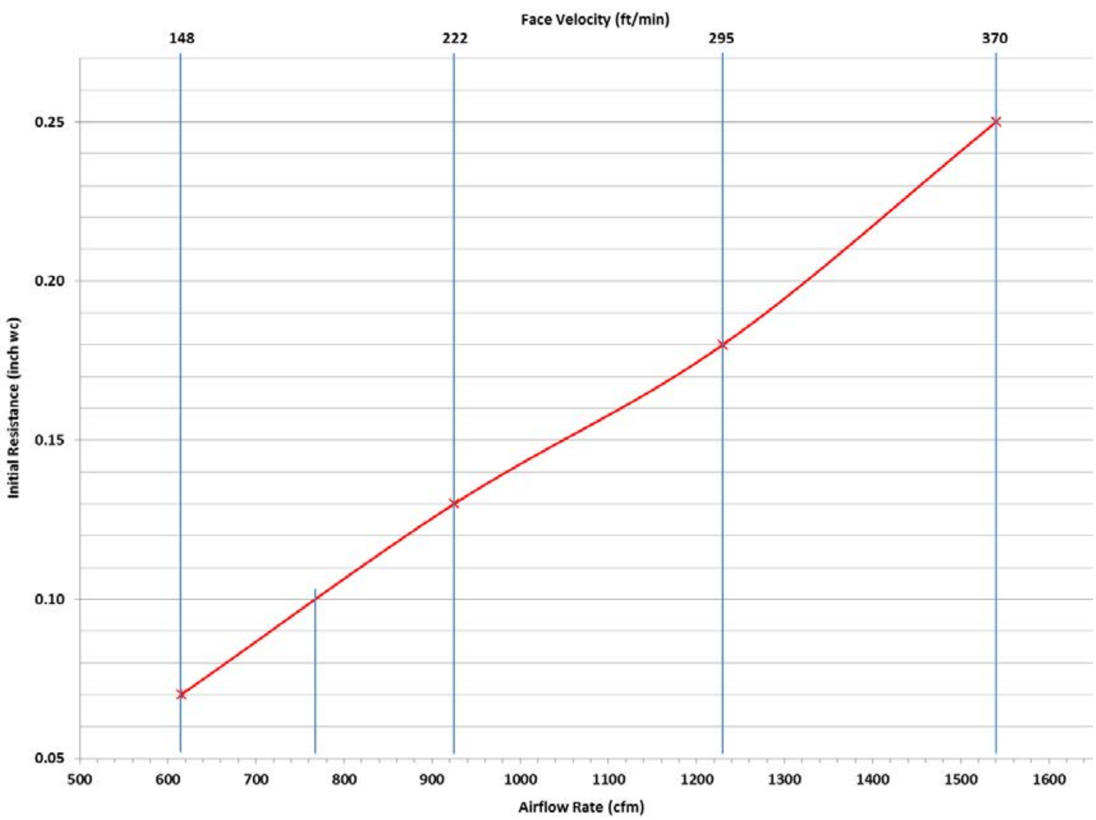
f_1 and f_2 = known values that are less than and greater than f respectively

p_1 and p_2 are the known values corresponding to f_1 and f_2

See Example 4-7 for sample calculations that determine the filter's rated airflow corresponding to a known pressure drop specification (0.1 inch w.c.).

Figure 4-4: Plot of Pressure Drop vs. Airflow for a 20" X 30" X 1" Depth Air Filter

From Manufacturer Label Information



Source: California Energy Commission

Example 4-7: Filter Selection Using Linear Interpolation

Question

Does the air filter label in Figure 4-3 indicate the filter would meet the airflow (750 cfm) and pressure drop (0.1 inch w.c.) requirements shown on the installer filter grille sticker in figure 4-2? How the airflow rate at 0.1 inch w.c. for the manufacturer's filter label shown in Figure 4-3 be determined?

Answer

The filter must be rated to provide greater than 750 cfm at the specified 0.1 inch w.c. pressure drop, or equivalently: the filter must be rated to provide a pressure drop less than 0.1 inch w.c at the specified 750 cfm.

Referring to equation 4-8b, calculate the unknown value "f" in cfm that corresponds to the known value "p" of 0.1 inch w.c..

Referring to Figure 4-4: p_1=0.7, p_2=0.13, f_1=615, f_2=925, and applying Equation 4-8b:

615 + [(0.1-0.07) ÷ (0.13-0.07)] x (925-615) yields 770 cfm

Therefore, since the filter is rated for greater than 750 cfm at 0.1 inch w.c, the filter complies.

Example 4-8: Filter Sizing

Question

A 1,200 cfm furnace is being installed in a new dwelling unit. It has a 20" x 20" x 1” inch filter rack furnished with a 1 inch depth filter installed in the unit. Is this filter in compliance?

Answer

The nominal face area of the filter rack is 20 inches by 20 inches to equal 400 sq in and since it is a 1 inch filter, the face area may not be less than 1200 (cfm)/150 (ft/min) x144 (in^2 / ft^2) = 1,152 sq in. Therefore, this filter installation does not comply.

Example 4-9

Question

For the same 1200 cfm furnace, what other options are there?

Answer:

The filter will be in compliance if it has a depth of 2” or more, and is properly sized by the system designer such that the duct system as a whole will be capable of meeting the HERS verification for fan efficacy specified in Section 150.0(m)13.

Otherwise, the required total system filter face area of 1,152 sq inches must be met using multiple remote wall or ceiling filter grilles for which the sum of the face areas are equal to or greater than 1152 sq inches, and the filters must be rated for pressure drop of 0.1 inch w.c. or less at the design airflow rates of each filter grille.

For any filter, the pressure drop, efficiency, and length of time the filter can remain in operation without becoming fully loaded with dust can all be improved by using filters that are deeper than 1 inch. As the depth of the filter is increased, the pressure drop across the filter at the same face area will be greatly reduced.

Example 4-10

Question

A ductless split system is being installed in a home. Must a designated MERV 13 filter be used?

Answer

No, the filtration requirements do not apply unless there is at least 10 feet of duct is attached to the unit.

Example 4-11

Question

If a customer has allergies and wants a MERV 16 or better filter. Is this in compliance?

Answer

Yes, a filtration greater than MERV 13 meets (exceeds) the minimum particle removal efficiency requirement, thus may be used provided all other applicable requirements in 120.1(b)1 are complied with.

4.3.2 High-Rise Residential Dwelling Unit Mechanical Ventilation

§120.1(b)2

This section will cover compliance and enforcement, typical design solutions, energy consumption issues, and the requirements specified by ASHRAE 62.2 as amended in the 2019 Energy Standards. The key changes from 2016 to 2019, applicable to high-rise residential dwelling units, of ASHRAE 62.2 and Title 24 Part 6 amendments to 62.2 include:

a. ASHRAE 62.2 now covers mid-rise and high-rise residential occupancies as well as single-family detached and low-rise attached multifamily dwellings.

b. Compliance with required dwelling unit ventilation using *variable* mechanical ventilation systems (intermittent or variable operation) requires the average mechanical ventilation rate (in cfm) over a three-hour period to be greater than or equal to the ventilation rate used for continuous ventilation. More complicated control strategies may be used if the system operation complies with the “relative exposure” calculations in normative Appendix C of ASHRAE 62.2.

c. Two options for compliance with dwelling unit ventilation are allowed for multifamily attached dwelling units: (1) installation of a balanced ventilation system, or (2) installation of an exhaust or supply-only system accompanied by sealing to a leakage rate of not more than 0.3 cfm 50 per sq. ft. of dwelling unit enclosure surface area. Home Energy Rating System (HERS) verification of dwelling unit ventilation and any applicable envelope leakage is required in accordance with NA1 and NA2 procedures. Certified Acceptance Test Technicians (ATT) may perform these field verifications only if the Acceptance Test Technician Certification Provider (ATTCP) has been approved to provide this service.

d. Kitchen range hood fans are now required to be verified by a HERS rater. The new verification protocol requires comparing the installed model to ratings in the HVI directory of certified ventilation products to confirm the installed range hood is rated to meet the required airflow and sound requirements specified in ASHRAE 62.2. Kitchen range hood fans that exhaust more than 400 cfm at their minimum speed are exempt from this requirement. Kitchen range hoods are required to discharge the exhaust airflow to outside. Recirculation range hood types are not allowed.

Compliance with the dwelling unit ventilation airflow specified in ASHRAE 62.2 is required in new dwelling units. Alterations to components of existing buildings that previously met any requirements of ASHRAE 62.2 must continue to meet requirements upon completion of the alteration(s).

4.3.2.1 Key Requirements for Most Newly Constructed Buildings

a. A dwelling unit mechanical ventilation system shall be provided. Typical solutions are described in Section 4.3.2.5 below. The airflow rate provided by the system shall be confirmed through field verification and diagnostic testing in accordance with the applicable procedures specified in Reference Nonresidential Appendix NA2.2.

b. Kitchens and bathrooms shall have local exhaust fans vented to outdoors.

c. Clothes dryers shall be vented to outdoors.

4.3.2.2 Other Indoor Air Quality Design Requirements

a. Ventilation air shall come from outdoors. It should not be transferred from adjacent dwelling units, garages, unconditioned attics or crawl spaces.

b. Ventilation system controls should be labeled. The dwelling occupant should be provided with instructions on how to operate the system.

c. Combustion appliances should be properly vented. Exhaust systems should be designed to prevent back drafting.

d. Walls and openings between the dwelling and a garage should be sealed or gasketed.

e. Habitable rooms should have windows with an opening ventilation area of at least 4 percent of the floor area.

f. Mechanical systems including heating and air-conditioning systems that supply air to habitable spaces shall have MERV 13 filters or better and be designed to accommodate the system's air filter's rated pressure drop at the system's design airflow rate.

g. Dedicated air inlets (not exhaust) that are part of the ventilation system design should be located away from known sources of outdoor contaminants.

h. A carbon monoxide alarm should be installed in each dwelling unit in accordance with NFPA Standard 720.

4.3.2.3 Air-Moving Equipment Requirements

Air-moving equipment used to meet the dwelling unit ventilation requirement and the local ventilation exhaust requirement should be rated in terms of airflow and sound:

a. Dwelling unit ventilation and continuously operating local exhaust fans must be rated at a maximum of 1.0 sone.

b. Demand controlled local exhaust fans must be rated at a maximum of 3.0 sone.

c. Kitchen range hood fans must be rated at a maximum of 3.0 sone at one or more airflow settings greater than or equal to 100 cfm.

d. Remotely located air-moving equipment (mounted outside habitable spaces) are exempt from the sound requirements provided there is at least four feet of ductwork between the fan and the interior grille.

4.3.2.4 Compliance and Enforcement

Compliance with ASHRAE 62.2 requirements must be verified by the enforcement agency, except for the following requirements that must be HERS verified in accordance with the procedures in Nonresidential Appendix NA1 and NA2.2:

a. Dwelling unit ventilation airflow rate

b. HVI ratings for kitchen range hood fans

All applicable certificates of compliance, installation, and acceptance need be completed before the certificate of verification must be registered with an approved HERS provider.

4.3.2.5 Typical Solutions for Multifamily Dwelling Unit Ventilation

4.3.2.5.1 System Types

There are generally three system types available for meeting the dwelling unit ventilation requirement (refer to Residential Compliance Manual Section 4.6.2 for descriptions of the system types identified below):

a. Exhaust ventilation - air is exhausted from the dwelling unit and replaced by infiltration.

b. Supply ventilation - outdoor air is supplied directly to the dwelling unit after being filtered.

c. Balanced ventilation – may be a single packaged unit containing supply and exhaust fans that moves approximately the same airflow through a heat or energy recovery core, or may utilize separate fans without heat exchange. In both cases air supplied from outdoors must be filtered (see Section 4.3.1 for air filter requirements).

Exhaust and balanced systems are most frequently used in multifamily buildings, but supply ventilation may also be used. Exhaust (or supply) systems in low-rise buildings typically use individual fans located in the dwelling units that exhaust directly to outdoors.

4.3.2.5.2 Multifamily Building Central Shaft Ventilation Systems

Use of central ventilation fans/shafts that are shared with multiple dwelling units in the building are more common in mid-rise and high-rise buildings. When a supply or exhaust system provides dwelling unit ventilation to more than one dwelling unit, the airflows in each dwelling unit must be equal to or greater than the required (minimum) ventilation rate, and the airflows for each dwelling unit must also be balanced to be no more than 20 percent greater than the specified rate (see Standards Section 120.1(b)2Av). The specified rate for the systems that share a common fan/shaft may be the minimum rate required for compliance, in which case each of the dwellings receiving airflow from a common fan/shaft must have ventilation airflow no more than 20 percent greater than the minimum dwelling unit ventilation airflow required by Equation 120.1-B. If the lowest airflow provided to any of the dwellings served by the common fan/shaft is a specific percent value greater than the minimum required for compliance, then the each of the dwellings receiving airflow from that common fan/shaft must have ventilation airflow no more than 20 percent greater than that lowest dwelling unit ventilation airflow. For example, if the lowest ventilation airflow among all dwellings served by the common fan/shaft is 2 percent greater than the minimum required for compliance, then all dwellings served by the common fan/shaft must be balanced to have ventilation airflow that is no more than 22 percent greater than the minimum ventilation airflow required for compliance.

These systems must utilize balancing devices to ensure the dwelling-unit airflows can be adjusted to meet this balancing requirement. These system balancing devices may include but are not limited to constant air regulation devices, orifice plates, and variable speed central fans.

Since supply and exhaust ventilation system types are required to operate continuously in multifamily dwellings (see Section 120.1(b)2Aivb2), and since Central Fan Integrated (CFI) systems are prohibited from operating continuously to provide the required dwelling unit ventilation (see Section 120.1(b)2Aii, the CFI ventilation system type is not allowed to be used in multifamily dwellings. Refer to residential compliance manual Section 4.6.2.3 for descriptions of the CFI ventilation system type. Certified Acceptance Test Technicians (ATT) may perform these field verifications only if the Acceptance Test Technician Certification Provider (ATTCP) has been approved to provide this service.

4.3.2.5.3 Multifamily Dwelling Unit Compartmentalization – Reducing Dwelling Unit Enclosure Leakage

Transfer air is the airflow between adjacent dwelling units in a multifamily building, which can be a major contributor to poor indoor air quality in the dwelling units. Transfer airflow is caused by differences in pressure between adjacent dwelling units, which forces air to flow through leaks in the dwelling unit enclosure. The pressure differences may be due to stack effects and wind effects, but unbalanced mechanical ventilation is also a major contributor to this problem. It is desirable to minimize or eliminate leaks in all of the dwelling enclosures in the building – to compartmentalize the dwellings - to prevent pollutants such as tobacco smoke, pollution generated from food preparation in the kitchen, odors, and other pollutants from being transferred to adjacent dwellings in the building.

Title 24 provides two compliance paths for mechanical ventilation that improve compartmentalization in multifamily buildings (choose one):

a. Install a balanced ventilation system. This may consist of either a single ventilation unit such as an energy recovery ventilator or heat recovery ventilation (HRV), or may consist of separate supply and exhaust fans that operate simultaneously and are controlled to balance the supply and exhaust airflows. The outdoor ventilation supply air must be filtered (MERV 13 or better).

b. Verify that the dwelling unit leakage is not greater than 0.3 cfm per sq. ft of dwelling unit enclosure area using the procedures in NA2.3 (blower door test). If the dwelling unit enclosure passes this blower door test, use of continuously operating supply ventilation systems, or continuously operating exhaust ventilation systems in that dwelling is allowed.

4.3.2.5.4 Dwelling Unit Ventilation Airflow Measurement

Nonresidential Appendix NA2.2.4 provides direction for measurement of supply, exhaust, and balanced system types. These measurement procedures are applicable when there is a fixed airflow rate required for compliance, such as for systems that operate continuously at a specific airflow rate or systems that operate intermittently at a fixed speed (averaged over any three-hour period), according to a fixed timer pattern for which the programmed pattern is verifiable by a HERS rater on site (Refer to ASHRAE 62.2 Section 4.5.1 Short Term Average Ventilation).

Variable or intermittent operation that complies with ASHRAE 62.2 Sections 4.5.2, and 4.5.3 complies with the dwelling unit mechanical ventilation requirements by use of varying ventilation airflow rates based on complicated calculations for relative exposure as specified in ASHRAE 62.2 normative appendix C. These calculation procedures provide the basis for "smart" ventilation controls implemented by use of digital controls that rely on the manufacturer's product-specific algorithms or software. Any ventilation system models that use these complex ventilation system controls in a ventilation product designed to be used to comply with Energy Standards Section 120.1 must submit an application to the Energy Commission to have the ventilation technology approved. These manufacturers are expected to provide with their applications, evidence that the system will perform to provide the required dwelling unit mechanical ventilation, and also provide a method that could be used by a HERS rater to verify that an installed system is operating as designed.

Listings of systems approved by the Energy Commission and certified by the manufacturer are located at the following URL:

http://www.energy.ca.gov/title24/equipment_cert/imv/

4.3.2.5.5 Dwelling Unit Ventilation Rate (Section 4 of ASHRAE 62.2)

Dwelling unit ventilation systems may operate continuously or on a short-term basis. If fan operation is not continuous, the average ventilation rate over any three-hour period must be greater than or equal to the Q_{tot} value calculated using Equation 4-9 in this section.

ASHRAE 62.2 provides for scheduled ventilation and real time control, but these control approaches require “equivalent exposure” calculations using methods in Normative Appendix C and complex controls would be required to operate the fan.

Use of a building infiltration credit is not applicable to calculation of the required dwelling unit mechanical ventilation for multifamily dwelling units.

When the performance compliance approach is used, the compliance software automatically calculates the ventilation rate based on Equations 4-9, and Q_{tot} is reported on the NRCC-PRF-01-E.

4.3.2.5.6 Total Ventilation Rate (Q_{tot})

The total ventilation rate is the combined volume of ventilation air provided by infiltration and the mechanical ventilation provided from fans, as follows:

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1)$$ *Equation 4-9*

Where:

Q_{tot} = total required ventilation rate (cfm)

A_{floor} = conditioned floor area (ft^2)

N_{br} = number of bedrooms (not less than one)

For multifamily units, the installed ventilation system must deliver the total ventilation rate Q_{tot} calculated from Equation 4-9.

Example 4-12: Required Ventilation

Question

What is the required continuous ventilation rate for a three-bedroom, 1,800 sq. ft. dwelling unit?

Answer:

Equation 4-9 yields a total ventilation rate of 84 cfm

$$Q_{tot} = 0.03A_{floor} + 7.5(N_{br} + 1) = 0.03(1800) + 7.5(3 + 1) = 84 \text{ cfm}$$

Example 4-13

Question

An HRV that delivers 80 cfm of outdoor air and exhausts 90 cfm of indoor air is being installed. The dwelling is required to have 86 cfm of ventilation airflow. Can this system be used?

Answer:

No. For balanced systems the supply and exhaust airflows can be averaged, and in this case, they average 85 cfm, which is slightly less than required 86 cfm.

The nominal rating of a fan can be very different than what it actually delivers when installed and connected to ductwork. Designers should always include some safety margin when sizing equipment. The length and size of ducting should be used to calculate the pressure drop. This is why dwelling unit ventilation rates must be verified by a HERS rater.

Example 4-14

Question

A 2,300 sq. ft. dwelling unit has exhaust fans running continuously in two bathrooms providing a total exhaust flow rate of 90 cfm, but the requirement is 98 cfm. What are the options for providing the additional 8 cfm?

Answer:

The required additional cfm could be provided either by increasing the size of either or both exhaust fans such that the combined airflow exceeds 98 cfm. Some fan models have speed adjustments which allow adjusting the fan airflow in the field after installation.

Example 4-15

Question

A builder wants to provide controls that disable the ventilation system so it does not bring in outside air during the hottest two hours of the day. Equation 4-9 determined the system needs to be 80 cfm continuous. How large must the fan be?

Answer:

If the average rate over three hours is 80 cfm and the fan only operates one hour, then it must be capable of delivering 3 x 80 = 240 cfm. ASHRAE 62.2 does not allow averaging ventilation over more than a three-hour period.

4.3.2.6 Control and Operation

From ASHRAE 62.2, Section 4.4, Control and Operation. A readily accessible manual on/off control, including but not limited to a fan switch or a dedicated branch-circuit overcurrent device, shall be provided. Controls shall include text or an icon indicating the system's function.

Exception: For multifamily dwelling units, the manual on/off control shall not be required to be readily accessible.

From Standards Section 150.0(o)1I: Compliance with ASHRAE 62.2 Section 4.4 (Control and Operation) shall require manual switches associated with dwelling unit ventilation systems to have a label clearly displaying the following text, or equivalent text: "This switch controls the indoor air quality ventilation for the home. Leave it on unless the outdoor air quality is very poor."

ASHRAE 62.2 requires that the ventilation system have an override control that is accessible to the occupants. The control must be capable of being accessed quickly and easily by the occupants. It can be a labeled wall switch, a circuit breaker located in the electrical panel, or it may be integrated into a labeled wall-mounted control. It cannot be buried in the insulation in the attic or inside the installed ventilation fan cabinet. The dwelling unit occupant must have easy access to modify the fan control settings or turn off the system if necessary.

For multifamily dwelling units, the manual on/off control is not required to be readily accessible to the dwelling unit occupant(s). Instead, the ventilation control may be located such that it is readily accessible to the person in charge of the multifamily building maintenance. This control strategy may be appropriate for multifamily buildings that use unbalanced (supply-only or exhaust-only) system types for which the Energy Standards require that all of the ventilation systems in the building operate continuously. Continuous operation of all ventilation fans in the building tends to minimize ventilation fan-induced pressure differences between adjoining dwellings, thus to reduce the leakage of transfer air between dwelling units. Transfer airflows that that originate in one dwelling unit may adversely affect the indoor air quality of the other dwelling units in the building if the transfer air contains pollutants such as tobacco smoke and PM2.5 from kitchen range cooking activities.

Balanced dwelling unit ventilation systems may operate continuously. If fan operation is not continuous, the average ventilation rate over any three-hour period must be greater than or equal to the minimum dwelling unit ventilation rate calculated by Equation 4-9 above.

Bathroom exhaust fans may serve a dual purpose to provide whole-dwelling unit ventilation operating at a low constant airflow rate, and also provide local demand controlled ventilation (DCV) at a higher "boost" airflow rate when needed. For these system types, the continuous whole-building airflow operation must have an on/off override which may be located in the bathroom or in a remote accessible location. The "boost" function is controlled by a separate wall switch located in the bathroom, or by a motion sensor or humidistat located in the bathroom.

Time-of-day timers or duty cycle timers can be used to control intermittent dwelling unit ventilation. Manual crank timers cannot be used, since the system must operate automatically without intervention by the occupant.

See Section 4.3.2.4.4 for additional information about Energy Commission approval of ventilation controls.

Example 4-16: Control Options

Question

A bathroom exhaust fan is used to provide dwelling unit ventilation. The fan is designed to be operated by a typical wall switch. Is a label on the wall plate necessary to comply with the requirement that controls be “appropriately labeled”?

Answer:

Yes. Since the fan is providing the required dwelling unit ventilation, a label is needed to inform the occupant that this switch controls the indoor air quality ventilation for the home, and directs the occupant to leave it on unless the outdoor air quality is very poor. If the exhaust fan were serving only the local exhaust requirement for the bathroom, then a label would not be required.

4.3.2.7 Local Exhaust (Section 5 of ASHRAE 62.2)

From ASHRAE 62.2,

5.1 Local Mechanical Exhaust. A local mechanical exhaust system shall be installed in each kitchen and bathroom. Nonenclosed kitchens shall be provided with a demand-controlled mechanical exhaust system meeting the requirements of Section 5.2. Each local ventilation system for all other kitchens and bathrooms shall be either one of the following two:

a. A demand-controlled mechanical exhaust system meeting the requirements of Section 5.2

b. A continuous mechanical exhaust system meeting the requirements of Section 5.3.

Exception: Alternative Ventilation. Other design methods may be used to provide the required exhaust rates when approved by a licensed design professional.

5.2 Demand-Controlled Mechanical Exhaust. A local mechanical exhaust system shall be designed to be operated as needed.

5.2.1 Control and Operation. Demand-controlled mechanical exhaust systems shall be provided with at least one of the following controls:

a. A readily accessible occupant-controlled on/off control.

b. An automatic control that does not impede occupant on control.

5.2.2 Ventilation Rate. The minimum airflow rating shall be at least the amount indicated in Table 5.1.

5.3 Continuous Mechanical Exhaust. A mechanical exhaust system shall be installed to operate continuously. The system may be part of a balanced mechanical system. See Chapter 10 of ASHRAE Guideline 24 for guidance on selection of methods.

5.3.1 Control and Operation. A readily accessible manual on/off control shall be provided for each continuous mechanical exhaust system. The system shall be designed to operate during all occupiable hours.

Exception: For multifamily dwelling units, the manual on/off control shall not be required to be readily accessible.

5.3.2 Ventilation Rate. The minimum delivered ventilation shall be at least the amount indicated in Table 5.2 during each hour of operation.

From ASHRAE 62.2 - Table 5-1 Demand-Controlled Local Ventilation Exhaust Airflow Rates

Application	Airflow
Enclosed Kitchen	• Vented range hood (including appliance-range hood combinations): 100 cfm (50 L/s) • Other kitchen exhaust fans, including downdraft: 300 cfm (150 L/s) or a capacity of 5 ach
Non-Enclosed Kitchen	• Vented range hood (including appliance-range hood combinations): 100 cfm (50 L/s) • Other kitchen exhaust fans, including downdraft: 300 cfm (150 L/s)
Bathroom	50 cfm (25 L/s)

From ASHRAE 62.2 - TABLE 5.2 Continuous Local Ventilation Exhaust Airflow Rates

Application	Airflow
Enclosed Kitchen	5 ach, based on kitchen volume
Bathroom	20 cfm (10 L/s)

Local exhaust (sometimes called *spot ventilation*) has long been required for bathrooms and kitchens to remove moisture and odors at their source. Building codes have required an operable window or an exhaust fan in bathrooms for many years and have generally required kitchen exhaust either directly through a fan or indirectly through a recirculating range hood and an operable window. The Energy Standards recognize the limitations of these indirect methods of reducing moisture and odors and requires that these spaces be mechanically exhausted directly outdoors, even if windows are present. Moisture condensation on indoor surfaces is a leading cause of mold and mildew in buildings. The occurrence of asthma is also associated with high interior relative humidity. Therefore, it is important to exhaust the excess moisture from bathing and cooking directly at the source.

The Energy Standards require that each kitchen and bathroom have an exhaust fan. Generally, this will be a dedicated exhaust fan in each room that requires local exhaust. Ventilation systems that exhaust air from multiple rooms using a duct system connected to a single exhaust fan are allowed as long as the minimum local exhaust requirement is met in all rooms served by the system. The standards define kitchens as any room containing cooking appliances. The definition of a bathroom is any room containing a bathtub, shower, spa, or other similar source of moisture. A room containing only a toilet is not required to have an exhaust fan; ASHRAE 62.2 assumes there is an adjacent bathroom with local exhaust.

Building codes may require that fans used for kitchen range hood exhaust ventilation be safety-rated by Underwriters Laboratories Inc. (UL) or some other testing agency for the particular location and/or application. Typically, these requirements address fire safety issues of fans placed within an area defined by a set of lines at 45 degrees F outward and upward from the cooktop. Few bathroom exhaust fans will have this rating, so cannot be used in these locations.

Example 4-17: Local Exhaust Required for Toilet

Question

A home is being built with 2.5 baths. The half-bath consists of a room with a toilet and sink. Is local exhaust required for the half bath?

Answer

No. Local exhaust is required only for bathrooms, which are defined by the Energy Standards as rooms with a bathtub, shower, spa or some other similar source of moisture. This does not include a simple sink for occasional hand washing.

Example 4-18

Question

The master bath suite in a dwelling has a bathroom with a shower, spa and sinks. The toilet is in a separate, adjacent room with a full door. Where do I need to install local exhaust fans?

Answer

The standards require local exhaust only in the bathroom, not the separate toilet room.

4.3.2.7.1 Demand-Controlled (Intermittent) Local Exhaust

The Energy Standards require that local exhaust fans be designed to be operated by the occupant. This usually means that a wall switch or some other control is accessible and obvious. There is no requirement to specify where the control or switch needs to be located, but bathroom exhaust fan controls are generally located next to the light switch, and kitchen exhaust fan controls are generally integrated into the range hood, mounted on the wall or counter adjacent to the range hood.

Bathrooms can use a variety of exhaust strategies. They can use ceiling-mounted exhaust fans or may use a remotely mounted fan ducted to two or more exhaust grilles. Demand-controlled local exhaust can be integrated with the dwelling unit ventilation system to provide both functions. Kitchens can have range hood exhaust fans, down-draft exhausts, ceiling- or wall-mounted exhaust fans, or pickups for remote-mounted inline exhaust fans. Generally, HVR/ energy recovery ventilator manufacturers do not allow exhaust ducting from the kitchen, because of the heat, moisture, grease, and particulates that should not enter the heat exchange core. Building codes require kitchen exhaust fans to be connected to metal ductwork for fire safety.

Example 4-19: Ducting Kitchen Exhaust to the Outdoors

Question

How does one know what kind of duct to use? If a builder is familiar with recirculating hoods and now needs to vent to outdoors, what should he or she look for?

Answer

A kitchen range hood or downdraft duct is generally a smooth metal duct that is sized to match the outlet of the ventilation device. It is often a six-inch or seven-inch-round duct, or the range hood may have a rectangular discharge. If it is rectangular, the fan will typically have a rectangular-to-round adapter included. Always use a terminal device on the roof or wall that is sized to be at least as large as the duct. Try to minimize the number of elbows used.

Example 4-20

Question

What are the requirements in a specific area?

Answer

Ask a local code enforcement agency for that information. Some enforcement agencies will accept metal flex, some will not.

4.3.2.7.2 Control and Operation for Intermittent Local Exhaust

The choice of control is left to the designer. It can be a manual switch or automatic control, like an occupancy sensor. Some exhaust fans have multiple speeds, and some fan controls have a delay-off function that operates the exhaust fan for a set time after the occupant leaves the bathroom. New control strategies continue to come to the market. The only requirement is that there is a control. Title 24, Part 11 may specify additional requirements for the control and operation of intermittent local exhaust.

4.3.2.7.3 Ventilation Rate for Demand-Controlled Local Exhaust

A minimum exhaust airflow of 100 cfm is required for vented kitchen range hoods, and 300 cfm or 5 ACH is required for other kitchen exhaust fans. A minimum exhaust airflow of 50 cfm is required for bathroom fans.

The 100 cfm requirement for the range hood or microwave/hood combination is the minimum to adequately capture the moisture, particulates, and other products of cooking and/or combustion. In kitchens that are enclosed, the exhaust requirement can also be met with either a ceiling or wall-mounted exhaust fan or with a ducted fan or ducted ventilation system that can provide at least five air changes of the kitchen volume per hour. Recirculating range hoods that do not exhaust pollutants to the outside cannot be used to meet the requirements of ASHRAE Standard 62.2 unless paired with an exhaust system that can provide at least five air changes of the kitchen volume per hour.

The Energy Standards require verification that range hoods are HVI certified to provide at least one speed setting at which they can deliver at least 100 cfm at a noise level of 3 sones or less. Verification must be in accordance with the procedures in Reference Nonresidential Appendix NA2.2.4.1.3. Range hoods that have a minimum airflow setting exceeding 400 cfm are exempt from the noise requirement. HVI listings are available at:

https://www.hvi.org/proddirectory/CPD_Reports/section_1/index.cfm

ASHRAE Standard 62.2 limits exhaust airflow when atmospherically vented combustion appliances are located inside the pressure boundary. This is particularly important to observe when large range hoods are installed. Refer to the Residential Compliance Manual Section 4.6.8.4 for more information.

Example 4-20: Ceiling or Wall Exhaust vs Demand-Controlled Range Hood in an Enclosed Kitchen

Question

A dwelling has an enclosed kitchen that is 12 ft. by 14 ft. with a 10 ft. ceiling. What size ceiling exhaust fan or range hood fan is required?

Answer

If a range hood exhaust is not used, either 300 cfm or 5 ACH minimum airflow is required. The kitchen volume is 12 ft. x 14 ft. x 10 ft. = 1680 ft^3. Five air changes are a flow rate of 1680 ft^3 x 5/ hr ÷ 60 min/hr = 140 cfm. This kitchen must have a ceiling or wall exhaust fan of 140 cfm. Otherwise a vented range hood fan that provides at least 100 cfm is required.

4.3.2.7.4 Continuous Local Exhaust

The Energy Standards allow the designer to install a local exhaust system that operates without occupant intervention continuously and automatically during all occupiable hours. Continuous local exhaust may be specified for compliance when the local exhaust ventilation system is also used to comply with the airflow rate required for continuous dwelling unit ventilation, as long as the fan airflow meets both the local and dwelling unit airflow rates. Continuous local exhaust may also be part of a pickup for a remote fan or HRV/ energy recovery ventilator system.

Continuously operating bathroom fans must operate at a minimum of 20 cfm. Continuously operating kitchen fans are only permitted for enclosed kitchens. Refer to Tables 5.1 and 5.2 in ASHRAE 62.2 (shown also in section 4.3.2.7 above) for other local demand controlled and continuous exhaust requirements.

Example 4-21: Continuous Kitchen Exhaust

Question

A new dwelling has an open-design, 12 ft by 18 ft ranch kitchen with 12 ft cathedral ceilings. What airflow rate will be required for a continuous exhaust fan?

Answer

A continuous exhaust fan cannot be used in non-enclosed kitchens. A vented range hood must be provided.

4.3.2.8 Other Requirements (Section 6 of ASHRAE 62.2)

See section 4.6.8 in the Residential Compliance Manual for additional information about other requirements from Section 6 of ASHRAE 62.2 that are adopted by Title 24, Part 6.

4.3.3 Natural Ventilation

§120.1(c)2

The 2019 Energy Standards changed the way naturally ventilated spaces are calculated by adopting ASHRAE 62.1. Under these new requirements, naturally ventilated spaces or portions of spaces must be permanently open to and within certain distances of operable wall openings to the outdoors. The space being ventilated, the size of the operable opening and the control of the opening are all considered under these new requirements. Naturally ventilated spaces must also include a mechanical ventilation system that complies with §120.1(c)3 as described in Section 4.3.3., except when the opening to the outdoors is permanently open or has controls that prevent the opening from being closed during periods of expected occupancy. This requirement for mechanical ventilation back-up to a naturally ventilated space protects the occupants from times or events where the outdoor air is not adequate for ventilation and does not rely on an individual to open the opening.

The space to be naturally ventilated is determined based on the configuration of the walls (cross-ventilation, single-sided or adjacent walls) and the ceiling height. For spaces with an operable opening on only one side of the space, only the floor area within two times the ceiling height from the opening is permitted to be naturally ventilated. For spaces with operable openings on two opposite sides of the space, only the floor areas within five times the ceiling height from the openings are permitted to be naturally ventilated. For spaces with operable openings on two adjacent sides of the space (two sides of a corner), only the floor areas along lines connecting the two openings that are within five times the ceiling height meet the requirement. Floor areas not along these lines connecting the windows must meet the one side or two opposite side opening calculation to be permitted to be naturally ventilated. The ceiling height for all of these cases is the minimum ceiling height, except for when the ceiling is sloped upwards from the opening. In that case, the ceiling height is calculated as the average within 20 feet of the opening.

Spaces or portions of space being naturally ventilated must be permanently open to operable walls openings directly to the outdoors. The minimum openable area is required to be 4 percent of the net occupiable floor area being naturally ventilated. Where openings are covered with louvers or otherwise obstructed, the openable area must be based on the free unobstructed area through the opening. Where interior spaces without direct openings to the outdoors are ventilated through adjoining rooms, the opening between rooms must be permanently unobstructed and have a free area of not less than 8 percent of the area of the interior room nor less than 25 sq. ft.

The means to open required operable openings must be readily accessible to building occupants whenever the space is occupied. The operable opening must be monitored to coordinate the operation of the operable opening and the mechanical ventilation system. This is achieved through window contact switches or another type of relay switch that interlocks the operable opening with the mechanical ventilation system. [§140.4(n)]

4.3.4 Mechanical Ventilation

§120.1(c)3

Mechanical outdoor ventilation must be provided for all spaces normally occupied. The Energy Standards require that a mechanical ventilation 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 (see 4.3.6 for updates to transfer air classification). 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.

The minimum outside air (OSA) as measured by acceptance testing, is required to be within 10 percent of the design minimum for both VAV and constant volume units. The design minimum outside air can be no less than the calculated minimum outside air

In summary:

1. Ventilation compliance at the space is satisfied by providing supply and/or transfer air.
2. Ventilation compliance at the air handling system level is satisfied by providing, at minimum, the outdoor air that represents the sum of the ventilation requirements of all the spaces 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 area outdoor air rate (R_a) from Table 4-12. This provides dilution for the building-borne contaminants like off-gassing of paints and carpets, or
2. For spaces designed for an expected number of occupants or spaces with fixed seating, the outdoor airflow rate to the zone must be 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 or as determined by the California Building Code.

Table 4-12: Minimum Ventilation Rates

Occupancy Category	Area Outdoor Air rate[1] R_a cfm/ft²	Min Air Rate for DCV[2] cfm/ft²	Air Class	Notes
Educational Facilities				
Daycare (through age 4)	0.21	0.15	2	
Daycare sickroom	0.15		3	
Classrooms (ages 5-8)	0.38	0.15	1	
Classrooms (age 9 -18)	0.38	0.15	1	
Lecture/postsecondary classroom	0.38	0.15	1	F
Lecture hall (fixed seats)	-	0.15	1	F
Art classroom	0.15		2	
Science laboratories	0.15		2	
University/college laboratories	0.15		2	
Wood/metal shop	0.15		2	
Computer lab	0.15		1	
Media center	0.15		1	A
Music/theater/dance	1.07*	0.15	1	F
Multiuse assembly	0.50	0.15	1	F
Food and Beverage Service				
Restaurant dining rooms	0.50	0.15	2	
Cafeteria/fast-food dining	0.50	0.15	2	
Bars, cocktail lounges	0.50	0.20	2	
Kitchen (cooking)	0.15		2	
General				
Break rooms	0.50	0.15	1	F
Coffee stations	0.50	0.15	1	F
Conference/meeting	0.50	0.15	1	F
Corridors	0.15		1	F
Occupiable storage rooms for liquids or gels	0.15		2	B
Hotels, Motels, Resorts, Dormitories				
Bedroom/living room	0.15		1	F
Barracks sleeping areas	0.15		1	F
Laundry rooms, central	0.15		2	
Laundry rooms within dwelling units	0.15		1	
Lobbies/pre-function	0.50	0.15	1	F
Multipurpose assembly	0.50		1	F

Occupancy Category	Area Outdoor Air Rate[1] R_a cfm/ft²	Min Air Rate for DCV[2] cfm/ft²	Air Class	Notes
Office Buildings				
Breakrooms	0.50	0.15	1	
Main entry lobbies	0.50	0.15	1	F
Occupiable storage rooms for dry materials	0.15		1	
Office space	0.15		1	F
Reception areas	0.15		1	F
Telephone/data entry	0.15		1	F
Miscellaneous Spaces				
Bank vaults/safe deposit	0.15		2	F
Banks or bank lobbies	0.15		1	F
Computer (not printing)	0.15		1	F
Freezer and refrigerated spaces (<50ºF)	-		2	E
General manufacturing (excludes heavy industrial and process using chemicals)	0.15		3	
Pharmacy (prep. Area)	0.15		2	
Photo studios	0.15		1	
Shipping/receiving	0.15		2	B
Sorting, packing, light assembly	0.15		2	
Telephone closets	0.15		1	
Transportation waiting	0.50	0.15	1	F
Warehouses	0.15		2	B
All others	0.15		2	
Public Assembly Spaces				
Auditorium seating area	1.07[a]	0.15	1	F
Places of religious worship	1.07[a]	0.15	1	F
Courtrooms	0.19[a]	0.15	1	F
Legislative chambers	0.19[a]	0.15	1	F
Libraries (reading rooms and stack areas)	0.15		1	
Lobbies	0.50	0.15	1	F
Museums (children's)	0.25	0.15	1	
Museums/galleries	0.25	0.15	1	F

Occupancy Category	Area Outdoor Air Rate[1] R_a cfm/ft²	Min Air Rate for DCV[2] cfm/ft²	Air Class	Notes
Residential				
Common corridors	0.15		1	F
Retail				
Sales (except as below)	0.25	0.20	2	
Mall common areas	0.25	0.15	1	F
Barbershop	0.40		2	
Beauty and nail salons	0.40		2	
Pet shops (animal areas)	0.25	0.15	2	
Supermarket	0.25	0.20	1	F
Coin-operated laundries	0.30		2	
Sports and Entertainment				
Gym, sports arena (play area)	0.50	0.15	2	E
Spectator areas	0.50	0.15	1	F
Swimming (pool)	0.15		2	C
Swimming (deck)	0.50	0.15	2	C
Disco/dance floors	1.50	0.15	2	F
Health club/aerobics room	0.15		2	
Health club/weight rooms	0.15		2	
Bowling alley (seating)	1.07	0.15	1	
Gambling casinos	0.68	0.15	1	
Game arcades	0.68	0.15	1	
Stages, studios	0.50	0.15	1	D, F

General notes:

[1] Ra was determined as being the larger of the area method and the default per person method. The occupant density used in the per person method was assumed to be one half of the maximum occupant load assumed for egress purposes in the California Building Code.

[2] If this column specifies a minimum cfm/ft² then it shall be used to comply with Section 120.1(d)4E.

Specific notes:

A – For high-school and college libraries, the values shown for "Public Assembly Spaces – Libraries" shall be used. B – Rate may not be sufficient where stored materials include those having potentially harmful emissions.

C – Rate does not allow for humidity control. "Deck area" refers to the area surrounding the pool that is capable of being wetted during pool use or when the pool is occupied. Deck area that is not expected to be wetted shall be designated as an occupancy category.

D – Rate does not include special exhaust for stage effects such as dry ice vapors and smoke.

E – Where combustion equipment is intended to be used on the playing surface or in the space, additional dilution ventilation, source control, or both shall be provided.

F – Ventilation air for this occupancy category shall be permitted to be reduced to zero when the space is in occupied-standby mode

Source: California Energy Commission, 2019 Building Energy Efficiency Standards, Table 120.1-A

As previously stated, each ventilation system must provide outdoor ventilation air as follows:

1. For a ventilation system serving a single space, the required system outdoor airflow is equal to the design outdoor ventilation rate of the space.
2. For a ventilation system serving multiple spaces, the required outdoor air quantity delivered by the 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 exact calculated outdoor air quantity. Instead, the supply air 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 ventilation 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.

Example 4-9: Ventilation for a Two-Room Building

Question

Consider a building with two spaces, each having an area of 1,000 sq ft. One space is used for general administrative functions, and the other is used as a classroom. It is estimated that the office will contain seven people, and the classroom will contain 50 people (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 0.38 cfm/ft² = 380 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 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 outside air = 900 cfm x (1,000 cfm / 2,500 cfm) = 360 cfm

Classroom outside air = 900 cfm x (1,500 cfm / 2,500 cfm) = 540 cfm

While this simplistic analysis suggests that the actual outside air 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.

4.1.1 Exhaust Ventilation

§120.1(c)4

The exhaust ventilation requirements are new for the 2019 Energy Standards. They are aligned with ASHRAE 62.1 and requires certain occupancy categories to be exhausted to the outdoors, as listed in Table 4-12. Exhaust flow rates must meet or exceed the minimum rates specified in 4-13. The spaces listed are expected to have contaminants not generally found in adjacent occupied spaces. Therefore, the air supplied to the space to replace the air exhausted may be any combination of outdoor air, recirculated air, and transfer air – all of which are expected to have low or zero concentration of the pollutants generated in the listed spaces. For example, the exhaust from a toilet room can draw air from either the outdoors, adjacent spaces, or from a return air duct or plenum. Because these sources of makeup air have essentially zero concentration of toilet-room odors, they are equally good at diluting odors in the toilet room.

The rates specified must be provided during all periods when the space is expected to be occupied, similar to the requirement for ventilation air.

Table 4-13: Minimum Exhaust Rates

Occupancy Category	Exhaust Rate (cfm/unit)	Exhaust Rate (cfm/ft^2)	Air Class	Notes
Arenas	-	0.50	1	B
Art classrooms	-	0.70	2	
Auto repair rooms	-	1.5	2	A
Barber shops	-	0.50	2	
Beauty and nail salons	-	0.60	2	
Cells with toilet	-	1.00	2	
Copy, printing rooms	-	0.50	2	
Darkrooms	-	1.00	2	
Educational science laboratories	-	1.00	2	
Janitor closets, trash rooms, recycling	-	1.00	3	
Kitchenettes	-	0.30	2	
Kitchens – commercial	-	0.70	2	
Locker rooms for athletic or industrial facilities	-	0.50	2	
All other locker rooms	-	0.25	2	
Shower rooms	20/50	-	2	G,H
Paint spray booths	-	-	4	F
Parking garages	-	0.75	2	C
Pet shops (animal areas)	-	0.90	2	
Refrigerating machinery rooms	-	-	3	F
Soiled laundry storage rooms	-	1.00	3	F
Storage rooms, chemical	-	1.50	4	F
Toilets – private	25/50	-	2	E
Toilets – public	50/70	-	2	D
Woodwork shop/classrooms	-	0.50	2	

Notes:
A – Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B – Where combustion equipment is intended to be used on the playing surface, additional dilution ventilation, source control, or both shall be provided.
C – Exhaust shall not be required where two or more sides comprise walls that are at least 50% open to the outside.
D – Rate is per water closet, urinal, or both. Provide the higher rate where periods of heavy use are expected to occur. The lower rate shall be permitted to be used otherwise.
E – Rate is for a toilet room intended to be occupied by one person at a time. For continuous systems operation during hours of use, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
F – See other applicable standards for exhaust rate.
G – For continuous system operation, the lower rate shall be permitted to be used. Otherwise the higher rate shall be used.
H – Rate is per showerhead.

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.1-B

4.1.2 Air Classification and Recirculation Limitations

§120.1(g)

New in the 2019 Energy Standards is the concept of air classification, a process that assigns an air class number based on the occupancy category then sets limits on transferring or recirculating that air. This offers designers clear guidance on what can and cannot be used for transfer, makeup or recirculation air. In previous Energy Standards transfer air was allowed as long as it did not have “unusual sources of indoor air contaminants,” which left the enforcement of this rule to be arbitrary. Now, all spaces listed in Table 4-12 are assigned an air class and specific direction is given for each class, which is in alignment with ASHRAE 62.1.

Class 1: This class consists of air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odor, suitable for recirculation or transfer to any space. Some examples include classrooms, lecture halls, and lobbies.

Class 2: This class consists of air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odors. Class 2 air is suitable for recirculation or transfer to any space with Class 2 or Class 3 air, and that is utilized for the same or similar purpose and involves the same or similar pollutant sources. Class 2 air may be transferred to toilet rooms and to any Class 4 air occupancies. Class 2 air is not suitable for recirculation or transfer to dissimilar spaces with Class 2 or Class 3 air. It is also not suitable in spaces with Class 1 air, unless the Class 1 space uses an energy recovery device, then recirculation from leakage carryover or transfer from the exhaust side is permitted. In this case the amount of Class 2 air allowed to be transferred or recirculated shall not exceed 10 percent of the outdoor air intake flow. Thus, HVAC systems serving spaces with Class 2 air shall not share the same air handler as spaces with Class 1 air. Some examples include warehouses, restaurants, and auto repair rooms.

Class 3: This class consists of air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor that is suitable for recirculation within the same space. Recirculation of Class 3 air is only permitted within the space of origin. It is not suitable for recirculation or transfer to any other spaces. However, when a space uses an energy recovery device, then recirculation from leakage carryover or transfer from the exhaust side of the energy recovery device is permitted. In this case the amount of Class 3 air allowed to be transferred or recirculated shall not exceed 5 percent of the outdoor air intake flow. HVAC systems serving spaces with Class 3 air shall not share the same air handler serving spaces with Class 1 or Class 2 air. Some examples include general manufacturing (excludes heavy industrial and processes using chemicals) and janitor closets.

Class 4: This class consist of air with highly objectionable fumes or gases, as well as potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Class 4 air is not suitable for recirculation or transfer within the space or to any other space. No leakage of Class 4 air from energy recovery devices is allowed. Some examples include spray paint booths and chemical storage rooms.

In addition to Tables 4-12 and 4-13, the Energy Standards also include air classifications for specific airstreams and sources as detailed in Table 4-14. In the event that Tables 4-12, 4-13 and 4-14 do not list the space or location, the air classification of the most similar space listed in terms of occupant activities or building construction shall be used.

Table 4-14: Airstreams or Sources

Description	Air Class
Diazo printing equipment discharge	4
Commercial kitchen grease hoods	4
Commercial kitchen hoods other than grease	3
Laboratory hoods	4[a]
Hydraulic elevator machine room	2

a. Air Class 4 unless determined otherwise by the Environmental Health and Safety professional responsible to the owner or to the owner's designee.

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.1-C

For ancillary spaces that are designated as Class 1 air but support a Class 2 air space, re-designation of Class 1 air to Class 2 air for ancillary spaces to Class 2 areas is allowed. For example, a bank lobby is designated as Class 1 while bank vaults or safety deposit areas are designated at Class 2. The ancillary space to the bank safety deposit area can be re-designated to Class 2 from Class 1.

4.3.5 Direct Air Transfer

The Energy Standards allow air to be directly transferred from one space to another to meet part of the ventilation supply, 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 may be a mixture of air from multiple spaces or locations, in which case the air mixture must be classified at the mixed highest classification. Transfer air must meet the requirements of air classification and recirculation limitations, as described above.

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 some spaces have a higher design outdoor ventilation rate and/or a lower cooling load relative to the other space.

4.3.6 Distribution of Outdoor Air to Zonal Units

§120.1(e)

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.

Not all spaces are required to have a direct source of outdoor air. Transfer air is allowed from adjacent spaces with direct outdoor air supply if the system supplying the outdoor air is capable of supplying the required outdoor air to all spaces at the same time. Air classification and recirculation limitations will apply, as explained above. An example of an appropriate use of transfer would be in buildings having central interior space-conditioning systems with outdoor air supply, and zonal units on the perimeter without a direct outdoor air supply.

4.3.7 Ventilation System Operation and Controls

§120.1(d)

4.3.7.1 Outdoor Ventilation Air and VAV Systems

Except for systems employing Energy Commission-certified DCV devices or space occupancy sensors, the Energy Standards require that the minimum rate of outdoor air calculated per §120.1(c)3 be provided to each space *at all times,* when the space is normally occupied according to §120.1(d)1. For spaces served by VAV systems, 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.

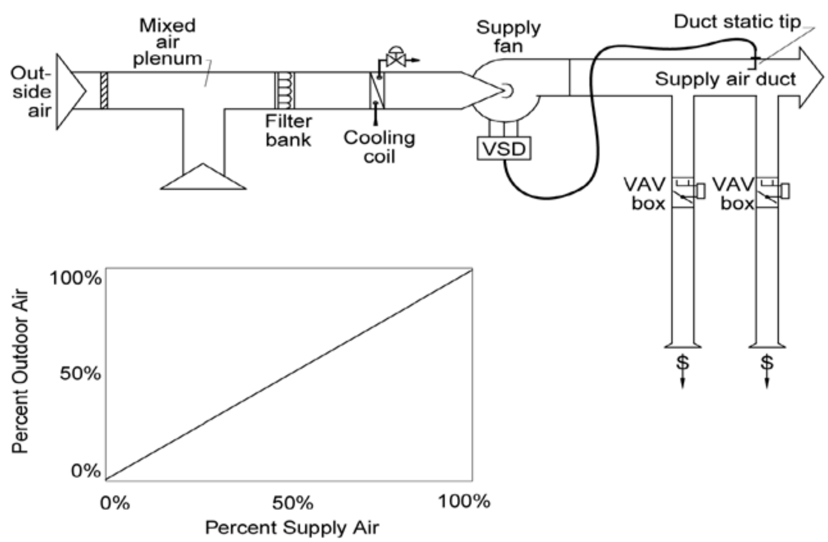
The design outdoor ventilation rate at the system level must always be maintained when the space is occupied, even when the fan has modulated to its minimum capacity §120.1(d)1. Section 4.3.13 describes mandated acceptance test requirements for outside air ventilation in VAV air handling systems where the minimum outside air will be measured at full flow with all boxes at minimum position.

Figure 4-5 shows a typical VAV system. In standard practice, the testing and balancing 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, which does not meet code. 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. Figure 4-5 shows 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.

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. Section 120.2(g) requires provision of “isolation zones” of 25,000 sq. ft. or less, which can be accomplished 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 period when not all the zones are occupied, the ventilation air can be reduced to the required ventilation air of just 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 4-5: VAV Reheat System with a Fixed Minimum Outdoor Air Damper Set Point



A. Fixed Minimum Damper Set Point

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(f)2.

B. Dual Minimum Set Point Design

This method complies with the Energy Standards. An inexpensive enhancement to the fixed damper set point design is the dual minimum set point design, commonly used on some packaged AC units. The minimum damper position is set proportionally based on fan speed or airflow between a set point determined when the fan is at full speed (or airflow) and minimum speed (or airflow). This method complies with the Energy Standards but is not accurate over the entire range of airflow rates or when wind or stack effect pressure fluctuates. With DDC, this design has a relatively low cost.

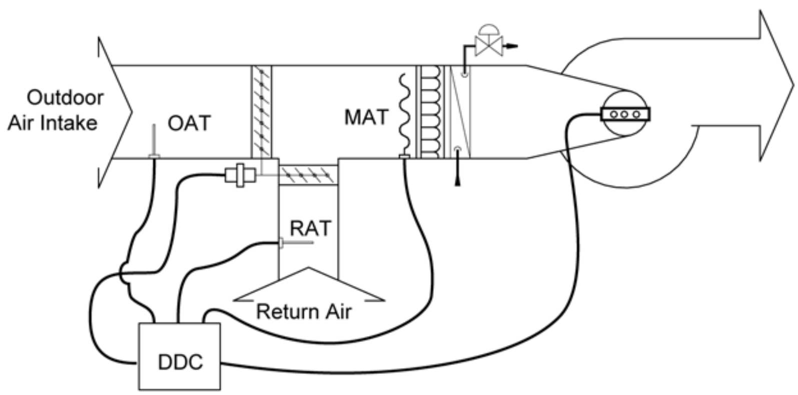
C. Energy Balance Method

The energy balance method uses temperature sensors located outside, as well as in the 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 4-6. 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 of outdoor air.
3. The airflow monitoring station is likely to be inaccurate at low supply airflows.
4. The denominator of the calculation amplifies sensor inaccuracy as the return air temperature approaches the outdoor air temperature.

Figure 4-6: Energy Balance Method of Controlling Minimum Outdoor Air



%OA = (MAT - RAT) / (OAT - RAT)
CFM - OA = %OA * CFM - SA

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 4-7) 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 should 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:

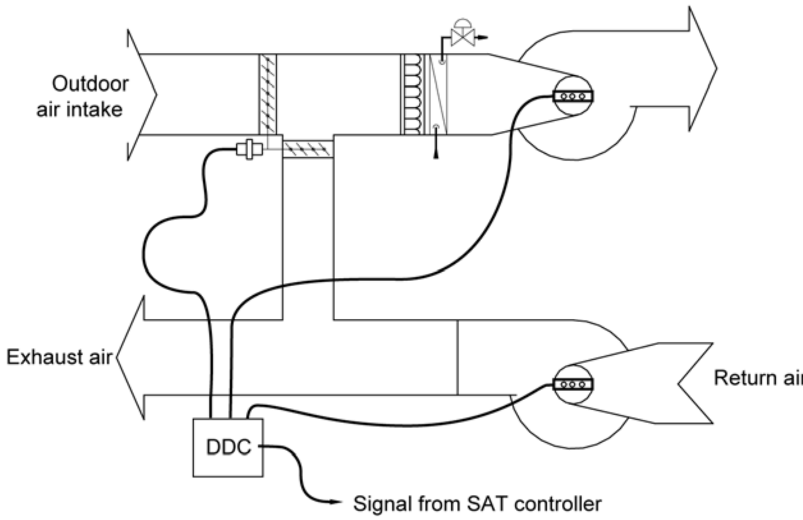
1. The relative accuracy of airflow monitoring stations is poor, particularly at low airflows;
2. The high cost of airflow monitoring stations;

[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.

3. 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.

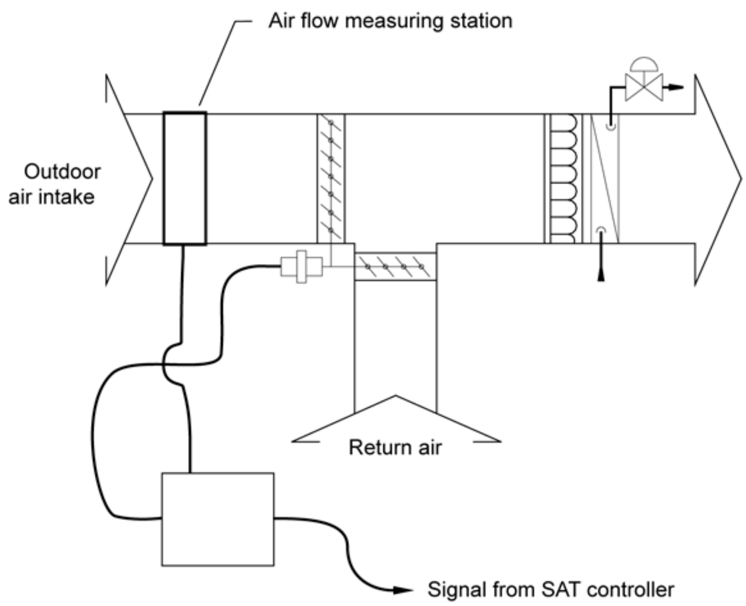
Figure 4-7: Return Fan Tracking



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 within a 5 to 15 percent turndown (the normal commercial ventilation range). Controlling the outdoor air damper by direct measurement with an airflow monitoring station (Figure 4-8) 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 pitot 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.

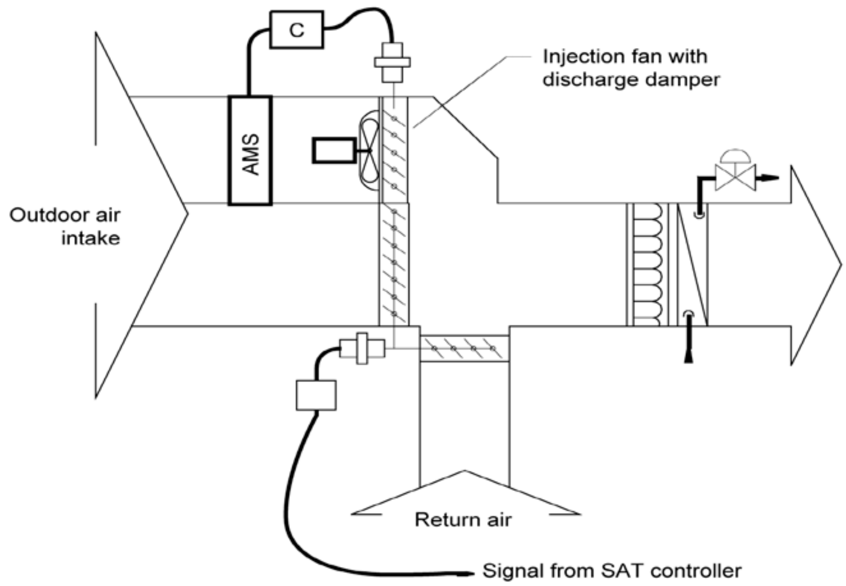
Figure 4-8: Airflow Measurement of 100 Percent Outdoor Air



F. Injection Fan Method

This method complies with the Energy Standards, but it is expensive and may require additional space. An airflow sensor and damper are required since fan airflow rate will vary, as mixed air plenum pressure varies. The injection fan method (Figure 4-9) 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; variable frequency drives [VFD]), which is modulated as required to achieve the desired ventilation rate. The discharge damper is required to shut off the intake when the air handling unit (AHU) is off, and also to prevent excess outdoor air intake when the mixed air plenum is significantly 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. Though effective, the cost of this method is high and often requires additional space for the injection fan assembly.

Figure 4-9: Injection Fan with Dedicated Minimum Outdoor Air Damper



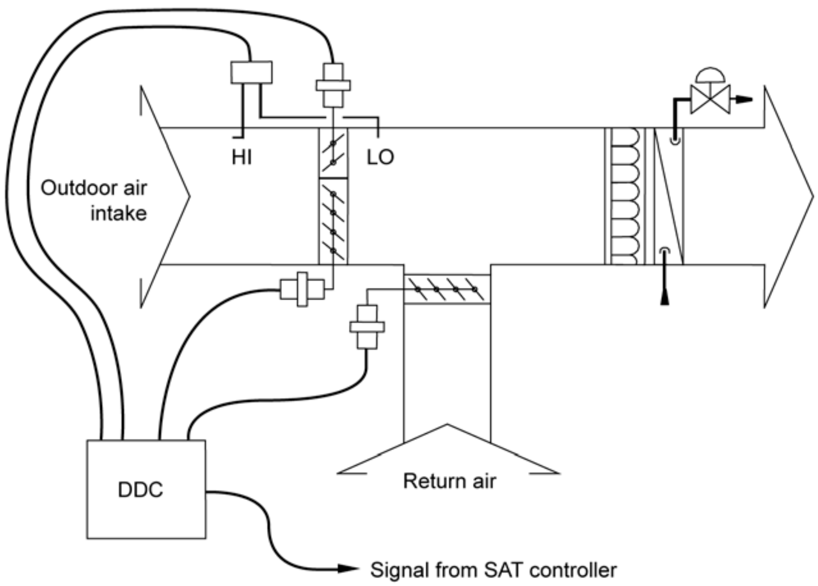
G. Dedicated Minimum Ventilation Damper with Pressure Control

This approach is low cost and takes little space. It can be accurate if the differential set point 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 4-10). 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 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 set point. 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 of 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 4-10: Minimum Outdoor Air Damper with Pressure Control



Example 4-10: Minimum VAV cfm

Question

If the minimum required ventilation rate for a space is 150 cfm, what is the minimum allowed airflow for its VAV box when the percentage of outdoor air in the supply air 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.

4.3.8 Pre-Occupancy Purge

§120.1(d)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(d)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. Three complete air changes

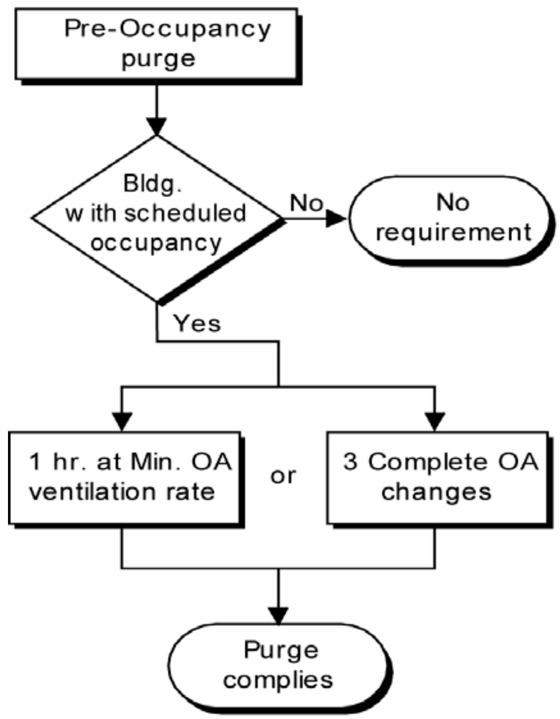
Either criterion can be used to comply with the Energy Standards. Three complete air changes means an amount of ventilation air equal to three times the volume of the occupied space. This air may be introduced at any rate provided for and allowed by the system, so that the actual purge period may be 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 way to integrate the two controls is to 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.

However, for spaces with occupancy controls which turn ventilation off when occupancy is not sensed, care must be taken in specifying controls and control sequences that the lack of sensed occupancy does not disable or override ventilation during the pre-occupancy purge period.

Figure 4-11: Pre-Occupancy Purge Flowchart



Example 4-11: Purge Period

Question

What is the length of time required to purge a space 10 ft high with an outdoor ventilation rate of 1.5 cfm/sq ft?

Answer

For three air changes, each sq ft of space must be provided with:

OA volume = 3 x 10 = 30 cf/ft²

At a rate of 1.5 cfm/sq ft, the time required is:

Time = 30 cf/ft² / 1.5 cfm/ft² = 20 minutes

Example 4-12: Purge with Natural Ventilation

Question

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: Purge with Occupancy Timer

Question

How is a purge accomplished in a building without a regularly scheduled occupancy, whose system operation is controlled by an occupancy sensor?

Answer

This building is most likely 24/7 accessible and a purge requirement would not apply for this building. The occupancy sensors and manual timers can only be used to control ventilation systems in buildings that are intermittently occupied without a predictable schedule.

4.3.9 Demand Controlled Ventilation

§120.1(d)3 and 4

Demand controlled ventilation 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; volatile organic compounds (VOC) and so-called “indoor air quality(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 the 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 delay 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 require the use of DCV systems for spaces. Those that have a design occupancy of 40 sq. ft./person or smaller (for areas without fixed seating where the design density for egress purposes is 40 sq. ft./person or smaller), and has at least one of the following:

1. An air economizer
2. Modulating outside air control
3. Design outdoor airflow rate greater than 3,000 cfm

B. Exceptions to this requirement:

1. The space exhaust is greater than the required ventilation rate minus 0.2 cfm/ft^2.

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.

2. DCV devices are not allowed in 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, areas designated for unvented food service preparation, daycare, sickroom, science lab, barber shop, or beauty and nail 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 this exception.

3. Spaces with an area of less than 150 sq. ft., or a design occupancy of less than 10 people, per §120.1(c)3 (Table 4-12 above).

   This recognizes the fact that DCV devices may not be cost effective in small spaces such as a 15 ft. by 10 ft. conference room or spaces with only a few occupants at design conditions.

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(c)3 requires a minimum of 15 cfm of outdoor air per person multiplied by 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) which 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.

A CO_2 sensor 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 that off-gas from furnishings and building materials. Hence, where permitted or required by the Energy Standards, DCV systems cannot reduce the outdoor air ventilation rate below the lowest rate listed in Table 4-12 (typically 0.15 cfm/ft^2) 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 lowest ventilation rate listed in Table 4-12, 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 4-12).

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 sq. ft. per person or less, with no less than one sensor per 10,000 sq. ft. of floor space. When a zone or a space is served by more than one sensor, signals from any sensor indicating that CO_2 is near or at the set point 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 professionals 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 three and six 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 set point would be 1000 ppm. (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(c)3. 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 minimum air rate for DCV for all rooms with DCV and the minimum air rate for all other spaces served by the system, as listed in Table 4-12. 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 degree Celsius (77 degrees F), factory calibrated or calibrated at start-up, and certified by the manufacturer to require calibration no more frequently than once every five 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, sensor manufacturers 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(c)3 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.

4.3.10 Occupant Sensor Ventilation Control Devices

§120.1(d)5

The use of occupant sensor ventilation control devices is mandated for spaces that are also required to have lighting shut-off controls per §130.1(c), such as offices 250 sq. ft. or less, multipurpose rooms 1,000 sq. ft. or less, classrooms, conference rooms, and restrooms, and where the space ventilation is allowed to be reduced to zero in Table 120.1-A (see note F in the right-hand column of the table).

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 if the ventilation system is controlled directly from the occupant sensor and is not subject to daylighting control or other manual 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).

4.3.11 Fan Cycling

§120.1(d)1

While §120.1(d)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. 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.

d. When a space has entered Occupied Standby Mode as permitted by §120.2(e)3.

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 CO_2 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 sq. ft. auditorium with fixed seating for 240 people require DCV?

Answer

Since the space has an occupant load factor of 8.3 sq. ft. per person (2,000 sq. ft. per 240 people), it meets the 40 sq. ft./person or less requirement triggering demand control ventilation if it has at least one of the following:

-Air economizer
-Modulating outside air control -Design outdoor airflow greater than 3,000 cfm

A single CO_2 sensor could be used for this space provided it is certified by the manufacturer to cover 2,000 sq. ft. 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 DCV required?

Answer

Yes, for each system that meets the criteria above.

Example 4-16

Question

Does the 2,000 sq ft auditorium in the previous examples require both DCV per Section 4.3.9. and occupant sensor ventilation control devices per Section 4.3.10?

Answer

No, only DCV is required because occupant sensor ventilation control devices are only required for spaces such as offices 250 sq ft or less, multipurpose rooms 1,000 sq ft or less, classrooms, conference rooms, or restrooms.

Example 4-17

Question

If a central AHU supplies five zones of office space (with a design occupant density of 100 sq ft per person and two zones with conference rooms (with a design occupant density of 35 sq ft per 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 five office zones plus 15 cfm per person for the two conference rooms.

4.3.11.1 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 set points 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.

4.3.12 Adjustment of Ventilation Rate

Section 120.1(c) 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 required by the Energy Standards, then the space-conditioning system must be adjustable. This way so the ventilation rate can be reduced in the future to 1) the amount required by the Energy Standards, or 2) 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(f).

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 desired in the future. 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.

4.3.13 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. DCV 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: Maintenance of Ventilation System

Question

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 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.

4.3.13.1 Ventilation Airflow

NA7.5.1

Ventilation airflow must 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.

4.3.13.2 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.

4.3.13.3 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 set point 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 sensor device manufacturers that their product will meet the requirements of §120.1(d)4F and will provide a signal that indicates the CO2 level is within range required by §120.1(d)4.; certification from the controls manufacturer that their product responds to the type of signal that the installed sensors supply and can be calibrated to the CO2 levels specified in §120.1(d)4; and that the CO2 sensors have an accuracy within plus or minus 75 ppm at 600 and 1,000 ppm concentrations, and require calibration no more frequently than once every five years.

4.4 Pipe and Duct Distribution Systems

4.4.1 Mandatory Measures

4.4.1.1 Requirements for Pipe Insulation

§120.3 and Table 120.3-A

Most piping conveying 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. Piping within fan coil units and within other heating or cooling equipment should be insulated based on the pipe diameter and the required value in the table.

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 degrees F and 105 degrees F, such as cooling tower piping or piping in water loop heat pump systems.
3. 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.
4. 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 degrees 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 shall not be used as protection for insulation exposed to weather.

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 4-10 : Insulation Thickness

$$T = PR\left[\left(1+\frac{t}{PR}\right)^{\frac{K}{k}} - 1\right]$$

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-ft^2 -°F).

k = The lower value of the conductivity range listed in Table 4-15 for the applicable fluid temperature, Btu-in/(h-ft^2 -°F).

Table 4-15: Pipe Insulation Thickness

Fluid Operating Temperature Range (°F)	Insulation Conductivity: Conductivity (in Btu·in/h·ft²·°F)	Insulation Conductivity: Mean Rating Temperature (°F)		Nominal Pipe Diameter (in inches): < 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
Space heating and Service Water Heating Systems (Steam, Steam Condensate, Refrigerant, Space Heating, Service Hot Water)				**Minimum Pipe Insulation Required (Thickness in inches or R-value)**				
Above 350	0.32-0.34	250	Inches	4.5	5.0	5.0	5.0	5.0
			R-value	R 37	R 41	R 37	R 27	R 23
251-350	0.29-0.32	200	Inches	3.0	4.0	4.5	4.5	4.5
			R-value	R 24	R 34	R 35	R 26	R 22
201-250	0.27-0.30	150	Inches	2.5	2.5	2.5	3.0	3.0
			R-value	R 21	R 20	R 17.5	R 17	R 14.5
141-200	0.25-0.29	125	Inches	1.5	1.5	2.0	2.0	2.0
			R-value	R 11.5	R 11	R 14	R 11	R 10
105-140	0.22-0.28	100	Inches	1.0	1.5	1.5	1.5	1.5
			R-value	R 7.7	R 12.5	R 11	R 9	R 8

				Nominal Pipe Diameter (in inches): < 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
Space cooling systems (chilled water, refrigerant and brine)				**Minimum Pipe Insulation Required (Thickness in inches or R-value)[1]**				
40-60	0.21-0.27	75	Inches	Nonres 0.5 Res 0.75	Nonres 0.5 Res 0.75	1.0	1.0	1.0
			R-value	Nonres R 3 Res R 6	Nonres R 3 Res R 5	R 7	R 6	R 5
Below 40	0.20-0.26	50	Inches	1.0	1.5	1.5	1.5	1.5
			R-value	R 8.5	R 14	R 12	R 10	R 9

Footnote to TABLE 120.3-A:

1. These thickness are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.

Source: California Energy Commission, Building Energy Efficiency Standards, *Table 120.3-A*

Example 4-19

Question

What is the required thickness for calcium silicate insulation on a four inch diameter pipe carrying a 300 degree F fluid?

Answer

From Table 4-15, using data for 300 degree F fluid:

PR = 2"
t = 4.5" (from the table for a 4 inch pipe with 300 degree F fluid)
K = 0.40 (Btu-in.)/(h-ft²-°F) (from calcium silicate insulation manufacturer’s conductivity data at 200 degree F)
k = 0.29 (Btu-in.)/(h-ft²-°F) (the lower value of the range for conductivity for 300 degree F fluid)

$$T = PR[(1 + t/PR)^{K/k} – 1]$$

$$T = 2[(1 + 4.5/2)^{(0.40/0.29)} – 1]$$

T = 8.2 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 in accordance with the California Mechanical Code Sections 601, 602, 603, 604, 605 and ANSI/SMACNA-006-*2006 HVAC Duct Construction Standards - Metal and Flexible*, 3rd Edition.

Healthcare facilities are exempt from §120.4 and shall comply with the applicable requirements of the California Mechanical Code.

A. Installation and Insulation

§120.4(a)

Portions of supply-air and return-air ducts or ductwork conveying heated or cooled air shall be insulated to a minimum installed level of R-8 when installed:

1. Outdoors
2. In a space between the roof and an insulated ceiling
3. In a space directly under a roof with fixed vents or openings to the outside or unconditioned spaces
4. In an unconditioned crawlspace
5. In other unconditioned spaces

Portions of supply-air ducts ductwork that are not in one of the above spaces shall be insulated to a minimum installed level of R-4.2 or be exposed in a directly conditioned space. For example, supply-air ducts that are inside the thermal envelope but concealed from view (such as ducts in a chase or above a hard or T-bar ceiling) are required to be insulated with at least R-4.2. However, if the ducts are exposed to directly conditioned space (i.e. ducts are visible to the occupants), then no insulation would be required.

B. Requirements of the California Mechanical Code

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 inch, 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 tests comparable to those that cloth-back rubber-adhesive duct tapes failed (the Lawrence Berkeley National Laboratory 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 ducts to fittings without 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. On their backing, these tapes have 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. Installation instructions in the box explains how to install the tape on duct core to fittings and a statement that the tape 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 degrees 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 three feet 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 pound per cubic foot 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 set point of 1.25 inches water gauge and a plenum return?

Answer

All duct work located within the return plenum must be sealed in accordance with the California Mechanical Code 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 California Mechanical Code.

4.4.2 Prescriptive Requirements for Space Conditioning Ducts

Each of these applicable prescriptive requirements 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)

Systems serving nonresidential buildings, including high-rise residential and hotel/motel guest rooms, shall have their ducts sealed when certain criteria are met. Healthcare facilities are exempt from §140.4(l) and shall comply with the applicable requirements of the California Mechanical Code.

Ducts that are part of 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, single zone, and serves an occupiable space.
2. The system serves less than 5,000 sq ft of conditioned floor area.
3. The system ductwork has 25 percent or more of the duct surface area located outdoors, in unconditioned space, in a ventilated attic, or a crawl space; where the U-factor of the roof is greater than the U-factor of the ceiling, or where 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 4.9.4.3.

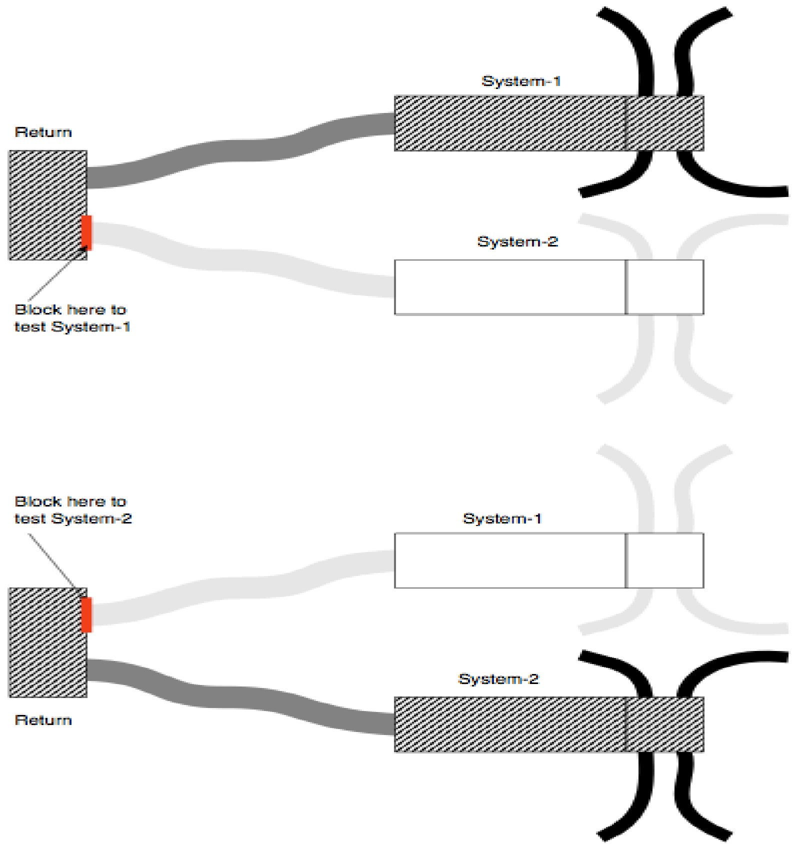
A. Duct Leakage Testing for Multiple Duct Systems With Common Return Ducts

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 which should be included in each system 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 the 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” method where both systems are tested together (as though it is one large system) and the results divided by the combined tonnage to get the target leakage may not be used as it allows a duct system with more the 6 percent leakage to pass if the combined system’s leakage is 6 percent or less.

Figure 4-12: 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 half of its ductwork is 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 25 percent of the duct surface area on the roof, the unit probably serves more than 5,000 sq ft of space. Most 15- and 20-ton units will serve spaces that are significantly larger than 5,000 sq ft. If the space is 5,000 sq ft 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 sq ft 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 sq ft of space, it does not have 25 percent 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)

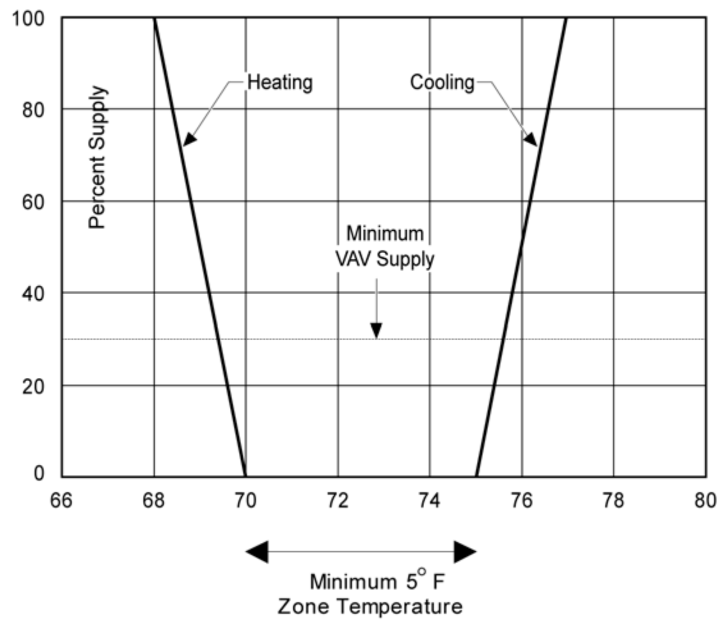
Thermostatic controls must be provided for each space-conditioning zone or dwelling unit to control the supply of heating and cooling energy within that zone. The controls must have the following characteristics:

1. When used to control **heating**, the thermostatic control must be adjustable down to 55 degrees F or lower.
2. When used to control **cooling**, the thermostatic control must be adjustable up to 85 degrees F or higher.
3. When used to control both **heating and cooling**, the thermostatic control must be adjustable from 55 degrees F to 85 degrees F and also provide a temperature range or **dead band** of at least 5 degrees 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 set points per 24-hour period. Also the thermostat must comply with the occupant controlled smart thermostat requirements in §110.12(a), 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 that provide demand shedding, as described later in Section 4.5.1.6.

The set point may be adjustable either locally or remotely, by continuous adjustment or by selection of sensors.

Figure 4-13: 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.
2. The perimeter system must have at least one thermostatic control for each building orientation of 50 ft or more.
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 are controlled by their own thermostat, and that the thermostat is 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 set points 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 DDC system. Some DDC systems employ a single cooling set point and a fixed or adjustable deadband. These systems comply if the deadband is adjustable or fixed at 5 degrees F or greater.

Thermostats with adjustable set points 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, and computer rooms. 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)

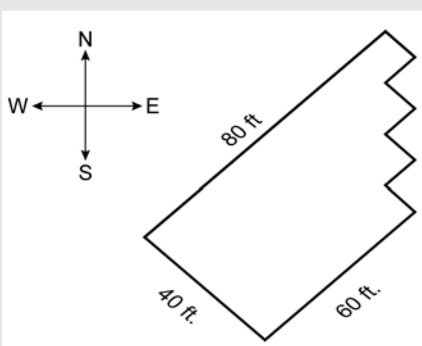
The Energy Standards require that thermostats in hotel/motel guest rooms have:

1. Numeric temperature set points in degrees F and degrees Celsius,
2. Set point stops that prevent the thermostat from being adjusted outside the normal comfort range (± 5 degree F or ± 3 degree Celsius). These stops must be concealed so that they are accessible only to authorized personnel.
3. Setback capabilities with a minimum of four separate set points per 24 hour period.

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 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 degrees F to 78 degrees F), while two additional electric thermostats could be provided, one for setback control (adjustable down to 55 degrees F) and one for set-up (adjustable up to 85 degrees F). These auxiliary thermostats would be wired to temporarily override the system to maintain the setback/setup set points during off-hours.

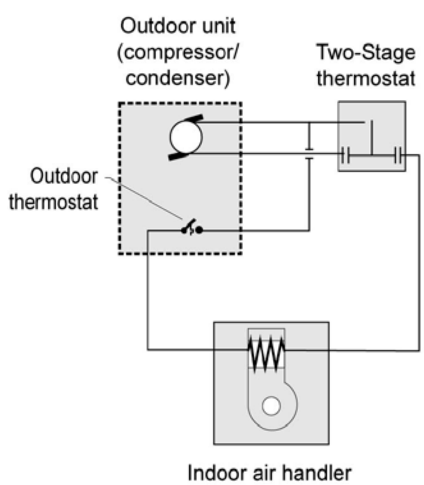
4.1.2.1 Heat-Pump Controls

§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 degrees F). This conventional control system is depicted schematically below in Figure 4-14.

Figure 4-14: Heat Pump Auxiliary Heat Control, Two-Stage and Outdoor Air Thermostats



4.5.1.3 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 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 four-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 seven-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 set point, 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 degrees F.
2. A setup cooling thermostat set point, 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 degrees F.

C. Occupant sensing zone controls

Space conditioning systems serving rooms that are required to have occupant sensing controls to satisfy the lighting control requirements of Section 130.1(c) and where Table 4-12 identifies the room or space is eligible to reduce the ventilation air to zero, shall incorporate this control strategy known as occupied standby mode. The room, space or zone is considered to be in occupied standby mode when all the rooms within the zone are unoccupied for more than five minutes. When a zone is in occupied standby mode, the cooling set point shall be increased by at least 2 degrees F and the heating set point shall be decreased by at least 2 degrees F, or for a multiple zone system with DDC to the zone level the cooling set point shall be increased by at least 0.5 degrees F and the heating set point shall be decreased by at least 0.2 degrees F. All airflow to the zone shall be shut off when in occupied standby mode. If the temperature in the zone drifts outside the deadband, then the full space conditioning system will turn on to satisfy the load in that zone.

This occupancy control must not prevent outside air ventilation of the space when the pre-occupancy ventilation purge cycle is required by §120.1(d)2. Pre-occupancy purge ventilates the space prior to scheduled occupancy each day to dilute and exhaust contaminants that have built up inside the building over night while the HVAC systems were off. Typically, the space is unoccupied during these periods and the occupancy control must not disable this scheduled ventilation cycle.

D. Exceptions for automatic shut off, setback and setup, and occupant sensor setback:

1. *Exception to A, B, and C:* It can be demonstrated to the satisfaction of the enforcement agency that the system serves an area that must operate continuously.
2. *Exception to A, B, and C:* Systems have a full load demand of 2 kW or less, 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.
3. *Exception to A and B:* Systems serve hotel/motel guest rooms, if they have a readily accessible manual shut-off switch.

E. Hotel/motel guest room controls:

§120.2(e)4

Hotel/motel guest rooms shall have captive card key controls, occupancy sensing controls, or automatic controls such that within 30 minutes of a guest leaving the room, set points are set-up of at least +5 degrees F (+3 degrees Celsius) in cooling mode and set-down of at least -5 degrees F (-3 degrees Celsius) in heating mode.

Example 4-26

Question

Can occupancy sensors be used in an office to shut off the VAV boxes during periods when 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 sq ft 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 sq ft, and each having its own time switch.

Example 4-28

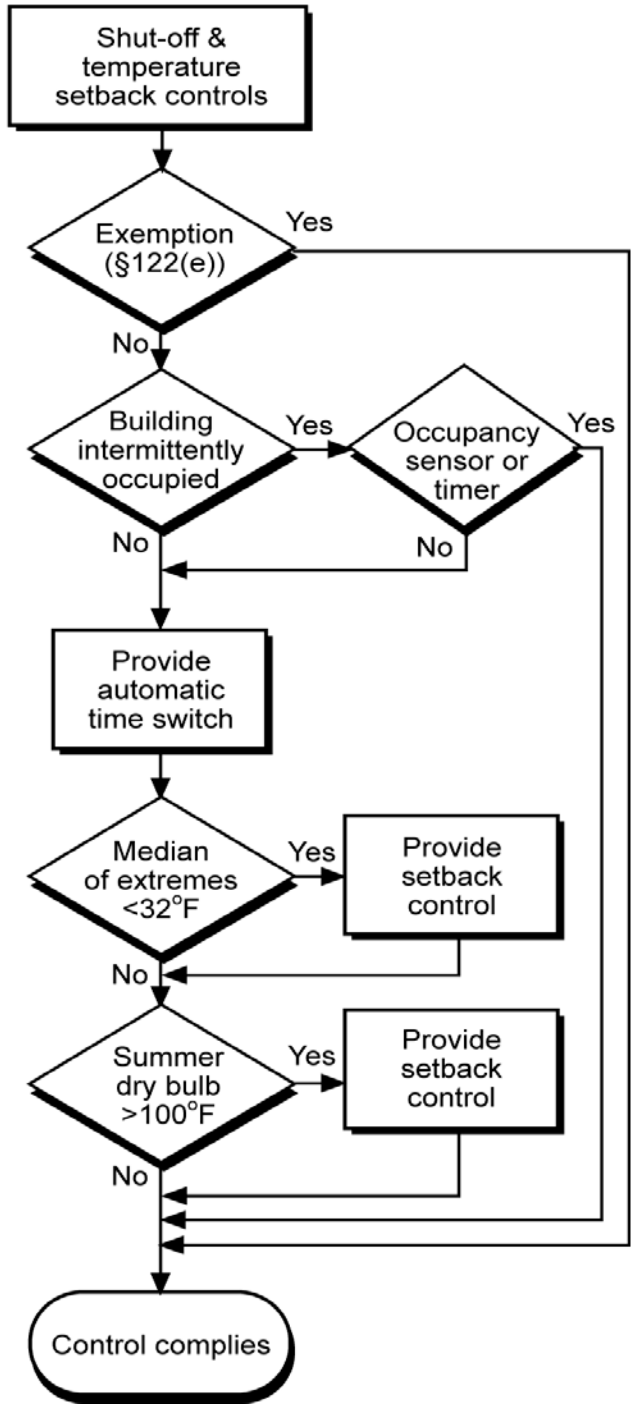
Question

Can a thermostat with set points 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 4-15: 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 sq ft (see Isolation), one-time switch may control the entire system.

4.5.1.4 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) or when occupancy sensors are used for ventilation control. 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 one-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 four-hour timer.

Exception 1: Equipment that serves an area that must operate continuously.

Exception 2: 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 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.

4.5.1.5 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 are occupied. Typically, this occurs during evenings or weekends when less people are working. When the total area served by a system exceeds 25,000 sq ft, 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 sq ft. 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 isolation 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 sq ft building require?

Answer

At least three. Each isolation zone may not exceed 25,000 sq ft.

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.

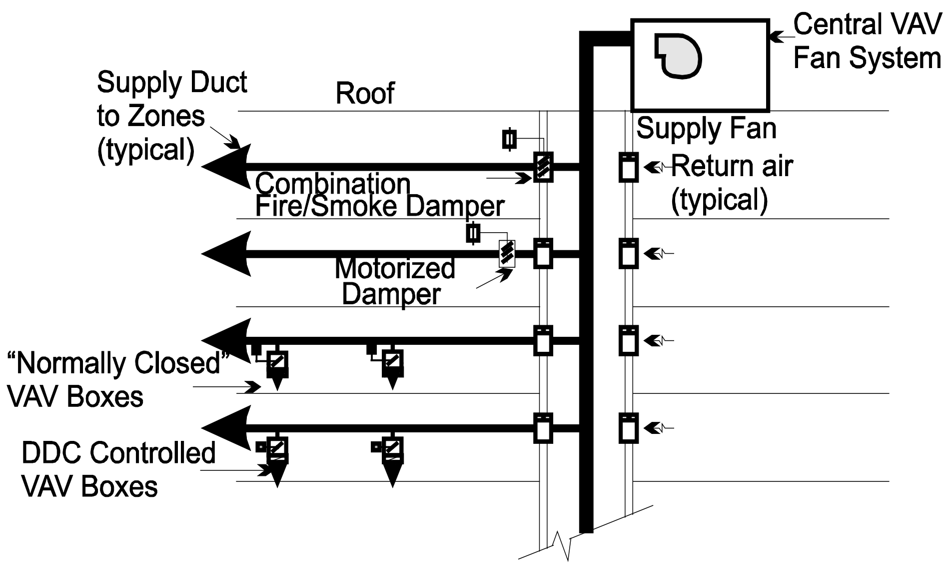
B. Isolation of Central Air Systems

Figure 4-18 below depicts four methods of area isolation with a central VAV 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 set points and unoccupied setback/setup set points. 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 numbered item) this method is somewhat obsolete. When applied, this method can only control a single trunk duct. 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. This control can only be used on a single trunk duct. 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). No isolation devices are required on the return.

Figure 4-16: 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.

C. Turndown of Central Equipment

Where isolation areas are provided, it is critical that the designer plans 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.

4.5.1.6 Automatic Demand Shed Controls

§110.12

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 the capability to remotely increase the operating cooling temperature set points by four degrees or more in all non-critical zones, via signal from a centralized contact or software point within an EMCS.
2. The controls shall have the capability to remotely decrease the operating heating temperature set points by four degrees or more in all non-critical zones, via signal from a centralized contact or software point within an EMCS.
3. The controls shall have the capability to remotely reset the temperatures in all non-critical zones to original operating levels, via 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 increase, decrease, and reset.
5. The controls shall have the following features:
   a. The ability to be disabled by authorized facility operators.
   b. Controlled manually by authorized facility operators to allow adjustment of heating and cooling set points globally from a single point in the EMCS.
   c. Upon receipt of a demand response signal, the space-conditioning systems shall automatically conduct a centralized demand shed (as specified in one and two 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 set point during a demand shed event might disrupt the process, including but not limited to data centers, telecom/private branch exchange 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 set point 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.

4.5.1.7 Economizer Fault Detection and Diagnostics

§120.2(i)

Economizer Fault Detection and Diagnostics (FDD) is a mandatory requirement for all newly installed air handlers with a mechanical cooling capacity greater than 54,000 Btu/hr and 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 DDC system.

Where required, the FDD system shall meet each of the following requirements:

1. Temperature sensors shall be permanently installed to monitor system operation of outside air, supply air, and return air.
2. Temperature sensors shall have an accuracy of ±2 degrees F over the range of 40 degrees F to 80 degrees F.
3. The controller shall have the capability of displaying the value of each sensor.
4. The controller shall provide system status by indicating the following conditions:
   a. Free cooling available.
   b. Economizer enabled.
   c. Compressor enabled. For systems that don’t have compressors, indicating “mechanical cooling enabled” also complies.
   d. Heating enabled, if the system is capable of heating.
   e. Mixed air low limit cycle active.
5. The unit controller shall allow manual initiation of each operating mode so that the operation of cooling systems, economizers, fans, and heating system can be independently tested and verified.
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 five 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. This could include loss of calibration, complete failure (either through damage to the sensor or its wiring) or failure due to disconnected wiring.

b. Not economizing when it should, meaning when programmed to do so. In this case, the economizer should be enabled yet is not providing free cooling. This leads to an unnecessary increase in mechanical cooling energy. For example, if the economizer high limit set point is too low (55˚F), or the economizer is stuck in the closed position.

c. Economizing when it should not, meaning when not programmed to do so. This is the opposite malfunction from the previous problem . In this case, conditions are such that the economizer should be at minimum ventilation position, but instead is open beyond the correct position. This leads to an unnecessary increase in heating and cooling energy. For example, if the economizer high limit set point is too high (82˚F), or the economizer is stuck in the open position.

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 programmed to do so, and economizing unnecessarily.

e. Excess outdoor air. This failure occurs when 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(during cooling mode when outdoor conditions are higher than the economizer high limit set point). 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 one through seven, above. The manufacturer submittal package is available in Joint Appendices *JA6.3 Economizer Fault Detection and Diagnostics Certification Submittal Requirements*.

For air handlers controlled by DDC (including packaged systems), FDD sequences of operations must be developed to adhere with the requirements of §120.2(i)1 through 7. FDD systems controlled by DDC are not required to be certified to the Energy Commission, but manufacturers, controls suppliers, or other market actors can choose to apply for certification. For DDC based FDD systems, a new acceptance test has been developed to test the sequences of operations in the field to verify that they in-fact comply with the required faults of §120.1(i).

Although not required by the Energy Standards, ASHRAE Guideline 36-2017 is a good reference for developing sequences of operations specifically for the faults listed in 120.2(i). The purpose of Guideline 36 is to provide uniform sequences of operation for heating, ventilating, and air-conditioning (HVAC) systems that are intended to maximize HVAC system energy efficiency and performance, provide control stability, and allow for real-time fault detection and diagnostics. To properly adhere to Guideline 36, all sequences of operations design elements in Sections 5.16.14 and/or 5.18.13 of that guideline must be implemented, including defining operating states, the use of an alarm delay, and the installation of an averaging mixed air temperature sensor. If a designer uses Guideline 36 to detect the required economizer faults in Title 24 Section 120.2(i), the sequences of operations should include Guideline 36 Fault Conditions numbers #2, 3, and 5 through 13, at a minimum. Other Title 24 FDD requirements in Section 120.2(i) and acceptance tests are not met by including these fault conditions into sequences of operations, and must be met through other means.

4.5.1.8 Direct Digital Controls

§120.2(j)

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. DCV (mandatory) - Section 4.3.9
2. Automatic Demand Shed Controls (mandatory) - Section 4.5.1.6
3. Optimum Start/Stop Controls (mandatory) - Section 4.5.1.9
4. Set point Reset Controls for VAV 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 4-16 below for a duplicate of this table.

Table 4-16: 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 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

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.2-A

Buildings that do not meet the specified minimum qualifications are not required to install DDC.

Follow the flowchart in Figure 4-19 to determine if a DDC system is required for newly constructed buildings, additions, or alterations. The Building Status Flowchart will indicate which equipment flowchart (Figure 4-20throughFigure 4-24) should be used for each type of HVAC equipment that will be installed in the building.

The flowcharts will indicate whether DDC is required for the building, how it should be applied to the equipment and whether it is required to be installed to the zone level.

Figure 4-17: Building Status Flowchart

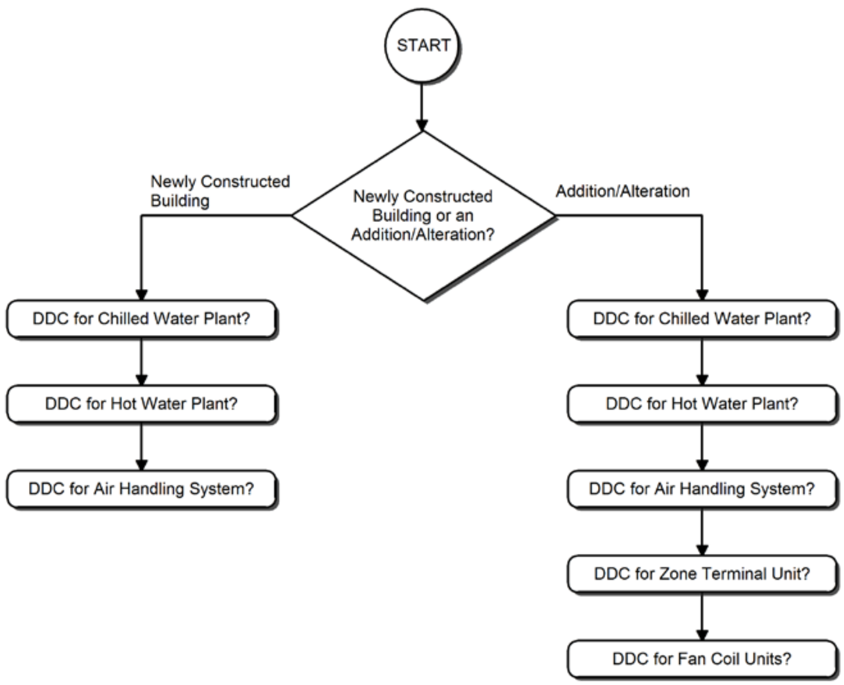


Figure 4-18: Chilled Water Plant Flowchart

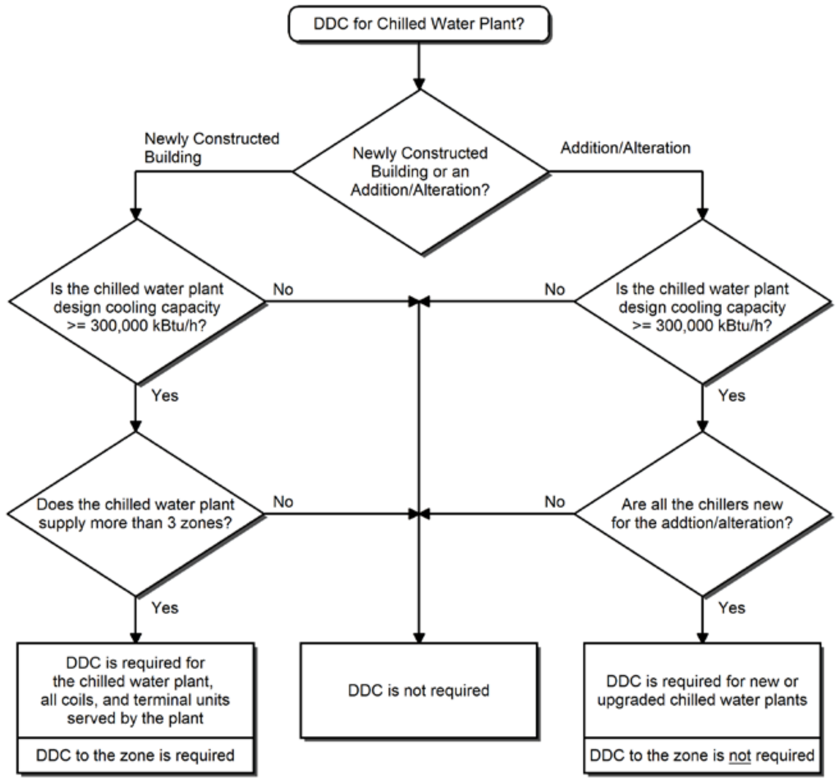


Figure 4-19: Hot Water Plant Flowchart

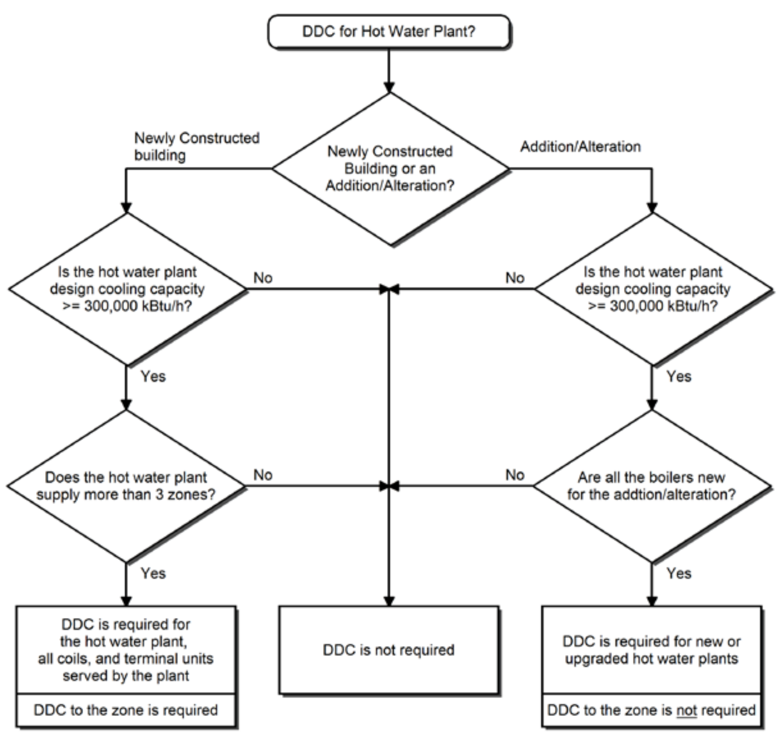


Figure 4-20: Air Handling System Flowchart

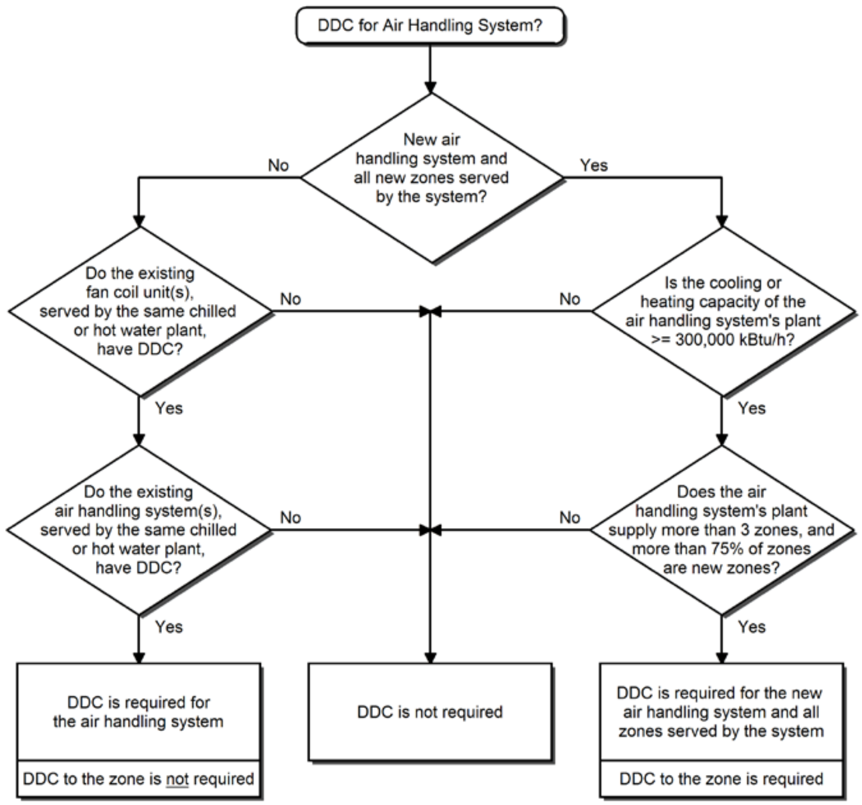


Figure 4-21: Zone Terminal Unit Flowchart

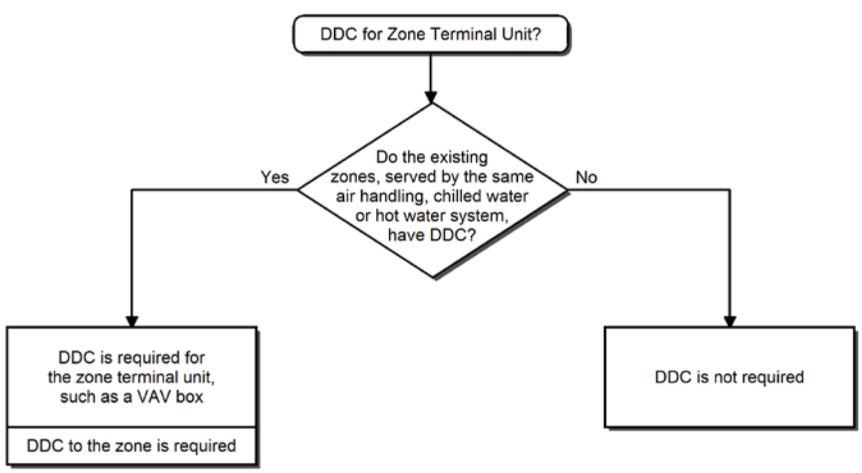
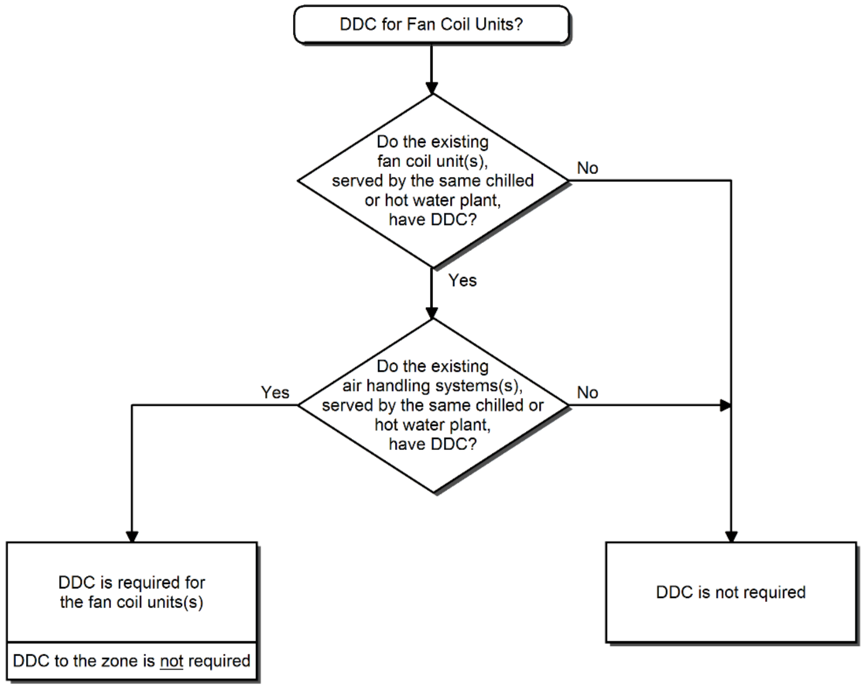


Figure 4-22: Fan Coil Units Flowchart



For additions or alterations to buildings, zones that are not part of the addition or alteration are not required to be retrofitted with DDC to the zone. 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 four 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 three 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

Maybe. 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, then 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 three 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. Trend and graphically display input and output points for new buildings
6. Reset set points in non-critical zones, signal from a centralized contact or software point, as described in 4.5.1.7.

4.5.1.9 Optimum Start/Stop Controls

§120.2(k)

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. This ensures that the space reaches the appropriate temperature during occupied hours only, without wasting energy to condition the space during unoccupied hours. It applies to heating and cooling.

Optimum start controls are designed to automatically adjust the start time of a space conditioning system each day. The purpose of these controls is to bring the space temperature to the desired occupied temperature levels at the beginning of scheduled occupancy. The controls 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 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.

Systems that must operate continuously are exempt.

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:

- Reheating of air that has been previously cooled by mechanical cooling equipment or an economizer.
- Recooling of air that has been previously heated. This does not apply to air returned from heated spaces.
- Simultaneous heating and cooling in the same zone, such as mixing supply air that has been previously mechanically heated with air that has been previously cooled, either by mechanical cooling or by economizer systems.

Zones served by VAV 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 DDC:

1. The volume of primary air that is reheated, re-cooled, or mixed air supply shall not exceed the larger of 50 percent of the peak primary airflow or the design zone outdoor airflow rate, per Section 4.3.
2. The volume of primary air in the dead band shall not exceed the larger of 20 percent of the peak primary airflow or the design zone outdoor airflow rate, per Section 4.3.

ii. The first stage of heating consists of modulating the zone supply air temperature set point up to a maximum set point no higher than 95 degrees F while the airflow is maintained at the deadband flow rate.

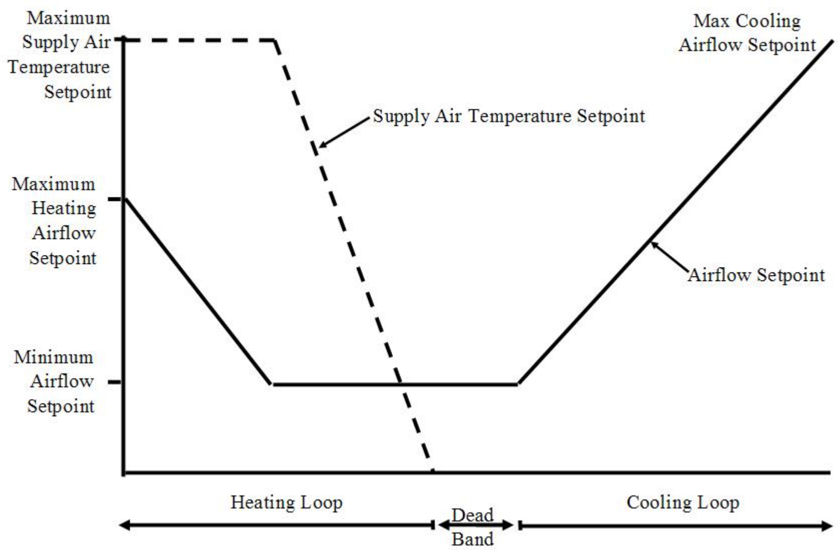
iii. The second stage of heating consists of modulating the airflow rate from the deadband flow rate up to the heating maximum flow rate.

iv. 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 30 percent of the peak primary airflow or 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 4-25 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 degrees F) as a first stage of heating then, if more heat is required, it increases airflow rate up to a “heating” maximum airflow set point, which is the same value as what traditional control logic uses as the minimum airflow set point. 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 4-23: 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 either 30 percent of the peak primary airflow or the minimum airflow required to ventilate the space, whichever is greater.

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. Systems with healthcare facilities

Example 4-35

Question

What are the limitations on VAV box minimum airflow set point for a 1,000 sq ft office having a design supply of 1,100 cfm and eight 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 set point 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 set point 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 set point 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. It must have a total mechanical cooling capacity over 54,000 Btu/h, a chilled water cooling system without a fan, or a chilled water cooling system that uses induced airflow. It must also have a cooling capacity greater than the systems listed in Table 4-17. The economizer may be either:

1. An air economizer capable of modulating outside air and return air dampers to supply all of the design supply air quantity as outside air;
2. A water economizer capable of providing all of the expected system cooling load at outside air temperatures of 50 degrees F dry-bulb and 45 degrees F wet-bulb and below.

Table 4-17 - Chilled Water System Cooling Capacity

Climate Zones	Total Building Chilled Water System Capacity, Minus Capacity of Cooling units with Air Economizers	
	Building Water-Cooled Chilled-Water Systems	Air-Cooled Chilled-Water Systems or District Chilled-Water Systems
15	≥ 960,000 Btu/h (280 kW)	≥ 1,250,000 Btu/h (365 kW)
1,2,3,4,5,6,7,8,9 10,11,12,13,14	≥ 720,000 Btu/h (210 kW)	≥ 940,000 Btu/h (275 kW)
16	≥ 1,320,000 Btu/h (385 kW)	≥ 1,720,000 Btu/h (505 kW)

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-C

Depicted below in Figure 4-28is 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, 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 (sq ft) 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 per min. Appropriately sized economizers that can supply 100 %percent of the supply airflow without large pressure drops typically have face velocities of less than 2,000 ft per min.

To maintain acceptable building pressure, systems with an airside economizer must have provisions to relieve or exhaust air from the building. In Figure 4-26, 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 4-27depicts 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 4-24: Air-Side Economizer Schematic

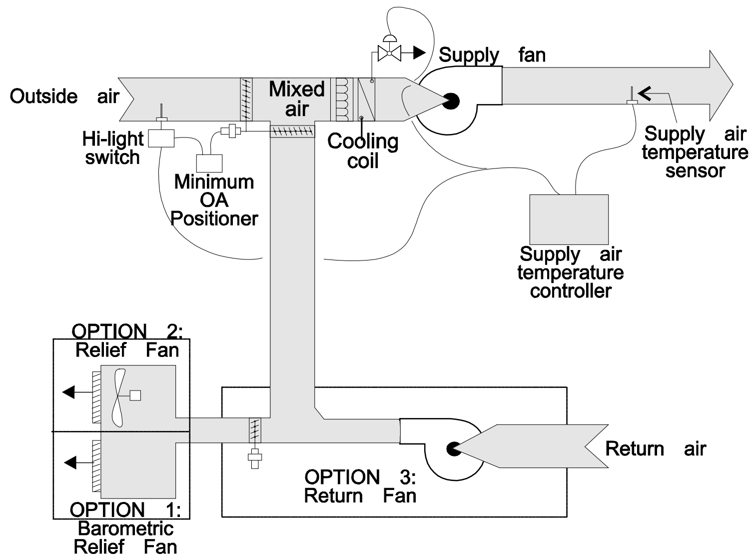
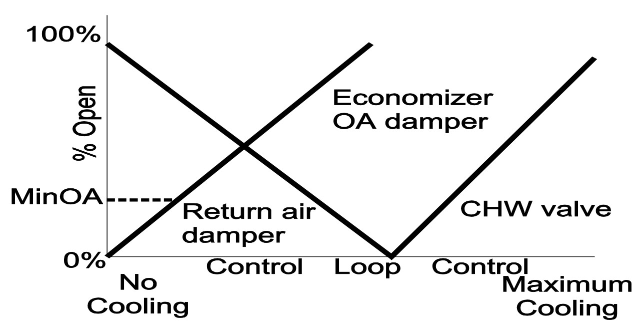


Figure 4-25: Typical Air-Side Economizer Control Sequencing



A. Economizers are not required where:

Exceptions to §140.4(e)1

1. Outside air filtration and treatment for the reduction of unusual outdoor contaminants make compliance unfeasible.
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. Cooling systems have the cooling efficiency that meets or exceeds the cooling efficiency improvement requirements in Table 4-18.
5. Fan systems primarily serving computer room(s). See §140.9 (a) for computer room economizer requirements.
6. Systems designed to operate at 100 percent outside air at all times.

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 all 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 Chilled Water Return (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%

Source: California Energy Commission, Building Energy Efficiency 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)2C

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 plus 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 set points 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]	Required High Limit (Economizer Off When): 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 Dry Bulb	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 set points 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) set points shall be capable of being set to within two degrees F and two Btu/lb of the set point listed.

[c] At altitudes substantially different than sea level, the fixed enthalpy limit value shall be set to the enthalpy value at 75 degrees F and 50 percent relative humidity. As an example, at approximately 6,000 foot elevation, the fixed enthalpy limit is approximately 30.7 Btu/lb.

Source: California Energy Commission, Building Energy Efficiency Standards, Table 140.4-B

D. Air Economizer Construction

§140.4(e)2D

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 five-year factory warranty for the economizer assembly.
2. Certification by the manufacturer that equipment has been tested and is able to open and close against the rated airflow and pressure of the system for at least 60,000 damper opening and closing cycles. Required equipment includes, but is not limited to, outdoor air dampers, return air dampers, drive linkages and actuators.
3. Economizer outside air and return air dampers shall have a maximum leakage rate of 10 cfm/sq ft 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 set point.
5. Economizer sensors shall be calibrated within the following accuracies:
   a. Dry bulb (db)and wet bulb (wb)temperatures accurate to plus or minus 2 degrees F over the range of 40 degrees F to 80 degrees F.
   b. Enthalpy accurate to plus or minus 3 Btu/lb over the range of 20 Btu/lb to 36 Btu/lb.
   c. Relative Humidity (RH) accurate to plus or minus 5 percent over the range of 20 percent to 80 percent.
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, 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)2E

Systems that include an 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 degrees 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 two stages of mechanical cooling capacity.
3. DX units not within the scope of number two (above), 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 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

Source: California Energy Commission, Building Energy Efficiency 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.

F. Water Economizer Specific Requirements

§140.4(e)3

Unlike air-side economizers, water economizers have parasitic energy losses that reduce the cooling energy savings. One of these losses comes from increases in pumping energy. To limit the losses, the Energy Standards require that precooling coils and water-to-water heat exchangers used as part of a water economizer system have either 1) a water-side pressure drop of less than 15 feet of water, or 2) a secondary loop so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (non-economizer) mode.

Water economizer systems must also be integrated with the mechanical cooling system so that they are capable of providing partial cooling--even when additional mechanical cooling is required to meet the remainder of the cooling load. This includes controls that do not false load the mechanical cooling system by limiting or disabling the economizer, or by any other means--such as hot gas bypass--except at the lowest stage of mechanical cooling.

Figure 4-26: Economizer Flowchart

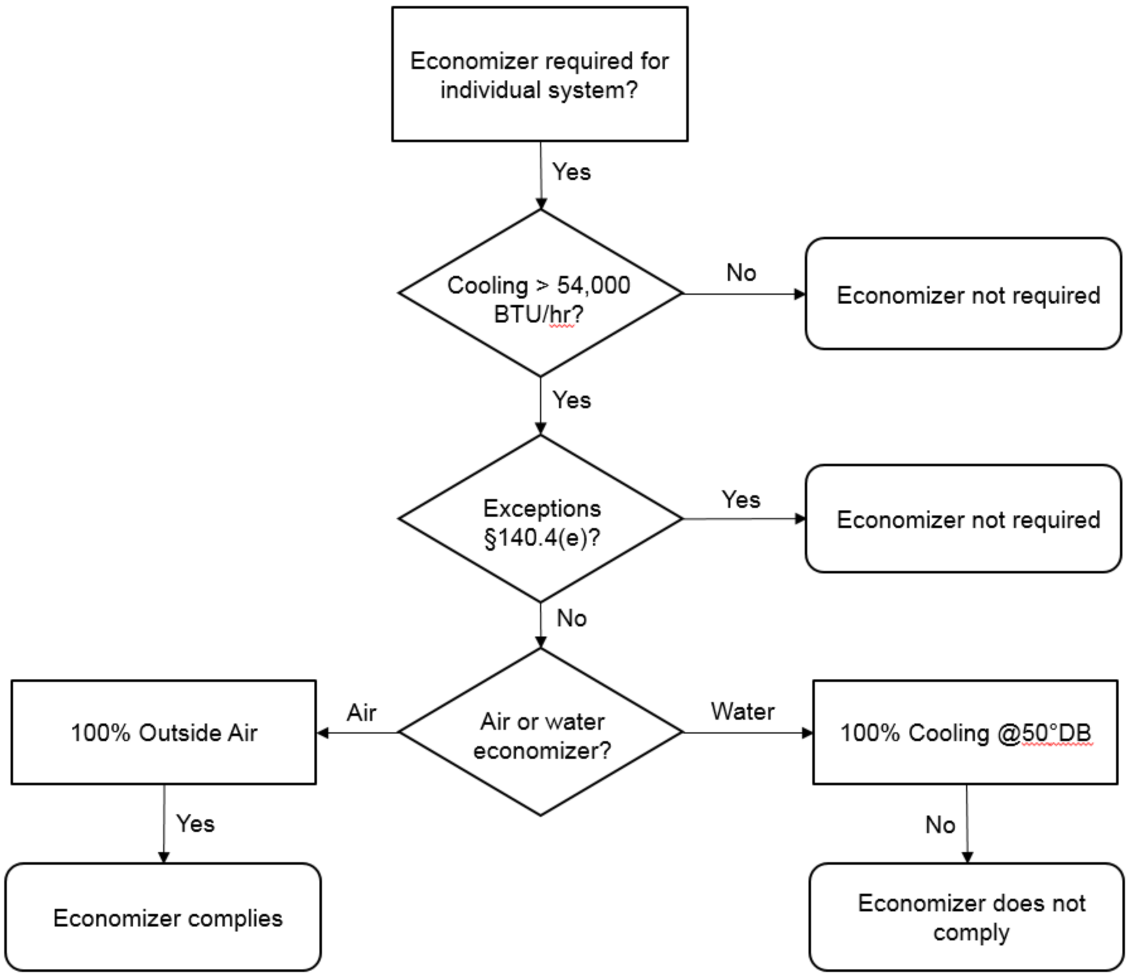
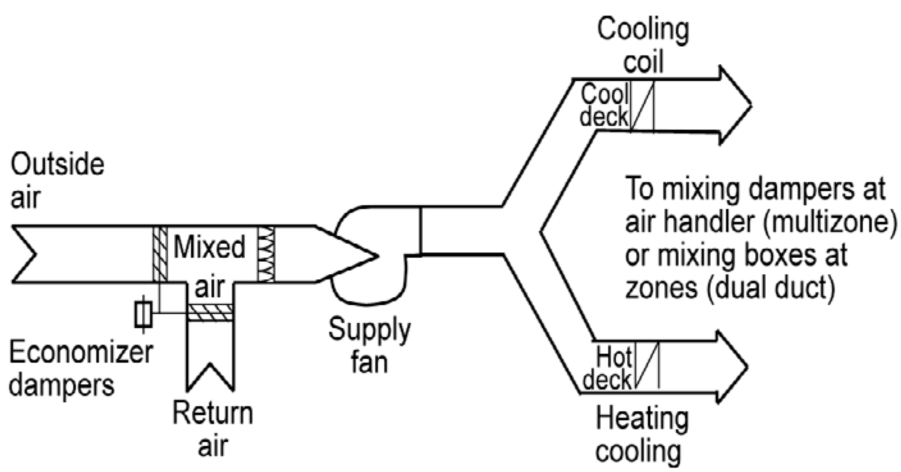


Figure 4-27: Single-Fan Dual-Duct System



Example 4-36

Question

If the design conditions are 94 degrees F db/82 degrees F wb can the 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 degrees F db/45 degrees F wb. 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 4-38)

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. In addition, the economizer must be equipped with a 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 Variable Air Volume (VAV) Supply Fan Controls

§140.4(c) 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 two stages of fan speed with no more than 66 percent speed when operating on stage one 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 4-28 shows typical performance curves for different types of fans. 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 certified manufacturer's test data shows static pressure set point is one-third of total design static pressure). These fans will not normally comply with these requirements unless a variable speed drive is used.

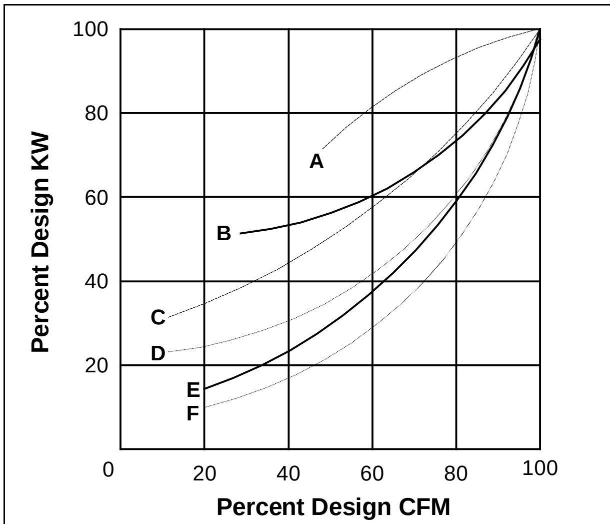
VAV fan systems that do not have DDC to the zone level are required to have the static pressure sensor located in a position such that the control set point is less than or equal to 1/3 of the design static pressure of the fan. For systems without static pressure reset, the further the sensor is from the fan the more energy will be saved. For systems with multiple duct branches in the distribution separate sensors in each branch must be provided to control the fan and 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 set point 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 dampers are 95 percent open.
2. A trim and respond algorithm to continually reduce the pressure until one or more zones indicate that they are unable to maintain airflow rate set points.
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 4-28: 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

Source: California Energy Commission, Building Energy Efficiency 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 degrees F and the design room temperature is 75 degrees F, then the difference is 20 degrees F, of which 25 percent is 5 degrees F. Therefore, the controls must be capable of resetting the supply temperature from 55 degrees F to 60 degrees 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 variable-speed drive (VSD) fan controls. The recommended control sequence is to lead with supply temperature set point reset in cool weather where reheat might dominate the equation and to keep the chillers off as long as possible. Thereafter the system can return to a fixed low set point in warmer weather when the chillers are likely to be on. During reset a demand-based control is employed that uses the warmest supply air temperature to satisfy all of the zones in cooling.

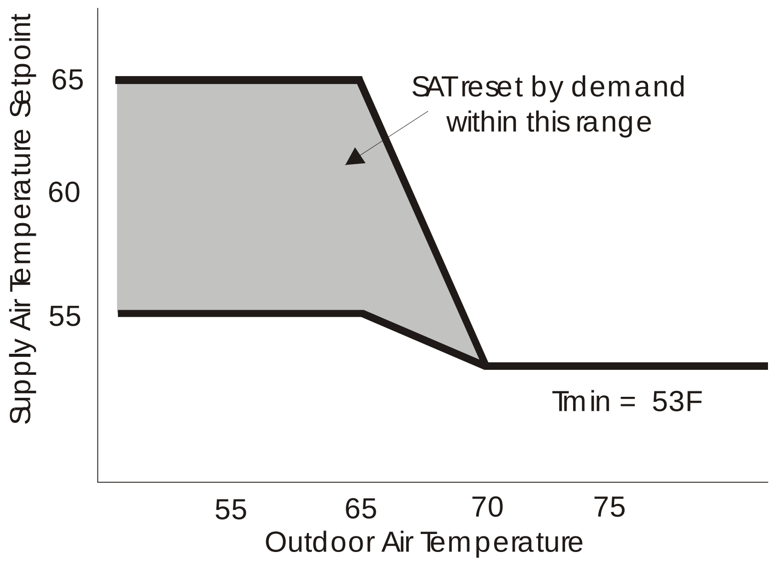
This sequence is described as follows: during occupied mode the set point is reset from T-min (53 degrees F) (when the outdoor air temperature is 70 degrees F and above) proportionally up to T-max (when the outdoor air temperature is 65 degrees F and below). T-max shall range from 55 degrees F to 65 degrees F and shall be the output of a slow reverse-acting proportional-integral loop that maintains the cooling loop of the zone served by the system with the highest cooling loop at a set point of 90 percent (SeeFigure 4-31).

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.
4. Systems serving healthcare facilities.

Figure 4-29: 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 of 7.5 hp or larger, the system must be capable of operating at two-thirds speed, or less. In addition, the system must 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 are powered by motors smaller than 7.5 hp.
2. Heat rejection devices are 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 one third of the fans on a condenser or tower with multiple fans have lead fans that 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 whichever value is greater: 50 percent or less of design flow 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.

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 three 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 four 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 three-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

A plant is 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 and 3

Plants with multiple chillers or boilers are required to provide either isolation valves or dedicated pumps. In addition, they must 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 greater than 500,000 Btu/h are required to provide controls to reset the hot or cold water temperature set points 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.

Exceptions for this requirement:

1. Hydronic systems that are designed for variable flow complying with §140.4(k)1
2. Systems serving healthcare facilities

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 with a design circulation pump brake horsepower greater than five 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 not required on central tenant condenser water systems (for water-cooled AC units and HPs) it is beneficial 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 allowing aggressive condenser water reset for energy savings in chilled water plants that are also cooled by the towers.

E. Variable-speed drive for Pumps Serving Variable Flow Systems

§140.4(k)6

Pumps on variable flow systems that have a design circulation pump brake horsepower greater than 5 bhp are required to have variable-speed drives. Alternatively, they may have 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 Set point

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 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 set point 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 energy of the pump riding the curve provides a beneficial heat that reduces the boiler use. This diminishes 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 degrees 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 degrees 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 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 five minutes. This can be accomplished by resetting the heating set point to 55 degrees 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 set point to 90 degrees F - unless the outside air temperature is less than the space temperature, in which case the cooling set point 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 any openings to the outdoors to.be operable. However, if operable openings are present, then they must comply with this requirement.

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 move 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 thermostat needs to be interlocked to the windows.

Exceptions to this requirement:

1. Interlocks are not required on doors with automatic closing devices
2. Any space without a thermostatic control
3. Healthcare facilities
4. High-rise residential dwelling units

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)

There are mandatory requirements (§110.2(e)) 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 manage 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/title24/2019standards/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 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 0.005 percent 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, deposits will form on the tower fill or clog 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 involves maintaining the following levels:

- Silica levels should be maintained at less than or equal to 150 ppm
- The Langelier Saturation Index should be maintained at less than or equal to 2.5 (see explanation below)
- The pH in new cooling towers using galvanized metal should be maintained at less than or equal to 8.3 until metal is passivated, which occurs after three-six months of operation

To meet compliance, an Energy Commission approved calculator (NRCC-MCH-06-E) allows the building owner to enter 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; 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 F is acceptable. Lastly, target tower cycles of concentration are entered into the calculator. The calculator computes the LSI based on the cycles of concentration entered by the user. The maximum value of the index 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 are considered by the Energy 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?

Answer

The Langelier Saturation Index predicts scaling. It indicates whether water will precipitate, dissolve, or be in equilibrium with calcium carbonate. The index is a function of hardness, alkalinity, conductivity, pH and temperature expressed as the difference between the actual system pH and the saturation pH.

Example 4-42

Question

Where is the 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. Also check with water treatment firms that are doing business in the area. They often have test data that they will share. Finally, it is possible to hire a water treatment firm to take samples of the water to test.

4.6.2 Prescriptive Requirements

4.6.2.1 Sizing and Equipment Selection

§140.4(a)

The Energy Standards require mechanical heating and cooling equipment (including electric heaters and boilers) serving high-rise residential buildings, hotel/motel buildings, and nonresidential buildings other than healthcare facilities to be the smallest size available, while still meeting 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.

Mechanical heating and mechanical cooling equipment serving healthcare facilities shall be sized to meet the design heating and cooling loads of the building or facility being served. Packaged HVAC equipment may serve a space with 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
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
3. Multiple units of the same equipment type are used, each having a capacity less than the design load. In combination, however, the units have 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) 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. For systems serving healthcare facilities, the method in the California Mechanical Code shall be used.
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 of the 2017 ASHRAE Handbook, Fundamentals Volume. Winter humidification or summer

dehumidification is not required. For systems serving healthcare facilities, the method in Section 320.00 of the California Mechanical Code shall be used.

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.

    For systems serving healthcare facilities, the method in Section 320.0 of the California Mechanical Code shall be used.

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 heating or cooling 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 2017 ASHRAE Handbook, Fundamentals Volume, Chapter 18.

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;

    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

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. 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 exceeds 5 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 air to the outdoors.

The 5 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, are normally off during the cooling peak, and there is no design heating load or they are not used during design heating operation.
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 5 hp.

Fans not directly associated with moving conditioned air to or from the space-conditioning system, or fans associated with a process within the building, or fan systems serving a healthcare facility are not included

For the purposes of the 5 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.

$$\text{Fan Adjustment} = 1 - \left(\frac{SP_a - 1}{SP_f} \right)$$

The fan power limit can be determined in either of two ways:

Option 1 specifies the maximum nameplate power. This option is simple to apply but does not consider special filter requirements, heat recovery devices, or other features that would increase the pressure drop across the fans, and thus increase fan power.

Option 2 specifies the limit in terms of maximum input power at the fan shaft, and includes adjustments to account for special filtering (or other devices) in the airstream that increase the static pressure the fan must overcome.

With both options, the power limit applies to all fans that operate at peak design conditions, including primary supply fans, return fans, exhaust fans, and series-type fan-powered VAV boxes. Parallel-type fan-powered VAV boxes typically do not operate at fan system design conditions and would not be included. Different limits apply to the fans in constant-volume and variable-volume systems. Single zone VAV systems use the constant volume criteria.

Option 1

The limit is placed on the fan system motor nameplate power. The limit depends on whether the fan system is a constant-volume or a variable-volume fan system. The limit for constant-volume fan systems is 0.0011 times the supply cubic feet per minute (cfm). The limit for variable-volume fan systems is 0.0015 times the supply volume (in cfm).

$$\text{hp} \leq \text{CFM}_S \times 0.0011 \quad \text{(Constant volume systems)}$$

$$\text{hp} \leq \text{CFM}_S \times 0.0015 \quad \text{(Variable volume systems)}$$

Where:

CFM_S = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute

Option 2

The limit is placed on the input power at the fan shaft instead of the nameplate power. This method is slightly more complicated but offers more flexibility for fan systems with special filtration requirements, or other features that increase static pressure. The input power of the proposed design fan depends on the design airflow (cfm), the static pressure that the fan has to work against, and the efficiency of the fan. Because the limit is applied at the fan shaft, the efficiency of the motor or the VSDis not considered. For a given fan, the input power at the shaft in given by the following equations:

$$\text{bhp}_i = \frac{\text{CFM}_i \times \text{PD}_i}{6356 \times \eta_i}$$

Where:

PD_i = the pressure drop across the *i*th individual fan

bhp_i = the input power of the *i*th individual fan

CFM_i = the airflow rate of the *i*th fan at design conditions

η_i = the efficiency of the *i*th individual fan

The total input power for the entire fan system is the sum of the input power of each of the fans that operate at peak design conditions and is explained by the following equation:

$$\text{bhp}_{Total} = \sum_{i=1}^{n} \text{bhp}_i$$

Where:

bhp_{Total} = the total input power for the fan system

bhp_i = the input power of the *i*th individual fan

The maximum input power permitted by the standard is explained by the following equations for constant-volume and variable-volume systems. The first part of the equation denotes the basic allowance for input power. The second part of the equation denotes additional input power allowed for special filtration or devices listed in Table 4-21 . The additional power for these devices is based on the flow rate of air through the device, not the total supply air flow rate.

$$\text{bhp} \leq \text{CFM}_s \times 0.0094 + \sum \frac{\text{CFM}_i \times \text{PD}_i}{4131} \qquad \text{(Constant volume systems)}$$

$$\text{bhp} \leq \text{CFM}_s \times 0.0013 + \sum \frac{\text{CFM}_i \times \text{PD}_i}{4131} \qquad \text{(Variable volume systems)}$$

Where:

CFM_s = the maximum design supply airflow rate to conditioned spaces served by the system in cubic feet per minute

PD_i = the pressure drop across the *i*th individual fan

bhp_i = the input power of the *i*th individual fan

CFM_i = the airflow rate of the *i*th fan at design conditions

4.6.2.4 Pressure Drop Adjustment Devices

The types of devices listed in Table 4-22 that qualify for additional fan power are as follows:

1. **Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms.** The basic input power allowance is based on the assumption that return air passes through an open plenum on its way back to the fan system. For systems where all of the return air is ducted back to the return, an additional pressure drop allowance of 0.5 inches of water is allowed. This credit may not be applied for air systems that have a mixture of ducted and non-ducted return.
2. **Return and/or exhaust airflow control devices.** Some types of spaces, such as laboratories, test rooms, and operating rooms, require that an airflow control device be provided at both the supply air delivery point and at the exhaust. The exhaust airflow control device is typically modulated to maintain a negative or positive space pressure relative to surrounding spaces. An additional pressure drop and associated input power adjustment are permitted when this type of device is installed. The credit may be taken when some spaces served by an air handler have exhaust airflow devices and other spaces do not. However, the credit is taken only for the cfm of air that is delivered to spaces with a qualifying exhaust airflow device.
3. **Exhaust filters, scrubbers, or other exhaust treatment.** Some applications require the air leaving the building be filtered to remove dust or contaminants. Exhaust air filters are also associated with some types of heat recovery systems, such as run-around coils. In this application, the purpose of the filters is to help keep the coils clean, which is necessary to maintain the effectiveness of the heat recovery system. When such devices are specified and installed, the pressure drop of the device at the fan system design condition may be included as a credit. When calculating the additional input power, only consider the volume of air that is passing through the device under fan system design conditions.
4. **Particulate filtration credit: MERV 16 and greater and electronically enhanced filters.** The primary purpose of filters is to keep the fans, coils, and ducts clean, and to reduce maintenance costs. A secondary purpose is to improve indoor air quality. MERV ratings are used as the basis of this credit. These ratings indicate the amount of particulate removed from the airstream. A higher MERV rating is more efficient and removes more material. The credit for filters with a MERV rating of 16 and greater and all electronically enhanced filters is based on two times the clean pressure drop of the filter at fan system design conditions. These clean pressure drop data are taken from manufacturers' literature.
5. **Carbon and other gas-phase air cleaners.** For carbon and other gas-phase air cleaners, additional input power is based on the rated clean pressure drop of the air-cleaning device at fan system design conditions.
6. **Biosafety cabinet.** If the device is listed as a biosafety cabinet, you can use this credit.
7. **Energy recovery device.** Energy recovery devices exchange heat between the outside air intake stream and the exhaust airstream. There are two common types of heat recovery devices: heat wheels and air-to-air heat exchangers. Both increase the pressure drop and require a system with a larger input power. The fan power allowance for the energy recovery ventilator is determined by the equations in Option 2 and the adjustment factor from Table 4-22. The adjustment factor is a function of the enthalpy recovery ratio. This is intended to encourage designers to

select energy recovery devices that have low pressure drops and high enthalpy recovery ratios, and thus provide a net energy reduction. This allows systems that have trouble meeting the fan power limit to gain a higher fan power allowance — by using larger energy recovery devices with higher enthalpy recovery ratios.

8. **Coil runaround loop.** The coil runaround loop is a form of energy recovery device that uses separate coils in the exhaust and outdoor air intakes with a pump in between. The credit is to account for the increased air pressure of these two coils.
9. **Exhaust systems that serve fume hoods.** Exhaust systems that serve fume hoods get an additional 0.35 inches of water credit to account for the pressure through the fume hood, ductwork, and zone valve or balancing devices. This credit applies to the exhaust fans only.

Table 4-22 Fan Power Limitation Pressure Drop Adjustment

Device	**Adjustment**
Credits	
Return or exhaust systems required by code or accreditation standards to be fully ducted, or systems required to maintain air pressure differentials between adjacent rooms	0.5 inches of water
Return and/or exhaust airflow control devices	0.5 inches of water
Exhaust filters, scrubbers, or other exhaust treatment	The pressure drop of device calculated at fan system design condition
Particulate filtration credit: MERV 16 and greater and electronically enhanced filters	Pressure drop calculated at two times the clean filter pressure drop at fan system design condition
Carbon and other gas-phase air cleaners	Clean filter pressure drop at fan system design condition
Biosafety cabinet	Pressure drop of device at fan system design condition
Energy recovery device, other than coil runaround loop	For each airstream [(2.2 x enthalpy recovery ratio) – 0.5] inches of water
Coil runaround loop	0.6 inches of water for each airstream
Exhaust system serving fume hoods	0.35 inches of water

Example 4-45

Question

A VAV reheat system serves a low-rise office building. The building is served by one VAV packaged rooftop unit with a 10 hp supply fan with a VSD. Four parallel fan-powered VAV terminal units are used on north-facing perimeter offices for heating. Two series fan-powered VAV boxes, each with a third1/3 hp fan with an electronically commutated motor, serve two interior conference rooms.

The space also uses a local exhaust fan for each of the four bathrooms. Fans for the system are listed below. Fan performance is as described in the table below.

Is this system in compliance with Section 140.4(c)?

Quantity	Fan Service	Design cfm, each	bhp	Nameplate Motor, hp
1	Supply fan with variable-speed drive	12,000	8.7	10
2	Condenser fans	9,300	0.7	1.0
1	Return fan	11,000	4.2	5.0
4	Bathroom exhaust fans	350	0.16	1/5
4	Parallel fan-powered VAV boxes	400	0.08	1/5
2	Series fan-powered VAV boxes	600	0.12	1/3

Answer

First, determine which fans to include in the nameplate fan system power calculation:

- The supply and return fans are clearly included in the fan power calculation.
- The condenser fans are not included because they circulate outdoor air and do not affect the conditioned air supplied to the space.
- The toilet exhaust fans are included because they exhaust from a conditioned space.
- The parallel fan-powered VAV boxes are not included in the fan power calculation because they operate in heating mode when the supply fan is not operating at design conditions.
- The series fan-powered boxes run continuously and are included in the fan power calculation.

The total nameplate power is 15.7 bhp, as shown below.

Nameplate Power = 10 + 5 + (4 x 1/5) + (2 × 1/3) = 16.5 hp

The total supply air delivered from the air handler is 12,000 cfm, and the allowed nameplate power for a variable-air-volume system is 18 hp as shown below.

Nameplate Powermax = 12,000 × 0.0015 = 18.0 hp

The total nameplate power of 16.5 hp is less than the allowed 18.0 hp, so the fan system complies with the standard. If the nameplate power exceeded the allowable limit, the system input power can be checked for compliance

Example 4-46

Question

A conventional VAV system serves an office building. Fan performance is as described in the table below. Is the system in compliance with Section 140.4(c)?

Quantity	Fan Service	Design cfm, each	bhp	Nameplate Motor hp
2	Supply fans with variable-speed drives	75,000	70.5	75 high efficiency
4	Economizer relief fans	32,000	3.5	5
1	Toilet exhaust	6,750	2.7	3 high efficiency
1	Elevator machine room exhaust fan	5,000	Unknown	3/4
2	Cooling tower exhaust fans	Unknown	Unknown	15
15	Conference room exhaust fans	500	240 W	—
120	Series-type fan-powered mixing boxes	1,300 (average)	Unknown	1/3

Answer

First, determine which fans to include in the fan power calculation:

- Supply fans are included.
- The economizer relief fans are not included because they will not operate at peak cooling design conditions. Had return fans been used, they would have to be included in the calculation.
- The toilet exhaust fan is included because it exhausts conditioned air from the building rather than have it returned to the supply fan, and it operates at peak cooling conditions.
- The elevator exhaust fan is not part of the system because it is assumed, in this case, that the makeup air to the elevator room is from the outdoors rather than from the building. Had makeup air been transferred from the conditioned space, the fan would have been included.
- The cooling tower fans operate at design conditions, but they also are not part of the system because they circulate only outdoor air. Although the cooling tower fan power does not contribute to the system fan power, it is required to meet the minimum efficiency requirements in Table 110.2-G.
- The conference room exhaust fans are assumed to be transfer fans. They simply exhaust air from the room and discharge it to the ceiling plenum. Because this air is not exhausted to the outdoors, the fans are not included.
- The series-type fan-powered VAV boxes are included because they assist in supplying air to the conditioned space and operate at design cooling conditions. If the boxes were the parallel type, they would not be included because they would not operate at design cooling conditions.

Second, using Option 1, add up the nameplate power (not input power) of the eligible fans. For this example, the fans that are included and their motor power requirements are as follows:

Fan Service	Quantity	Motor hp, each	Total hp
Supply fans	2	75	150
Toilet exhaust fan	1	3	3
Fan-powered VAV boxes	120	1/3	40
Total fan system power			193

Third, determine the supply air rate. This is the total airflow rate supplied through the heating or cooling source, which in this case is equal to the total of the two supply fan airflow rates, 2 × 75,000 = 150,000 cfm. The supply rate is not the total of the fan-powered VAV box airflow rates; although this is the ultimate supply air rate to the conditioned space, this entire airflow does not flow through the heating or cooling source. The airflow rate from the exhaust fan is also not included in the supply air rate for the same reason.

Fourth, determine the criteria from Table 140.4-A. The series fan-powered VAV boxes supply a constant flow of air to the conditioned space, but the primary airflow, the airflow through the cooling source, varies as a function of load which meets the definition of a VAV system. Using Option 1, the maximum nameplate power for the system is 225 hp as shown below.

hp = CFMs × 0.0015

hp = 150,000 × 0.0015 = 225 hp

Fifth, compare the allowable fan system power with the proposed power. The actual fan system nameplate power of 193 hp is less than the 225 hp limit, so this system complies. If the system did not comply, the designer could consider using larger ducts to reduce static pressure or shifting to parallel fan-powered VAV boxes.

Example 4-47

Question

A hotel/motel building has floor-by-floor supply air-handling units but central toilet exhaust fans and minimum ventilation supply fans. How is the standard applied to this system?

Answer

Each air handler counts as a fan system. The energy of the central toilet exhaust and ventilation fans must be allocated to each air handler on a cfm-weighted basis. For instance, if one floor receives 2000 cfm of outdoor air, and the outdoor air fan supplies a total of 10,000 cfm with a 5 hp motor, 20 percent (2000/10,000 cfm) of the fan power (1 hp) is added to the fan power for the floor's fan system. The airflow rates from the exhaust and ventilation fans must be included in the fan power calculation because these 140.4(c) requires to add exhaust fan power.

Example 4-48

Question

A wing of an elementary school building is served by eight water-source heat pumps, each equipped with a 3/4 hp fan motor and serving a single classroom. Ventilation air is supplied directly to each classroom by a dedicated outdoor-air system. Each classroom requires 500 cfm of outdoor air, so the system delivers the total of 4000 cfm of conditioned outdoor air using a 5 hp fan. Does this system need to comply with Section 140.4(c)?

Answer

Each water-source heat pump is a separate fan system because each has a separate cooling and heating source. The power of the dedicated outdoor-air system fan must be allocated to each heat pump on a cfm-weighted basis. For each classroom, 12.5 percent (500/4000 cfm) of the fan power (12.5 percent of 5 hp = 0.625 hp) is added to the fan power for the heat pump (0.75 + 0.625 = 1.375 hp). In this instance, even with the dedicated outdoor-air system fan allocated, each heat-pump fan system is less than the 5 hp threshold in Section 140.4(c), so the system does not need to comply with Section 140.4(c).

Example 4-49

Question

A variable-volume air handler serving a lab system has a fan system design supply airflow of 10,000 cfm. The supply fan has a 20 hp (nameplate) supply fan motor that operates at an input power of 13.9 bhp. The exhaust fan has a five hp motor that operates at an input power of 3.20 bhp. Flow control devices in the exhaust are used to maintain pressure relationships between spaces served by the system.

The air handler uses MERV 13 filters and exhaust air is completely ducted. The system uses outdoor air and has a run-around heat recovery system with coils in the supply and exhaust airstreams, each with 0.4 in. of water pressure drop at design airflow.

Does this fan system comply with the fan power requirements in Section 140.4(c)??

Answer

For this system, Option 2 is required in order to consider the additional pressure drop of the return air ducts, airflow control devices, and the heat recovery device. MERV 13 filters are required per Section 120.1(c) 1B so no fan credit is awarded. From Table 140.4-A, the allowable system input power for the system is:

bhp = CFMs × 0.0013 + A

= 10,000 × 0.0013 + A = 13.0 + A

From Table 140.4-B, the pressure drop adjustment for the pressure drop adjustment for the fully ducted return (DR) is 0.5 in. of water, the pressure drop adjustment for the exhaust flow control device (FC) is 0.5 in. of water, and the pressure drop adjustment for a run-around loop heat recovery device is 0.6 in. of water per airstream. The airflow through all of these devices is 10,000 cfm, so the additional input power that is allowed is 5.33 bhp, as calculated below.

A = [CFMDR × PDDR + CFMFC × PDFC + 2 × (CFMHX × PDHX)] / 4,131

A = [10,000 × 0.5 + 10,000 × 0.5 + 2 × (10,000 × 0.6)] / 4131 = 5.33 bhp

The total allowed input power is 13.0 bhp plus 5.33 bhp, or 18.3 bhp, which is greater than the fan system input power of 13.9 bhp plus 3.20 bhp, or 17.1 bhp. Therefore, the system meets the standard's requirements.

4.6.2.5 Fractional HVAC Motors for Fans

§140.4(c)4

HVAC fan motors that are one 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 the National Electric Manufacturers Assciation (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 direct current (DC) motors. These motors have higher efficiency than permanent split capacitor (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 three 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.
3. Motors that are part of space conditioning serving healthcare facilities.

4.6.2.6 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.
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).
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.
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.
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 sq ft.
    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. The existing mechanical systems use electric reheat (when adding VAV boxes) added capacity cannot exceed 20 percent of the existing installed electric capacity, under any one permit application in an alteration.
7. The existing VAV 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 in an addition.
8. Heating systems serve as emergency backup to gas heating equipment.

The Energy Standards 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 degrees 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 degrees 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.

4.6.2.7 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 the flow that is produced by the smallest pump or50 percent of the design flow for the cell.

In a large plant at low load operation, not all the cells are typically run 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- two fans at half speed use less than one third of the energy of one 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 do not 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.

Fortunately, 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 low-flow nozzles can eliminate the need for a tower isolation control point, this option 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 the 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.

4.6.2.8 Centrifugal Fan Limitation

§140.4(h)4

Open cooling towers with a combined rated capacity of 900 gpm and greater are prohibited from using centrifugal fans. The 95 degree F condenser water return, 85 degree F condenser water supply and 75 degree 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.

4.1.2.2 **Cooling Tower Efficiency**

§140.4(h)5

Prescriptively, axial fan open-circuit cooling towers with a combined rated capacity of 900 gpm or greater must achieve a rated efficiency no less than 60 gpm/hp. This efficiency is rated at specific temperature conditions which are 95 degree F condenser water return; 85 degree F condenser water supply; and 75 degree F outdoor wet-bulb temperature as listed in Table 4-7. There are a couple of exceptions to this requirement:

1. Cooling towers which are installed as a replacement to an existing chilled water plant, if the tower is located on an existing roof or inside an existing building.
2. Cooling towers that are serving buildings in Climate Zones 1 or 16.

As with all prescriptive requirements, axial-fan open-circuit cooling towers with a capacity of 900 gpm or larger and less than 60 gpm/hp may be used when complying with the performance method. The towers must still comply with the mandatory minimum efficiency rating of 42.1 gpm/hp as listed in Table 4-7. .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 represents fixed speed compressors and Path B represents 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 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 greater than 600 volts. This is due to the fact that the cost of a VSD is much higher on medium voltage service.
2. Chillers attached to a heat recovery system with a design heat recovery capacity greater than 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 systems with a charging temperature of less than 40 degrees F. This again requires a high lift operation for chillers.
4. In a building with more than three chillers only three 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 types 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.

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 system with a design temperature of less than 40 degrees F.

   This addresses the fact that air-cooled chillers can operate very efficiently at low ambient air temperatures. Since thermal energy storage systems operate for long hours at night, these systems may be as efficient as a water-cooled plant. 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 water-cooled systems using the lowest chiller efficiency allowed by §110.2.
4. Systems serving healthcare facilities.

4.1.2.3 **Exhaust System Transfer Air**

§140.4(o)

The standard prescriptively requires the use of transfer air for exhaust air makeup in most cases. The purpose is to avoid supply air that requires increased outdoor air intake, which would require conditioning, for exhaust makeup when return or relief air from neighboring spaces can be used instead. The requirement limits the supply of conditioned air to not exceed the larger of: 1.) the supply flow required for space heating or space cooling, 2.) the required ventilation rate, or 3.) the exhaust flow, minus the available transfer air from conditioned spaces or plenums on the same floor and within 15 ft and not in different smoke or fire compartments. Available transfer air does not include air required to maintain pressurization and air that cannot be transferred based on air class as defined by in §120.1.

There are a few exceptions to this requirement:

1. Biosafety laboratories classified Level 3 or higher
2. Vivarium spaces
3. Spaces that are required by applicable codes and standards to be maintained at positive pressure relative to adjacent spaces. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.
4. Spaces where the demand for transfer air may exceed the available transfer airflow rate and where the spaces have a required negative pressure relationship. For spaces taking this exception, any transferable air that is not directly transferred shall be made available to the associated air-handling unit and shall be used whenever economizer or other options do not save more energy.
5. Healthcare facilities

A compliant example would be a space with a restroom with 300 cfm of exhaust. The makeup air would consist of 60 cfm of supply air and 240 cfm of transfer air from an adjacent ceiling return air plenum. The amount of air required for the space is 60 cfm for heating and cooling and the rest of the makeup air is transferred from the return air plenum.

A non-compliant example would be if the same space had a constant air volume box with reheat supplying all of the makeup air. The reheat would be needed to prevent the space from being overcooled. Since there is transfer air available in the adjacent plenum, the maximum allowed supply air would be only what's required for space heating or cooling, which would be 60 cfm.

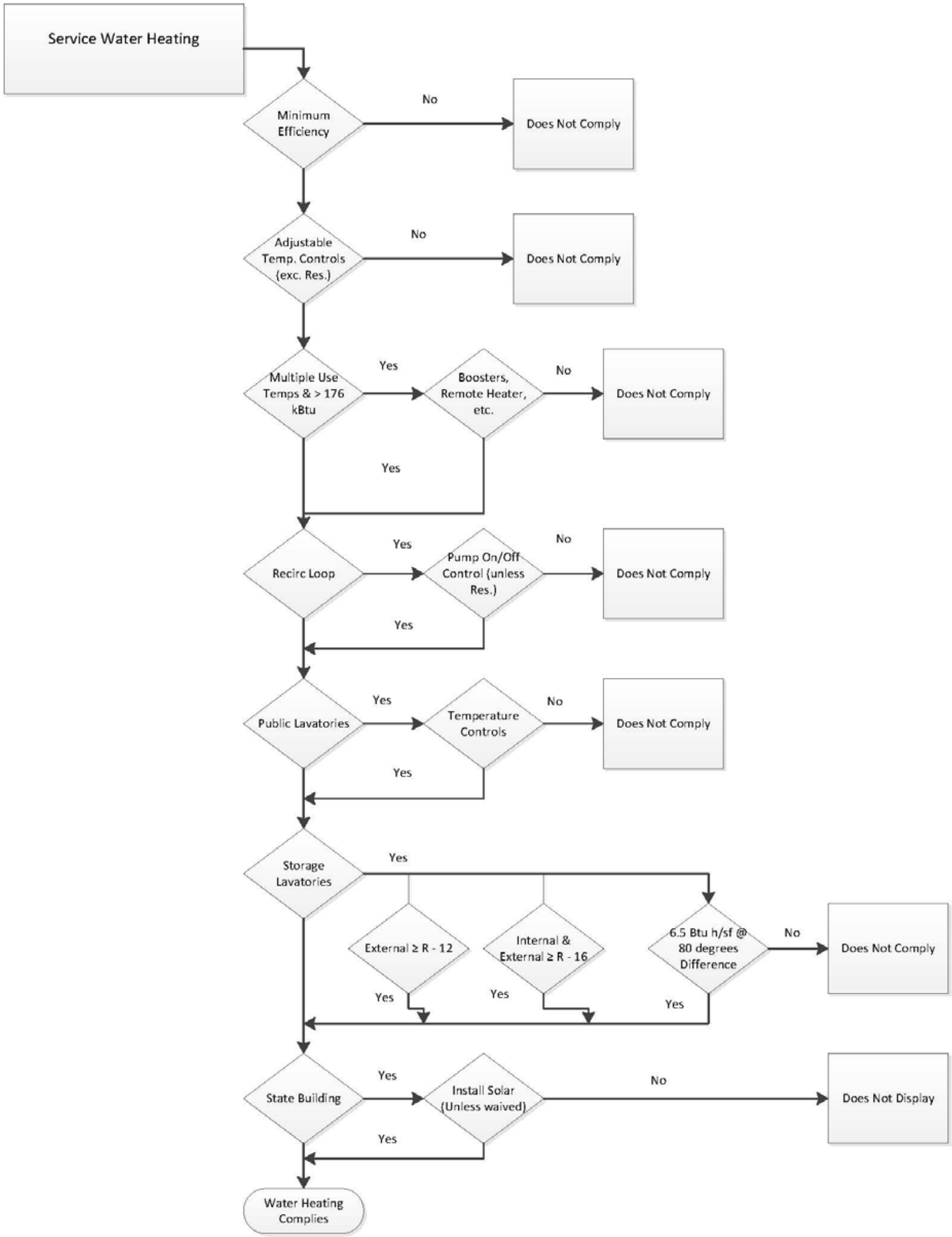
4.7 Water Heating Requirements

§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 buildings, hotels and motels, which must also comply with the Residential Energy Standards §150.1(c)8, described below, as well as in the Residential Compliance Manual.

There are no acceptance requirements for water heating systems or equipment. However, a high-rise residential building, hotel and motel water heating system must meet the distribution system eligibility criteria for that portion of the system that is applicable.

Figure 4-30: 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.

Systems covered by California Plumbing Code Section 613.0 shall instead follow the requirements of that section.

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.

Systems serving healthcare systems are exempted from this requirement.

4.7.1.4 Storage Tank Insulation

§110.3(c)3

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 sq ft. This corresponds to an effective resistance of R-12.3.

4.7.1.5 Service Water Heaters in State Buildings

§110.3(c)5

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.

4.7.1.6 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 4-23, the nominal pipe diameters grouping ranges have changed, as well as the thickness of insulation required for each pipe diameter range. The table is repeated below for ease of reference:

Table 4-23: Pipe Insulation

FLUID TEMPERATURE RANGE (°F)	CONDUCTIVITY RANGE (in Btu-inch per hour per sq ft 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 eight ft 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

Source: California Energy Commission, Building Energy Efficiency Standards, Table 120.3-A

4.7.1.7 Systems with Recirculation Loops

§110.3(c)4

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)4A

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; and 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 four 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)4B

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

Many systems are allowed to operate until they completely fail due to the difficulty of repair or servicing. Repair labor costs can be reduced significantly by planning ahead and designing for easy pump replacement. Provisions 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 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 §110.3(c)5C.

D. Connection of Recirculation Lines

§110.3(c)4E

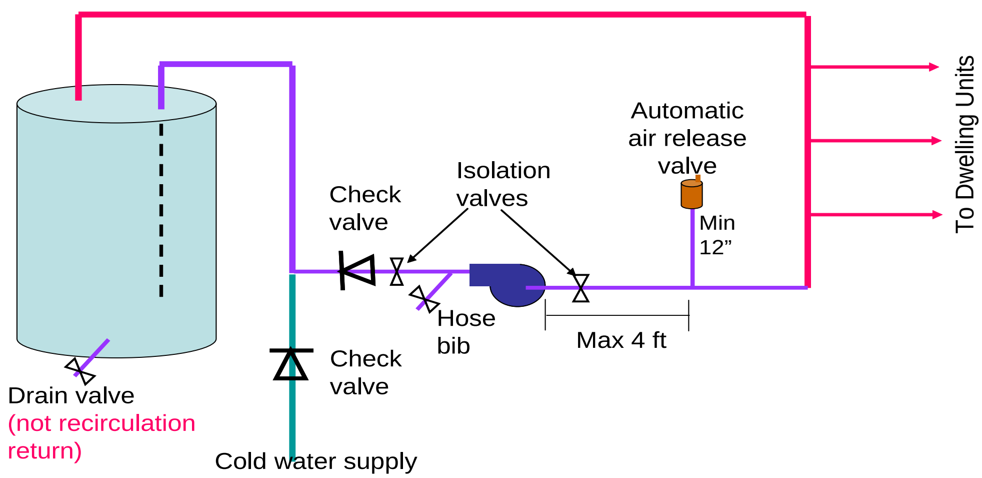
Manufacturer specifications should always be followed to assure optimal performance of the system. The cold water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

E. Backflow Prevention in Cold Water Supply

§110.3(c)4F

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. The system shall comply with the expansion tank requirements as described in the California Plumbing Code Section 608.3.

Figure 4-31: 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. The applicability of the mandatory features listed above will change depending on whether the water heating system has a central system or uses individual water heaters.

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 4-23.

- The first five feet of pipe for 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 must 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 three quarters of an 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 is required. Insulation is also 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 is not 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 an 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 four inches of insulation are not required to have pipe insulation. Any section of pipe not covered with at least four inches of insulation must be insulated.
- In walls, all of the requirements must be met for compliance with Quality Insulation 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. A new provision allows a reduced SSF in certain climate zones, if drain water heat recovery devices are installed. 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 a 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 the 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 2019 Energy Standards is 35 percent. Industry standard sizing for an active system is generally 1.5 sq ft collector area per gallon capacity for solar tanks. For more detailed guidance and best practices, there are many publicly available industry design guidelines. Two such resources developed by or 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 the solar tank. The design should minimize the length of plumbing, and thus reduce pipe surface areas susceptible to heat loss as well as the quantity of piping materials needed for the installation. The distance between collectors and the 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 4-34In 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, refer to the Universal Plumbing Code.

Figure 4-32: Example of a Dual-Loop Recirculation System

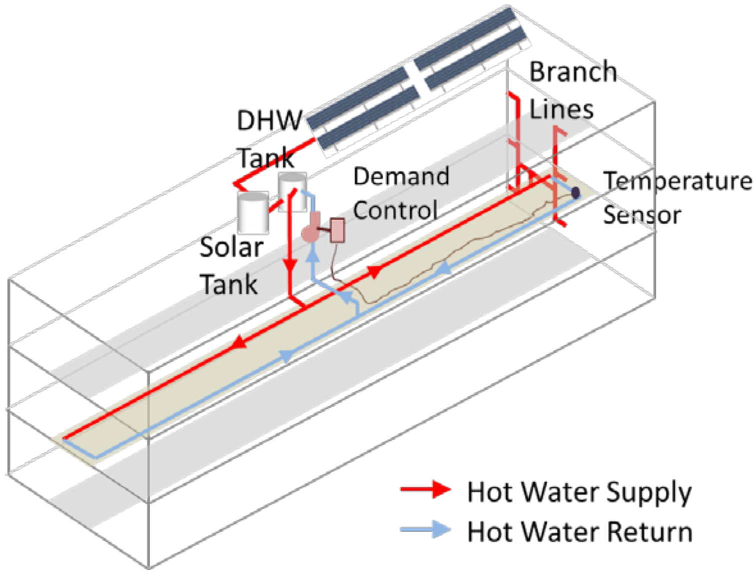
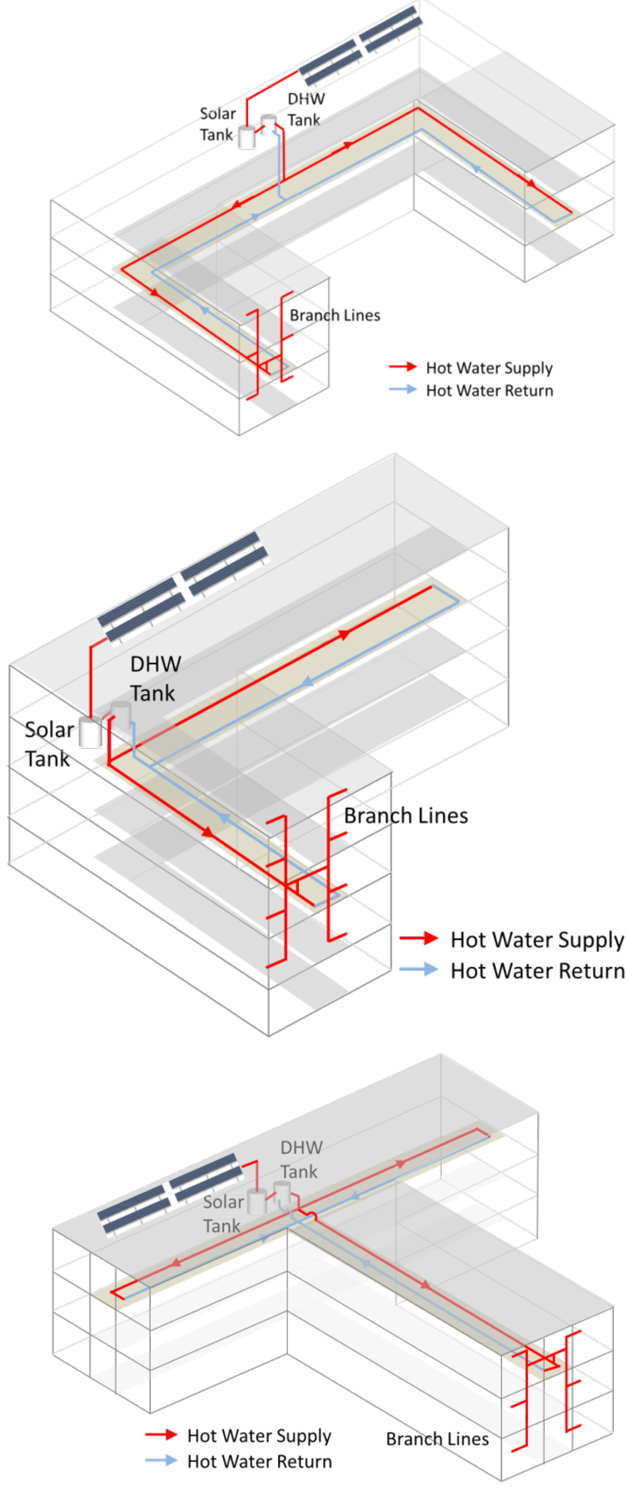


Figure 4-34 provides an example of how to implement dual-loop design in a low-rise multi-family building with a simple layout. In this example, the water heating equipment is located in the middle of the top floor with each recirculation loop serving exactly half of the building. The recirculation loops are located in the middle floor to minimize branch pipe length to each of the dwelling units. Figure 4-34also 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 an 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 section. 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 4-35shows examples of dual-loop recirculation system designs in buildings that have complicated floor plans.

Figure 4-33: 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. For 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 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. 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 domestic hot water (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. 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
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
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.

No electric resistance heating, except:

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.

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 one of three 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, (example: 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 Energy Commission. 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 based on features required for prescriptive compliance. Detailed information can be found in the Nonresidential Alternative Calculation Methods (ACM) Approval Manual.

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 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 base case 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 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.

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 the envelope, HVAC system, indoor lighting and covered processes.

The alternative calculation method defines the modeling rules for developing the base-case model of the building and mechanical systems. The base-case HVAC system(s) is modeled on a system(s) according to 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, generally, 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 requirements.

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 do not need to 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 4-24: Requirements for Additions and Alterations

Mandatory Measure	Application to Additions and Alterations
§110.1 – Mandatory equirements 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 only the isolation areas that need it and other isolation areas can be shut off. This applies to additions larger than 25,000 sq ft and to the replacement of existing systems when the total area served is greater than 25,000 sq ft. §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 for all newly added air handler units 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 DDC in new construction, additions or alterations for certain applications and qualifications. It also requires certain capabilities for mandated DDC systems. §120.2(k) requires 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 the 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.

For more detailed information, see Chapter 11, Performance Approach.

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 when 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 Systems 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 (e.g., insulation levels, sealing materials and methods).

If the ducts are part of a single zone constant volume system serving less than 5,000 sq ft and more than 25 percent of the ducts are outdoors or in unconditioned areas (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 more 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.

Alternatively, 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.
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, 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. Certified Acceptance Test Technicians (ATT may perform these field verifications only if the Acceptance Test Technician Certification Provider (ATTCP) has been approved to provide this service.

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 sq ft) 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). 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, which 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, 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. In addition, the system shall include a setback thermostat that meets requirements of §110.12(a).

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 §110.12(a), the existing thermostat must be replaced with one that does comply. All newly installed space-conditioning systems requiring a thermostat shall be equipped with a thermostat that complies with §110.12(a). A thermostat compliant with §110.12(a) is also known as an occupant controlled smart thermostat, 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 an office. Do the Energy Standards apply to this type of work?

Answer

No. 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, the mandatory requirements of §120.1-§120.4 and the prescriptive requirements of §140.4.

Example 4-53

Question

A 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

Yes. 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 sq ft addition is being added to a 25,000 sq ft 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 sq ft addition is being added to a 50,000 sq ft office. The existing packaged VAV system has unused capacity and will be used to serve the addition as well as the existing building. This system has DDC 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 Packaged VAV. However, the ductwork serving the addition would have to be sealed and insulated according to the requirements of §120.4 and the hot water piping would have to be insulated according to the requirements of §120.3 In addition, 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 sq ft addition is added to a 50,000 sq ft 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. For more detailed information, see Section 4.3.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 sq ft addition contains a large 400 sq ft conference room. What additional requirements are triggered in this instance?

Answer

In this case, the demand control requirements of §120.1(d)3 would apply to the conference room, since it has an occupant density greater than 25 persons per 1,000 sq ft and the ackaged VAV system serving the building has an air economizer. If the existing system did not have an air economizer, then the demand control requirements would not apply. A CO2 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 apply, unless the Exception 2 to §141.0(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

Four hundred 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 it would have to be replaced 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

Minimum efficiency requirements that regulated appliances and other equipment must meet are in §110.1 and §110.2. 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 4-11

$$Efficiency = \frac{Output}{Input}$$

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) of Title 20.

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, they are considered to be a form of space heater.

Thermal or combustion 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 12

$$\%\ \text{Combustion Eff} = \frac{(\text{Energy to HX}) \times 100}{\text{Total Fuel Energy Input}}$$

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 4-13

$$\%\ \textit{Thermal Efficiency} = \frac{(\textit{Energy Transferred to Medium})}{(\textit{Total Fuel Input})}$$

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 . Fan systems, as defined in §140.4(c), 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- has 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 to meet 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 (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 is a system that 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 is a system with an air damper whose position is controlled on the basis of measured airflow. The set point 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 air compartment, or chamber, other than the occupied space being conditioned- to which one or more ducts are connected and which forms part of either the supply air, return air or exhaust air system. The return air temperature is usually within a few degrees of space temperature. This may include uninhabited crawl spaces, areas above a ceiling or below a floor, air spaces below raised floors of computer/data processing centers, or attic spaces.

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); 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. The regulations in §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, 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. The regulation in §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 4-36.

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 dry bulb 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 for ventilation purposes, 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 4-34: Integrated Air Economizer

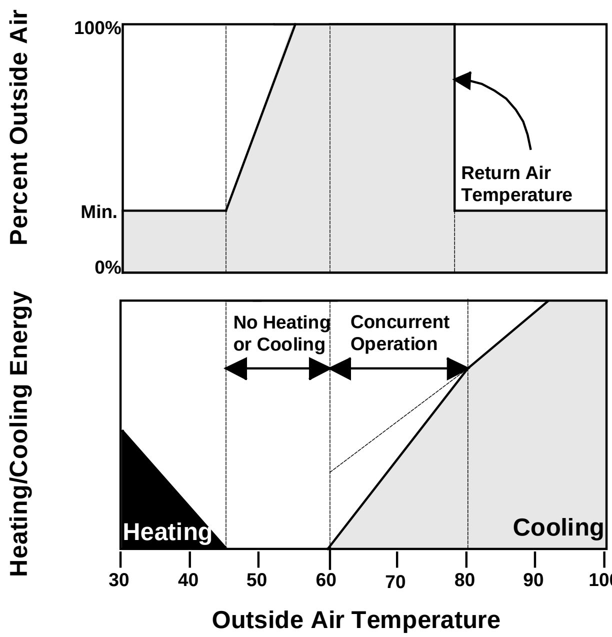
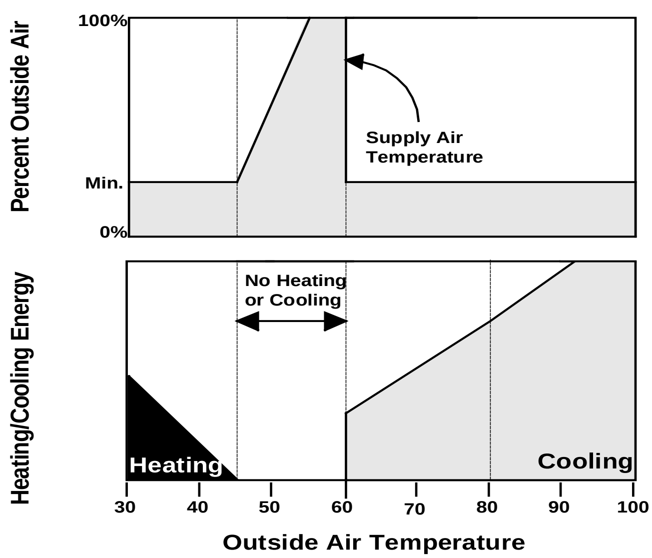


Figure 4-35: Nonintegrated Air Economizer



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.

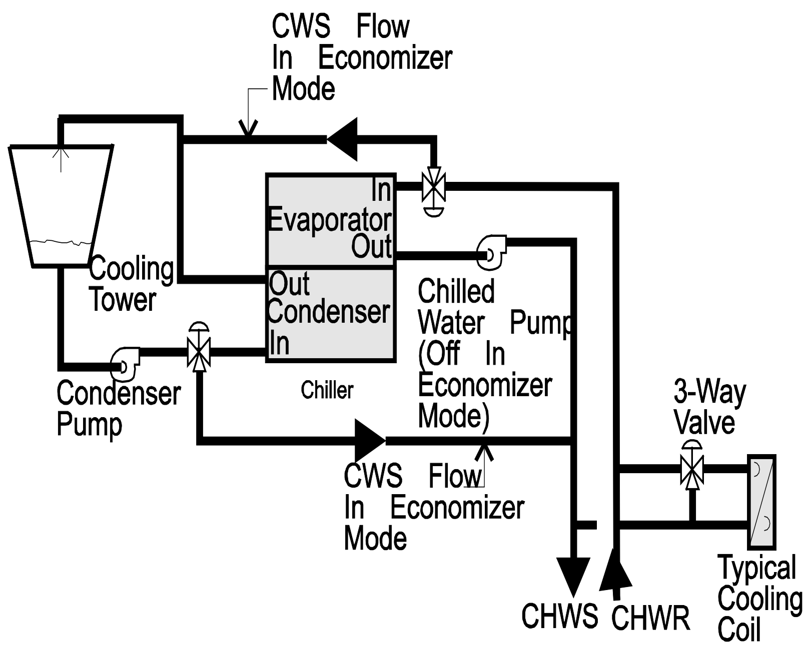
As with an air economizer, a water economizer must be integrated into the system so that the economizer can supply a portion of the cooling concurrently with the refrigeration system.

There are three common types of water-side economizers:

1. **Strainer-cycle or chiller-bypass water economizer** - The system depicted in **Figure 4-38**, 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** - The system depicted in Figure 4-39 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** - The system depicted in Figure 4-41below, 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 all of the anticipated cooling load at the off-design outdoor-air condition of 50 degree F dry bulb/45 degree 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 4-36: "Strainer-Cycle" Water Economizer



This system does not meet the prescriptive requirement as it cannot operate in parallel with the chiller

Figure 4-37: Water-Precooling Water Economizer with Three-Way Valves

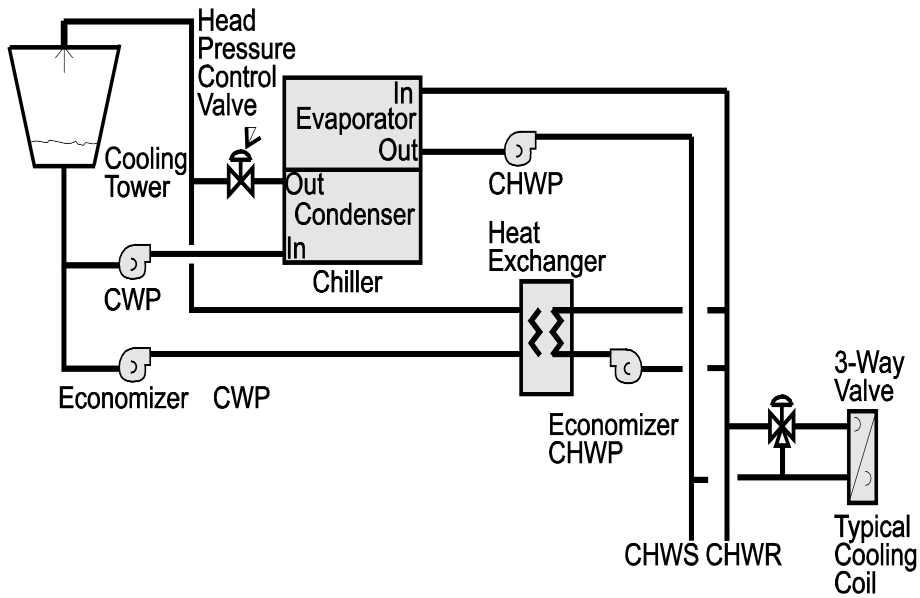


Figure 4-38: Water-Precooling Water Economizer with Two-Way Valves

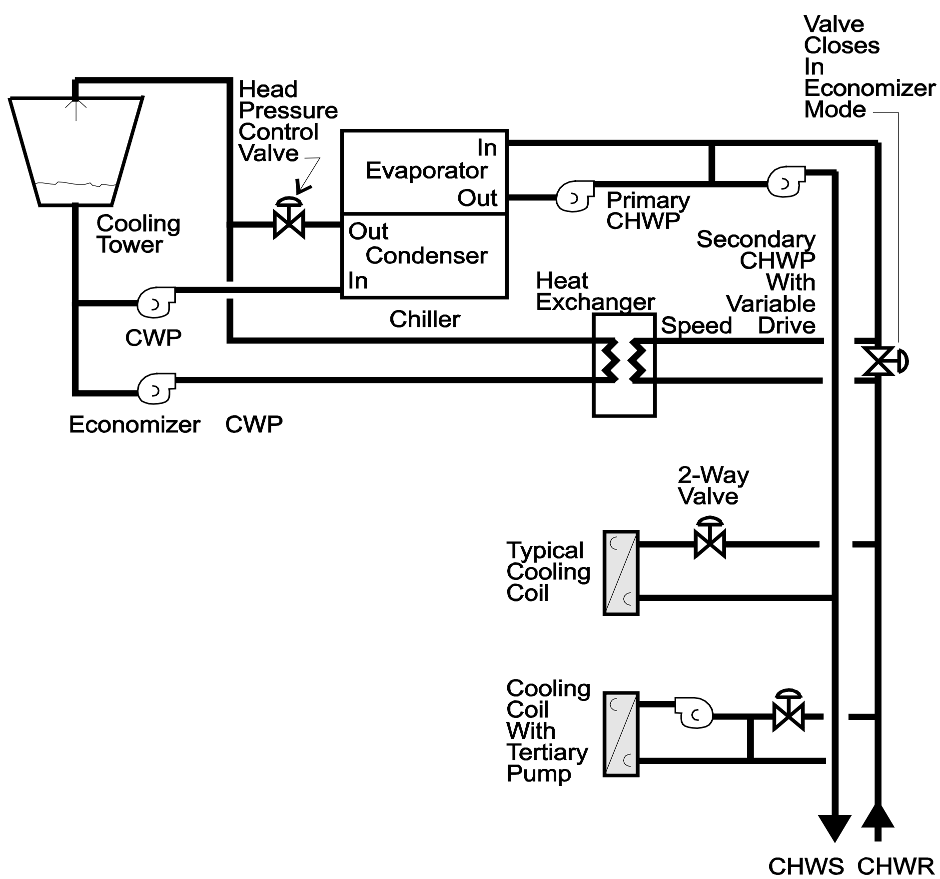
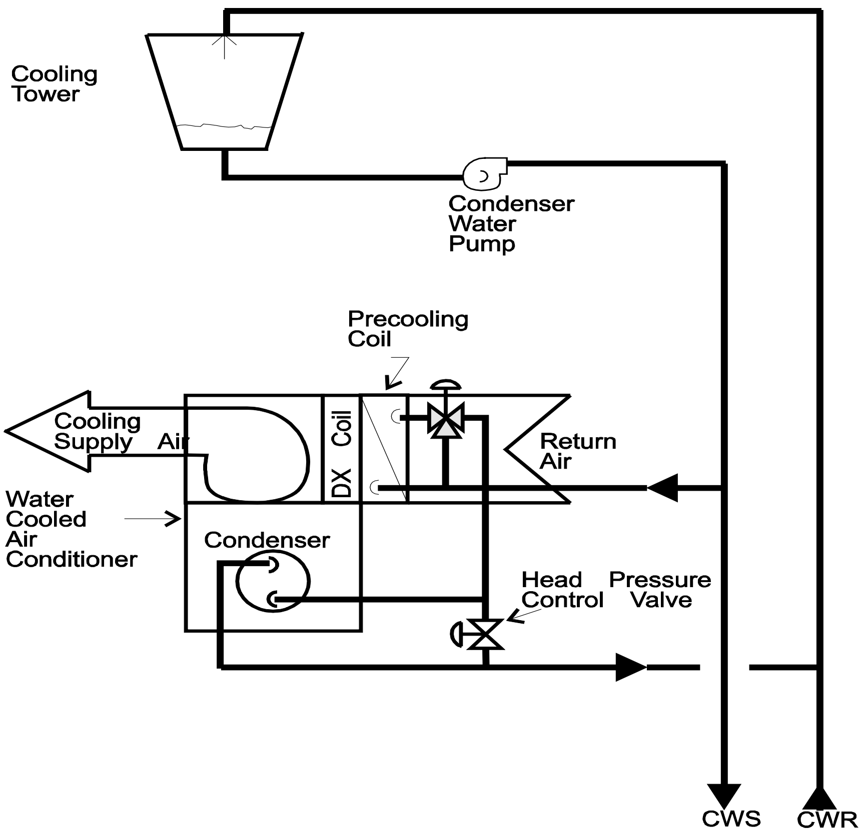


Figure 4-39: Air-Precooling Water Economizer



4.10.8 Unusual Sources of Contaminants

The regulation in §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 air classification is designated in Tables 4-12, 4-13, and 4-14. In addition, guidance for such spaces not listed 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. If the equipment is 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 (DCV)

DCV 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) greater than or equal to 25 people per 1000 sq ft (40 sq ft per person), according to §120.1(c)3. DCV is also allowed as an exception in the ventilation requirements for intermittently occupied systems, see §120.1(d)1,). 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).

The regulation in §120.1 allows for DCV devices that employ a CO_2 sensor. CO_2 sensors measure the level of CO_2, 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.

DCV 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 when the space needs to comply with the occupant sensor control requirements for lighting, see §130.1(c).

Some examples include:

- Offices smaller than 250 sq ft
- Multipurpose rooms smaller than 1,000 sq ft
- Classrooms, conference rooms, and restrooms of any size

4.10.10 Intermittently Occupied Spaces

The DCV 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 require base ventilation 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 and Inspection 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.

The use of each document is briefly described. The information and format of these may be included in the equipment schedule:

NRCC-MCH-E: Certificate of Compliance

This dynamic document is required for every job, and it is required t on the plans. The following are included in the NRCC-MCH-E and only applicable forms will be required to be filled out.

- Major components of the heating and cooling systems, and service hot water and pool systems
  - Outdoor air ventilation rates
  - System fan power consumption

NRCC-PLB-E: Certificate of Compliance – Water Heating System General Information

This dynamic document is required for every job, and it is required t on the plans. The following are included in the NRCC-MCH-E and only applicable forms will be required to be filled out.

- All hot water systems
- Individual water heating systems installed in dwelling units in high-rise residential buildings and hotel / motels
- Central water heating systems that service multiple dwelling units installed in high-rise residential buildings and hotel/motels

4.11.1 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-E Certificate of Compliance document printed on the plans.

4.11.2 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.

For more detailed information on acceptance tests, see Chapter 13.

4.11.2.1 Acceptance 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 document results
3. Document the operating and maintenance information, complete the certificate of installation and indicate test results on the certificate of acceptance, and submit the certificates to the enforcement agency prior to receiving a final occupancy permit.

4.11.2.2 Administration

The administrative requirements contained in the Energy Standards require the following:

1. Requirements for acceptance testing of mechanical systems and equipment shown in the table below are included in the plans and specifications:

Table 4-25: 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

2. Within 90 days of receiving a final occupancy permit, record drawings be provided to the building owners
3. Operating and maintenance information be provided to the building owner
4. 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 proper function the relief air. 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.

4.11.2.3 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.

4.11.2.4 Testing

The construction inspection is the first step in performing the acceptance tests. In general, this inspection should identify that:

1. Mechanical equipment and devices are properly located, identified, and calibrated.
2. Set points and schedules are established.
3. Documentation is available to identify settings and programs for each device.
4. Select tests to verify acceptable leakage rates for air distribution systems while equipment access is available. Testing is to be performed on the following devices:
   - VAV 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.

4.11.2.5 Roles and Responsibilities

The installing contractor, engineer of record or owner's 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 owner's agent (upon completion of all required acceptance 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.

4.11.2.6 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 at 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.

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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 conditioned and unconditioned nonresidential buildings. This chapter 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 Energy Standards primarily requires that total lighting power is within a specified budget, and that lighting controls allows for the efficient operation of installed lighting. This ensures that energy efficient equipment is used to satisfy building lighting needs.

5.1.1 What's New for the 2019 California Energy Code?

Significant changes for indoor lighting systems in the 2019 update to the Energy Standards include:

- Revisions to all indoor lighting power allowances so that the allowances are based on LED lighting technologies.
- Compliance with the standard is allowed for other appropriate lighting technologies.
- Revisions to Lighting Power Density (LPD) values in Tables 140.6-B thru 140.6-G.
- Revision and streamlining of luminaire classification and wattage requirements.
- New lighting power adjustment for small aperture tunable white LED and dim-to-warm LED luminaires.
- New mandatory occupancy sensing controls for restrooms.
- Clarification and streamlining of manual area control requirements, multi-level lighting control requirements, and automatic daylighting control requirements.
- New Power Adjustment Factors (PAFs) for advanced daylighting devices including clerestories, horizontal slats, and light shelves.
- Revisions and streamlining of alteration requirements. Changes include merging three sections into a single "Altered Indoor Lighting Systems" section and aligning two reduced power options on controls. Table 141.0-F was also revised and consolidated.
- Elimination of the installation certification requirements for line voltage track lighting current limiters and supplementary overcurrent protection panels.
- Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) must comply with some applicable indoor lighting controls requirements as well as the indoor lighting power requirements under the "prescriptive method."

5.1.2 Scope

- The Energy Standards nonresidential indoor lighting requirements are contained in §100.0, §110.9, §110.12, §120.8, §130.0, §130.1, §130.4, §140.0, §140.1, §140.3, §140.6, and §141.0. Their supporting definitions are in §100.1.
- The nonresidential indoor lighting requirements apply to nonresidential buildings, high-rise residential buildings (except dwelling units), and hotel/motel occupancies (including guest rooms).
- The nonresidential indoor lighting requirements are the same for unconditioned spaces and conditioned spaces. Trade-offs are not allowed between unconditioned and conditioned spaces.
- Interior common areas in low-rise multi-family residential buildings are required to comply with the nonresidential indoor lighting requirements if the common area exceeds 20 percent of the building floor area (See §150.0(k)6B).
- High-rise residential dwelling units are required to comply with low-rise residential lighting requirements. The low-rise residential lighting requirements are covered in chapter 6 of the 2019 Residential Compliance Manual.
- Hotel/motel guest rooms are covered by portions of both the nonresidential indoor lighting requirements and the low-rise residential indoor lighting requirements. The low-rise residential indoor lighting requirements are covered in chapter 6 of the 2019 Residential Compliance Manual.
- Qualified historic buildings are not covered by the Energy Standards, as stated in exception 1 to §100.0(a). They are regulated by the California Historical Building Code. However, non-historical components of the buildings such as lighting equipment may need to comply with the Energy Standards. 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 Residential Functional Areas in Nonresidential Buildings

The following functional areas in nonresidential, high-rise residential, and hotel/motel occupancies are required to comply with the low-rise residential lighting standards as defined in §130.0(b):

- High-rise residential dwelling units.
- Outdoor lighting attached to a high-rise residential or hotel/motel building and separately controlled from inside of a dwelling unit or guest room.
- Fire station dwelling accommodations.
- 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.

- Dormitory and senior housing dwelling accommodations.

Note that the above requirements also apply to additions and alterations to functional areas of existing buildings specified above.

All other functional areas in nonresidential, high-rise residential, and hotel/motel occupancies such as common areas, shall comply with the applicable nonresidential lighting standards.

5.1.4 Indoor Lighting Power Allotments

Lighting power allotments are the established maximum lighting power that can be installed based on the compliance approach used, the building type, and building 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 nonresidential building occupancy type (as defined in §100.1). The complete building method may also be used for a tenant space in a multi-tenant building if at least 90 percent of the tenant space is one building occupancy type. A single lighting power density value governs the entire building or tenant space.

B. **Prescriptive approach – Area Category Method**: applicable for any permit situation including tenant improvements. Lighting power density 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. The Tailored Method and the Area Category Method can be used in conjunction when some areas in a building use the Tailored Method while others use the Area Category Method.

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 envelope 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 Compliance Process - Forms, Plan Check, Inspection, Installation, and Acceptance Tests

The compliance process begins with the builder submitting certificates of compliance to the responsible code enforcement agency. The certificates provide all design information necessary to show that the proposed project will comply with the Energy Standards. Construction may not begin until all certificates of compliance are reviewed and approved by the agency.

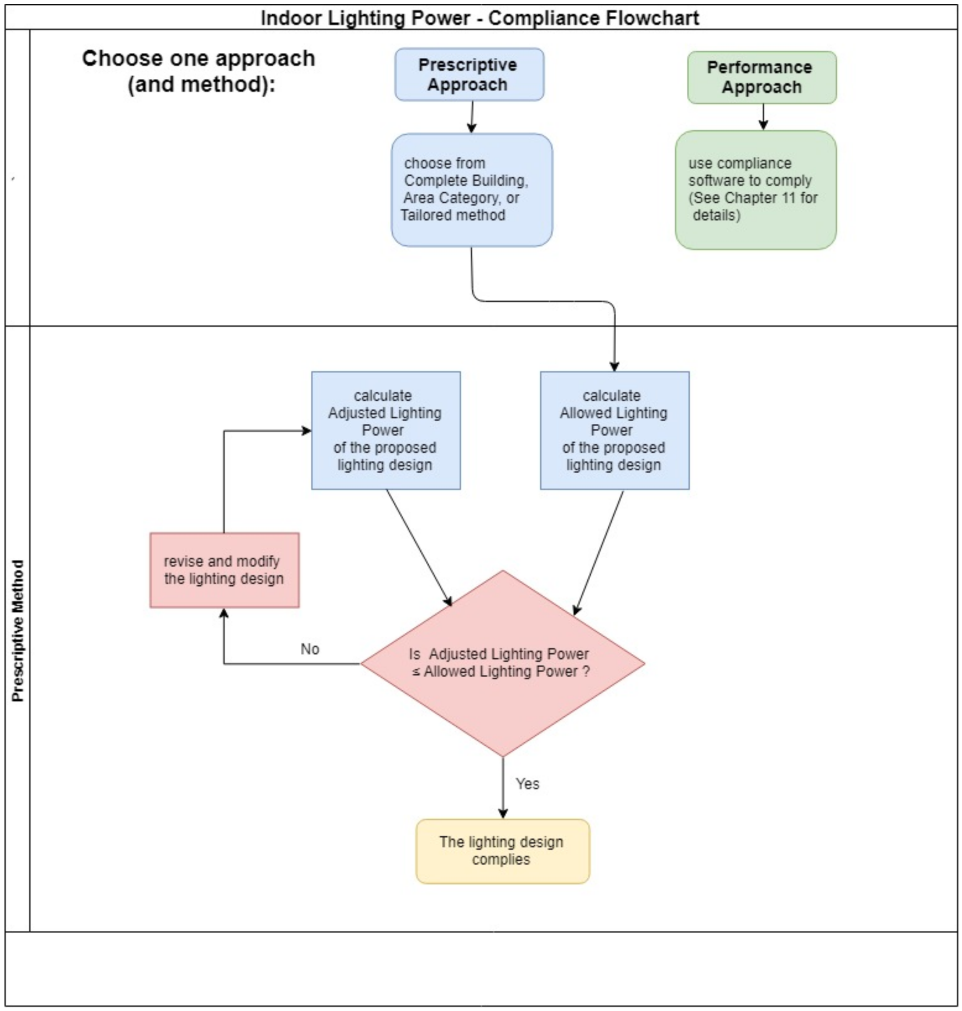
As construction proceeds, builders must submit certificates of installation certifying that installed equipment and systems meet or exceed the design criteria specified in the approved certificates of compliance. Code enforcement officials may conduct field inspections to verify information submitted 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 per code requirements.

If inspections or acceptance tests identify noncompliant or nonfunctional systems, these defects must be fixed. Once the code enforcement agency determines the project complies with all building code requirements, including the energy code, the building will receive a certificate of occupancy that certifies that the building is in compliance with the building code.

5.1.6 Compliance Process - Overview

Figure 5-1 below, shows the process for complying with the nonresidential indoor lighting requirements.

Figure 5-1: Lighting Compliance Flowchart



A. Choose a compliance method (refer to the top part of Figure 5-1):

First, select either the prescriptive or performance approach for complying with the nonresidential indoor lighting power requirements of the Energy Standards.

For the performance approach method, lighting power calculations can be performed using an approved software program (such as CBECC-Com). Refer to the compliance software documentation for details.

For the prescriptive approach, choose from among the complete building method, the area category method, or the tailored method.

Next, calculate the “allowed” lighting power and the “adjusted” lighting power.

Allowed lighting power is the total of all of the lighting allowed (using lighting power values from Table 140.6-B, C and D).

Adjusted lighting power is design lighting power *minus* lighting control credits *minus* lighting power reduction.

B. **Evaluate the calculations – allowed lighting power vs adjusted lighting power**

If you calculate that the adjusted lighting power is less than or equal to the allowed lighting power, the proposed lighting complies with the Energy Standards.

If you calculate that the adjusted lighting power is greater than the allowed lighting power, the proposed lighting does not comply with the Energy Standards. In that case, either the proposed lighting power must be reduced, or additional lighting credits must be acquired through improved efficiency in other systems.

5.2 General Requirements

Some requirements in the nonresidential lighting standards are classified as "mandatory requirements" because they are required regardless of the compliance approach used. All projects must comply with all mandatory requirements.

It is the responsibility of the designer to design the lighting system and specify products that meet these requirements. It is the responsibility of the installer to install the lighting and controls specified on the plans. It is the responsibility of code enforcement officials to verify that the mandatory features and specified devices are included on the plans and installed in the field.

The mandatory measures for nonresidential indoor lighting include:

- Certain functional areas in nonresidential buildings must 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), §110.1, and §110.9(a)).
- Requirements for how luminaires shall be classified (according to technology),and how installed lighting power shall be determined (§130.0).
- Required indoor lighting controls (§130.1).
- Lighting control acceptance testing (§130.4(a)).
- Lighting control Certificates of Installation (§130.4(b)).

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.

5.3 Luminaire Classification and Determination of Power

§130.0(c)

Luminaires and light sources emit light and provide illumination to spaces. The Energy Standards include a system of classification to account for the power of luminaires and lighting systems and to use the information for compliance purpose.

Below is the list of various types of luminaires as described and classified in Section 130.0(c) of the Energy Standards:

- Luminaires with line-voltage lamp holders
- Luminaires with ballasts

- Inseparable solid state lighting (SSL) luminaires and SSL luminaires with remote ballasts
- LED tape lighting and LED linear lighting
- Modular lighting systems
- Other lighting equipment

For meeting the prescriptive or performance requirements for indoor lighting, the wattage of all planned lighting systems, including permanent lighting and portable lighting, shall be determined as follows.

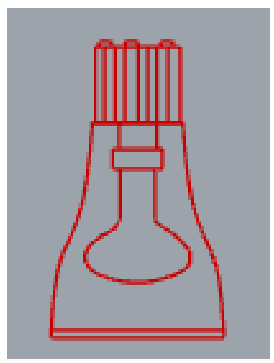
A. Luminaires with line-voltage lamp holders

The wattage of luminaires with line-voltage lamp holders not containing permanently installed ballast or transformers shall be the maximum rated wattage of the luminaire.

For recessed luminaires with line-voltage medium base sockets, wattage shall not be less than 50 watts per socket, or the rated wattage of the installed JA8 compliant lamps.

The 2019 Energy Standards allow the wattage of JA8 lamps to be used as the wattage of recessed luminaires. This provides another option for designers, engineers and installers for their compliance use of luminaires with line-voltage lamp holders.

Figure 5-2 Sample of Luminaire with line-voltage lamp holders



Source: CEC Staff

B. Luminaires with ballasts

The wattage of luminaires with permanently installed or remotely installed ballasts shall be the operating input wattage of the rated lamp/ballast combination.

This wattage information can be found in the ballast manufacturer’s catalogs based on independent testing lab report as specified in UL 1598.

Figure 5-3 Samples of Luminaires with ballasts:

Fluorescent-lamp luminaire (Left); HID-lamp luminaire (Right)

Source: Acuity Brands Lighting, Inc.; Source: CEC Staff

C. Inseparable Solid State Lighting (SSL) luminaires and SSL luminaires with remotely mounted drivers

The wattage of inseparable SSL luminaires and SSL luminaires with remote ballasts shall be the maximum rated input wattage of the SSL luminaires.

Inseparable SSL luminaires are luminaires manufactured with the solid state lighting components which are not readily removed or replaced from the luminaires by the end users.

SSL luminaires shall be tested in accordance with UL 1598, 2108, 8750 or IES LM-79.

Figure 5-4 Samples of SSL Luminaires:

Recessed Downlight Luminaires (Left; Right)

Source: © 2018 Lutron Electronics Co., Inc. All rights Reserved

D. LED tape lighting and LED linear lighting

LED tape lighting can be installed in length by installers on a project site as determined by the lighting design requirements. LED tape lighting is not like legacy luminaires which are manufactured in a pre-determined dimension per customer order.

The wattage of the luminaire or lighting system shall be the sum of the installed length of the tape lighting *times* its rated linear power density in W/ft (or the maximum rated input wattage of the driver or power supply providing power to the lighting system).

Tape lighting shall be tested in accordance with UL 2108, 8750, or IES LM-79.

Figure 5-5 Samples of Tape Lighting

Source: NORA Lighting

E. Modular lighting systems

Track mounted luminaires as well as rail mounted luminaires are examples of modular lighting systems. The wattage of modular lighting systems that allow the addition or relocation of luminaires without altering the wiring of the systems shall be determined as follows.

The wattage shall be the greater of 30 watts per linear foot of track or plug-in busway; or, the rated wattage of all of the luminaires in the system (where the luminaire wattage is as specified by UL 1574, 1598, 2108, or 8750)

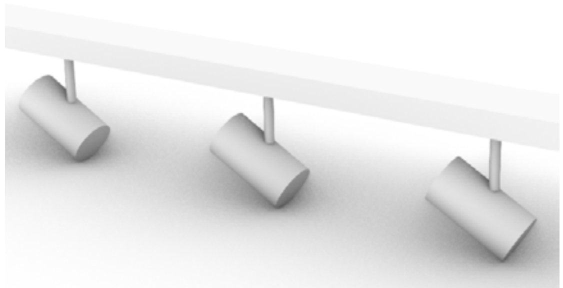
1. For line-voltage track lighting and plug-in busway served by a track lighting current limiter, the wattage shall be the volt-ampere rating of current limiter as specified by UL 1077
2. For line-voltage track lighting and plug-in busway served by a track lighting protection panel, the wattage shall be the sum of ampere rating of all of the overcurrent protection devices times the branch circuit voltage for the track lighting protection panel; or
3. For other modular systems with power supplied by a driver, power supply or transformer, including low-voltage lighting systems, the wattage shall be the maximum rated input wattage of the driver, power supply or transformer as specified by UL 2108 or 8750

4. For power-over-Ethernet lighting system, the wattage shall be the total power rating of the system less any installed non-lighting devices.

Figure 5-6 Samples of Modular Lighting Systems:

A Track Lighting System 3D View (Top);

Track Lighting Systems in a Lobby Lighting Application (Bottom)



Source: CEC

Source: Acuity Brands Lighting, Inc.

F. Other lighting equipment

For all other lighting equipment not addressed by item A through E, the wattage of the lighting equipment shall be the maximum rated wattage of the lighting equipment, or operating input wattage of the system, based on independent testing lab reports as specified by UL1547, 1598, 2108, 8750, or IES LM-79.

Example 5-1 Power-over-Ethernet (PoE) Lighting

Question

What is a Power-over-Ethernet (PoE) lighting system?

Answers

A Power-over-Ethernet (PoE) lighting system is an emerging lighting technology which provides low-voltage direct current (DC) and communication over ethernet cabling. The direct current powers the luminaires of the system. Most conventional lighting systems use alternating current (AC) to power luminaires.

A PoE lighting system usually contains three main components – a powered device (PD), ethernet cabling, and power sourcing equipment (PSE) such as ethernet switches. PSE is a general term used for PoE power supply.

PSEs supply power via Ethernet cabling to PD’s, such as PoE luminaires.

Example 5-2 Power-over-Ethernet (PoE) Lighting

Question

What is the wattage of a PoE lighting system that contains a PoE switch, PoE luminaires, occupancy sensors, one daylight sensors, wall switch stations?

Answers

One way to determine the answer is to account for the wattage of all of the luminaires in the lighting system as the wattage of the PoE lighting system. Since there are nine PoE luminaires plus other non-lighting loads (sensors and switches), the wattage of the PoE lighting system is the sum of the wattage of all PoE luminaires excluding the sensors and switches.

Another way is to account for the total power rating of the system less any non-lighting devices such as occupancy sensors, sensing devices and switch controls.

5.4 Mandatory Lighting Controls

§131.0

This section contains information about lighting controls that must be installed, regardless of the method, 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. Manual area controls. Manual on and off 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. Shut-off controls. Automatically shutting off or reducing light output of lighting when the space is vacant.
4. Automatic daylighting controls. Separately controlling general lighting in the day lit area based on amount of daylight in the space.
5. Demand responsive lighting controls. Installing controls that are capable of receiving and automatically responding to a demand response signal.

5.4.1 Manual Area Controls

§130.1(a) of Part 6; §10-103(a)2 of Part 1

Each building area shall provide lighting controls that allow lighting in that area to be manually turned on and off. The manual area controls provide the building users and occupants a mean to control the light while they are in the space.

For egress lighting required by the Building Code (California Building Code), there is a provision that allows the egress lighting to be continuously on for up to 0.2 W/sq ft. of indoor lighting power during occupancy.

Egress lighting that complies with this wattage limitation is not required to comply with manual area control requirements if:

1. The means of egress area is shown on the building plans (including specifications) and is submitted to the enforcement agency.
2. The egress lighting controls are inaccessible to unauthorized personnel.

5.4.1.1 Requirements for On and Off Controls

The manual on and off lighting controls shall meet all of the following requirements:

1. Be readily accessible.

   EXCEPTION: Public restrooms having two or more stalls, parking areas, stairwells, and corridors may use a manual control not accessible to unauthorized personnel.

2. Be located in the same room or area as the lighting that is being controlled by that controller.

   EXCEPTION:

   i. For 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, arenas, psychiatric and secure areas in healthcare facilities, and other areas where placement of a manual area control poses a health and safety hazard, the manual area control shall instead be located so that a person using the control can see the lights or area controlled by that control, or visually signal or display the current state of the controlled lighting.

   ii. Healthcare facility restrooms and bathing rooms that are intended for a single occupant can have lighting controls located outside the enclosed area but directly adjacent to the door.

3. General, floor display, wall display, window display, case display, ornamental, and special effects lighting require separate controls that allow each type of lighting to be turned on and off but without turning on or off other types of lighting or other equipment.

5.4.2 Multi-Level Lighting Controls

§130.1(b) & Table 130.1-A

Multi-level lighting control requirements allow the lighting level to be adjusted to accommodate the activities of a room.

This requirement applies to general lighting in enclosed spaces 100 sq. ft. or larger and with a connected general lighting load greater than 0.5 W/sq. ft. General lighting does not include task lights, display, or ornamental lighting.

The lighting also must have the required number of control steps and meet the uniformity requirements in accordance with Table 130.1-A.

Dimming can be implemented in steps or over a continuous range. Continuous dimming provides a smoother transition of light levels in comparison to stepped dimming, and is one factor to consider when choosing one dimming technology over another.

EXCEPTION: The following applications are not required to comply with the multi-level lighting control requirements.

1. An area enclosed by ceiling height partitions with only one luminaire containing no more than two lamps.
2. Restrooms.
3. Healthcare facilities.

Note that there are two exceptions to part of the requirements of Table 130.1-A for classrooms and other space types. Refer to end of Table 5-1 appeared on next two pages.

Table 5-1 (Table 130.1-A): Multi-Level Lighting Controls and Uniformity Requirements

<table>
<tr><th>Luminaire Type</th><th colspan="4">Minimum Required Control Steps
(percent of full rated power[1])</th><th>Uniform level of illuminance shall be achieved by:</th></tr>
<tr><td>Line-voltage sockets except GU-24</td><td colspan="5" rowspan="4">Continuous dimming 10-100%</td></tr>
<tr><td>Low-voltage incandescent systems</td></tr>
<tr><td>LED luminaires and LED source systems</td></tr>
<tr><td>GU-24 rated for LED</td></tr>
<tr><td>GU-24 sockets rated for fluorescent > 20 watts</td><td colspan="5" rowspan="2">Continuous dimming 20-100%</td></tr>
<tr><td>Pin-based compact fluorescent > 20 watts[2]</td></tr>
<tr><td>GU-24 sockets rated for fluorescent ≤ 20 watts</td><td colspan="4" rowspan="3">Minimum one step between 30-70%</td><td rowspan="3">Stepped dimming; or
Continuous dimming; or
Switching alternate lamps in a luminaire</td></tr>
<tr><td>Pin-based compact fluorescent ≤ 20 watts[2]</td></tr>
<tr><td>Linear fluorescent and U-bent fluorescent ≤ 13 watts</td></tr>
<tr><td rowspan="2">Linear fluorescent and U-bent fluorescent > 13 watts</td><td colspan="4">Minimum one step in each range:</td><td rowspan="2">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</td></tr>
<tr><td>20-40%</td><td>50-70%</td><td>75-85%</td><td>100%</td></tr>
</table>

<table>
<tr><td>Track Lighting</td><td>Minimum one step between 30 – 70%</td><td>Step dimming; or
Continuous dimming; or
Separately switching circuits in multi-circuit track with a minimum of two circuits.</td></tr>
<tr><td>HID > 20 watts</td><td rowspan="3">Minimum one step between 50 – 70%</td><td rowspan="3">Stepped dimming; or
Continuous dimming; or
Switching alternate lamps in each luminaire, having a minimum of 2 lamps per luminaire, illuminating the same area and in the same manner.</td></tr>
<tr><td>Induction > 25 watts</td></tr>
<tr><td>Other light sources</td></tr>
<tr><td colspan="3">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</td></tr>
<tr><td colspan="3">EXCEPTION 1 to Table 130.1-A Minimum Required Control Steps: Classrooms with a connected general lighting load of 0.7 watts per square feet or less shall have a minimum of one control step between 30-70 percent of full rated power, regardless of luminaire type.
EXCEPTION 2 to Table 130.1-A Minimum Required Control Steps: Library stack aisles, aisle ways and open areas in warehouses, parking garages, parking areas, loading and unloading areas, stairwells, and corridors shall have a minimum of one control step between 20-60 percent of full rated power, regardless of luminaire type.</td></tr>
</table>

5.4.3 Shut-Off Controls

§130.1(c)

All installed indoor lighting shall be equipped with controls that are able to automatically reduce lighting power when the space is typically unoccupied.

EXCEPTION: Healthcare facilities are not required to meet the shut-off control requirements.

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 a space enclosed by ceiling height partitions not exceeding 5,000 square feet.

D. 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: In the following functional areas, the area controlled may exceed 5,000 square feet, but may not exceed 20,000 square feet:

a. Mall
b. Auditorium
c. Single tenant retail
d. Industrial
e. Convention center
f. Arena

E. Separate controls for general, display, ornamental, and display case lighting.

Automatic time-switch controls may include a manual-on mode.

5.4.3.1 **General Exceptions to §130.1(c)1:**

The following applications are exempted from the shut-off controls requirements of §130.1(c)1:

1. An area that is in 24-hour use every day of the year.
2. Lighting complying with occupant sensing control requirements of §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 sq. ft. or smaller, multipurpose rooms of less than 1,000 sq. ft., classrooms of any size, conference rooms of any size, or restrooms of any size in accordance with §130.1(c)5.
3. Lighting complying with partial off occupant sensing controls requirements of §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.
4. Up to 0.1 watts per sq. ft. of lighting may be continuously illuminated for egress lighting purpose.
5. Electrical equipment rooms.
6. Lighting that is designated as emergency lighting, and 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 may be used to comply with the automatic shut-off control requirements in §130.1(c)1 only in closets smaller than 70 sq. ft., and server aisles in server rooms.

The maximum timer setting shall be 10 minutes for closets, and 30 minutes for server aisles.

5.4.3.3 **Automatic Time-Switch Controls**

Automatic time-switch controls other than an occupant sensing control, shall include manual override and holiday shut-off.

A. **Manual Override Feature**

A manual override shall be incorporated with lighting controls that meet all of the following:

1. Complies with §130.1(a); and
2. Allows the lighting to remain on for no more than two hours when an override is initiated.

EXCEPTIONS: The following functional areas may have exceed the override time by two hours when a captive-key override is utilized:

- Malls
- Auditoriums
- Single tenant retail
- Industrial
- Arenas

B. **Holiday "Shut-off" Feature**

An automatic holiday shut-off feature shall be incorporated with the automatic time-switch control and will turn off all loads for at least 24 hours before resuming the normally scheduled operation.

EXCEPTIONS: The following functional areas are not required to incorporate the holiday shut-OFF feature:

- Retail stores and associated malls
- Restaurants
- Grocery stores
- Churches
- Theaters

5.4.3.4 **Occupant Sensing Controls**

A. **Part 1 - 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 sq. ft. or smaller.

b. Multipurpose rooms of less than 1,000 sq. ft.

c. Classrooms of any size.

d. Conference rooms of any size.

e. Restrooms 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).

For areas not required by §130.1(b) to have multi-level lighting controls, occupant sensing controls may function as one of the following:

a. A normal occupant sensor.

b. A partial-on occupancy sensor.

c. A vacancy sensor.

Note that multipurpose rooms less than 1,000 sq. ft., classrooms greater than 750 sq ft. and conference rooms greater than 750 sq. ft. are required to be equipped with an occupancy sensor that controls the HVAC thermostat setup and setback and ventilation (§120.2(e)3). That means the occupancy sensor or lighting control system in the space must be capable of triggering the HVAC without fully triggering the lighting load.

In addition to the cost benefit to having the occupancy sensor used to control the lighting also control the HVAC system, it would become immediately apparent if the occupancy sensor fails.

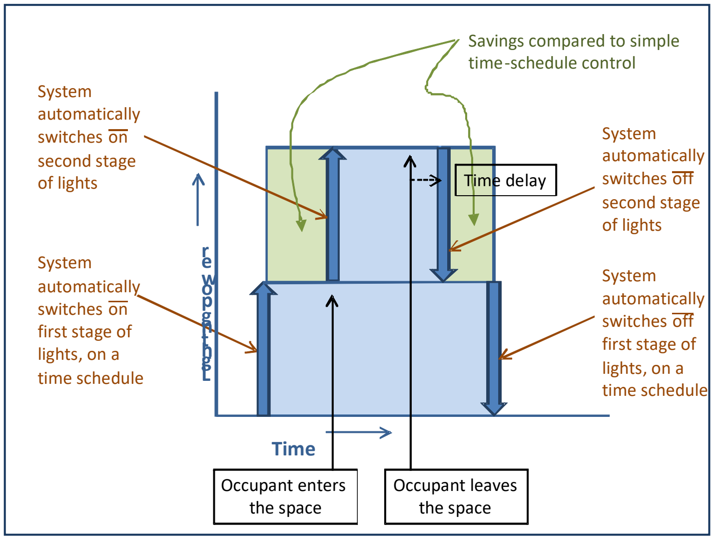
This method of controlling cooling, ventilation and lighting satisfies the requirements of §120.2(e)3 and §130.1(c), so no additional shutoff controls are required in these spaces (except with lighting associated with the egress path. That may remain energized until the building is scheduled to normally be unoccupied).

B. Part 2 - Full or partial off occupant sensing controls – areas where the 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 full or partial off occupancy sensor to reduce or turn off lighting when an area is unoccupied. Lighting in the listed spaces (warehouses, library book stack aisles, and stairwells and corridors) must reduce lighting power by at least 50 percent when they are unoccupied.

Figure 5-7: Functional Diagram for Partial-OFF Occupant Sensor



Egress lighting equipment is exempted and may remain at full power until the building is beyond the “normally occupied” schedule. At that 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 it 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 caused by a limitation of the dimming or bi-level ballast technology for high-intensity discharge (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) and will produce deeper savings during the “after hours” periods.

B. In certain library book stack aisles, 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 will independently control lighting in each aisle way and will 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 automatically activated from all designed paths of egress.

Note: These subsections indicate that the lighting power must be reduced by *at least* 50 percent, but the decision to turn off the lights fully may be made by the designer.

The lighting in this section must also comply with the other portions of §130.1(c) that require lighting to be fully shutoff when the building is typically unoccupied. If a partial-off occupancy sensor is used to reduce lighting when a space is unoccupied, it can be paired with an automatic time switch to turn lighting off fully when the building is unoccupied.

C. Part 3 - Partial off occupant sensing controls – areas where the 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)1. 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 like the requirement for the majority of building lighting.

A. Lighting in stairwells and common area corridors that provide access to guestrooms and dwelling units in 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 requires 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. The following apply to general lighting in parking garages, parking areas and loading and unloading areas, general lighting shall be controlled:

1. Lighting shall be controlled by occupant sensing controls having at least one control step between 20 percent and 50 percent of design lighting power.
2. Lighting shall be controlled using no more than 500 watts of rated lighting power 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. 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.

For these spaces, lighting power must be reduced by at least 50 percent of the design lighting power, and the lighting must be reduced while maintaining similar levels of uniformity to the full power conditions. Note that the zoning of the controls requires careful consideration of paths of egress to ensure that the sensor coverage in the zone is adequate. 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 both of 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:

- Must have a lamp plus ballast mean system efficacy of greater than 75 lumens per watt. (The lamp plus ballast mean system efficacy is the rated mean lamp lumens at 40 percent of lamp life[1] divided by the ballast rated input watts.)
- Must be 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. Controls provisions in §130.1(c)7B do not apply to open rooftop parking.

§130.1(c)7 indicates that the controls 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 §130.1(c)7 are not required to meet the other requirements in §130.1(c) for full shutoff capability (they do not need to be fully shutoff during unoccupied hours).

5.4.3.5 Requirements and Applications 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 that will switch off lighting power within 20 minutes after the room has been vacated.

EXCEPTION: One luminaire in a hotel or motel guest room that meets all the following criteria does not have to be controlled by a captive card key control, occupancy sensing control, or automatic controls:

[1] Illuminating Engineering Society. Section 13.3 “Life and Lumen Maintenance” in The Lighting Handbook: 10th Edition Reference and Application. 2011. New York.

- The luminaire must be classified as high efficacy (where high efficacy is defined in §150.0(k) and Table 150.0-A).
- The luminaire is switched separately from the other lighting in the room.
- The switch for that luminaire is located within 6 feet of the entry door.

This exception allows the occupant to manually control one luminaire. The switch must be located near the entry door to allow the occupant to turn the lighting on when entering the room.

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.

Automatic daylighting 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 §100.1.

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, and exclusive of daylighting (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 a window, a clerestory, a roof monitor, or a 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. 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 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, the skylit daylit zone plan area for a rectangular skylight must be rectangular. For a circular skylight the zone plan area must be circular.

Note: Modular furniture walls should not be considered a permanent obstruction.

Figure 5-8: Skylit Daylit Zone Diagram

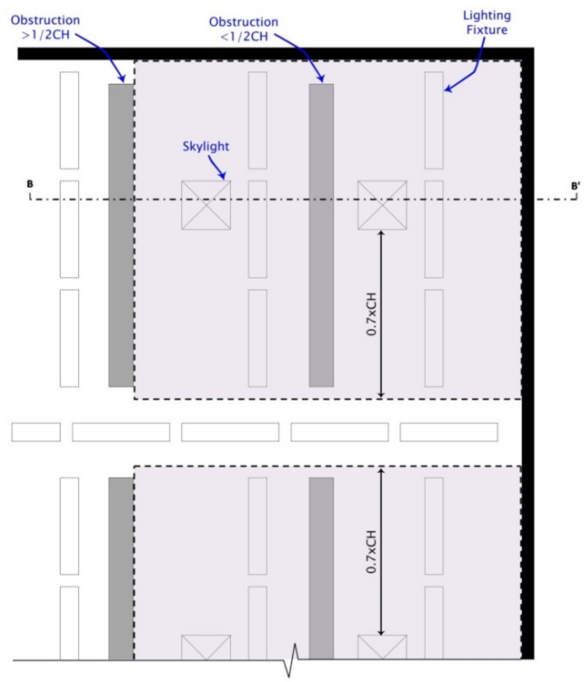
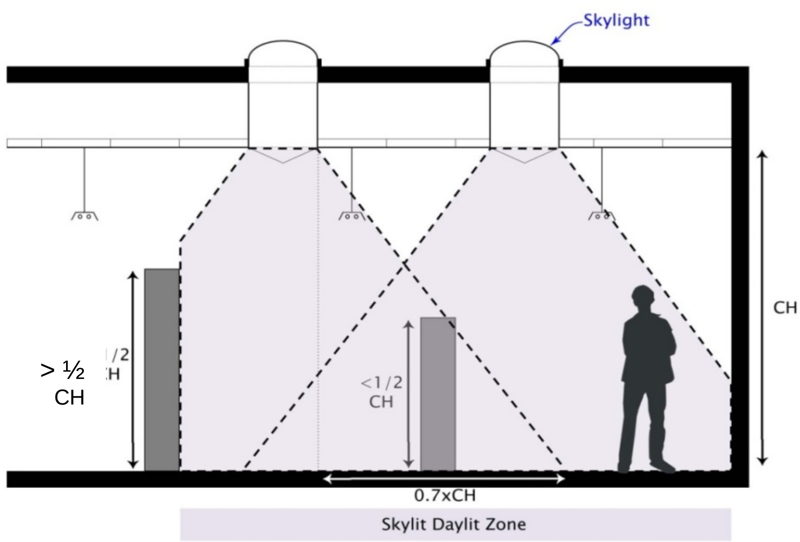


Figure 5-9: Skylit Daylit Zone Diagram 2



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 should not be considered a permanent obstruction.

Figure 5-10: Primary Sidelit Daylit Zone Diagram 1

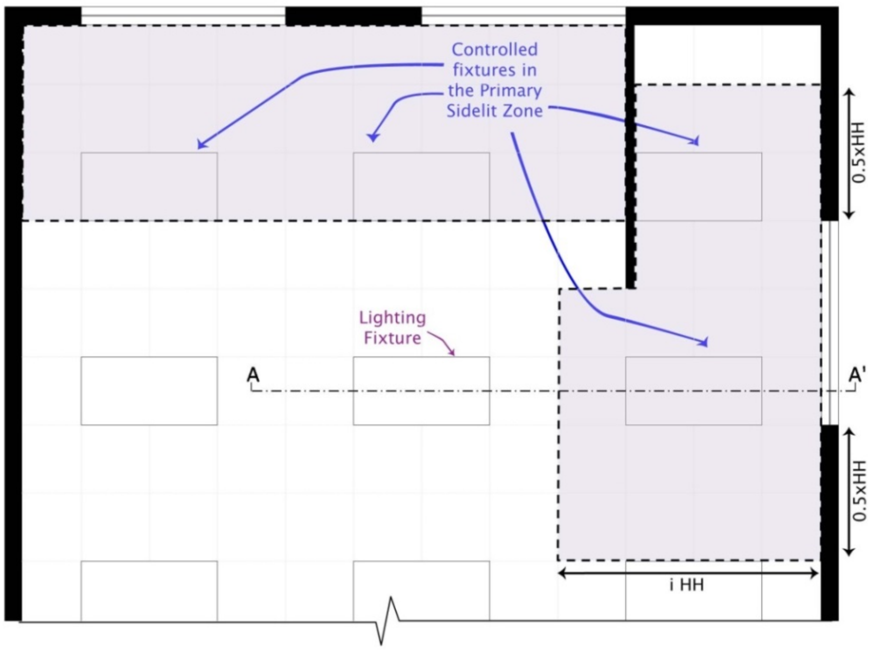
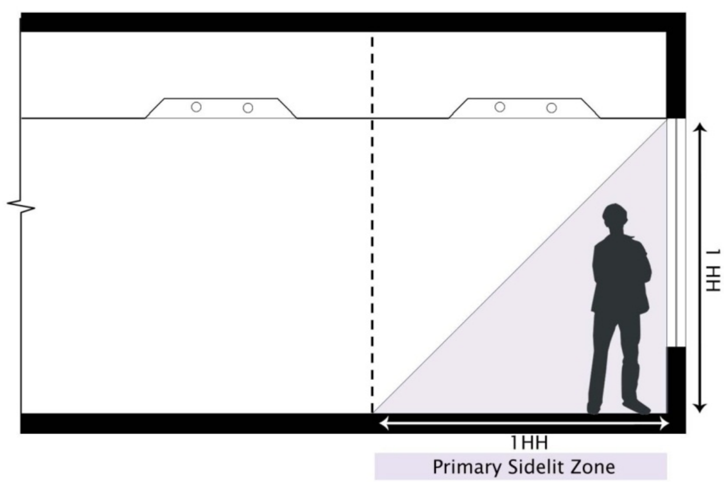


Figure 5-11: Primary Sidelit Daylit Zone Diagram 2



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 should not be considered a permanent obstruction.

The daylighting controls in the skylit daylit zone and the primary sidelit daylit zone are mandatory and cannot be traded away for other efficiency measures when using the performance approach (whole building energy simulation). The daylighting controls requirements in the secondary sidelit daylit zone is prescriptive and 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 5-12: Secondary Sidelit Daylit Zone Diagram 1

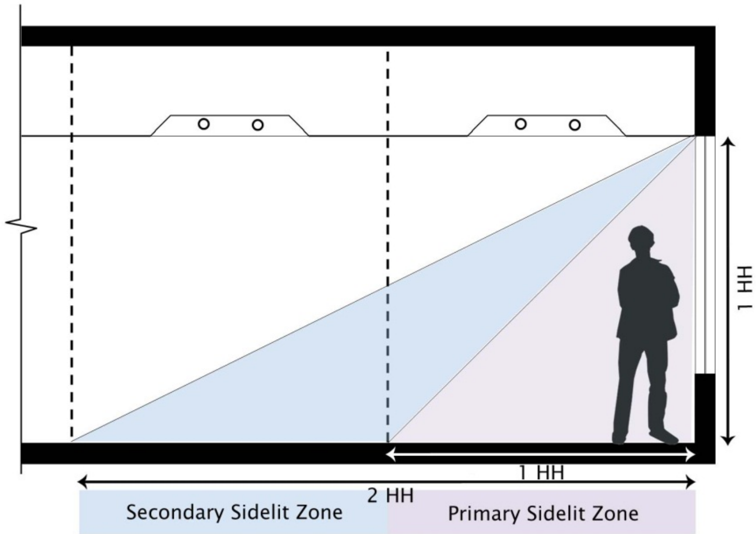
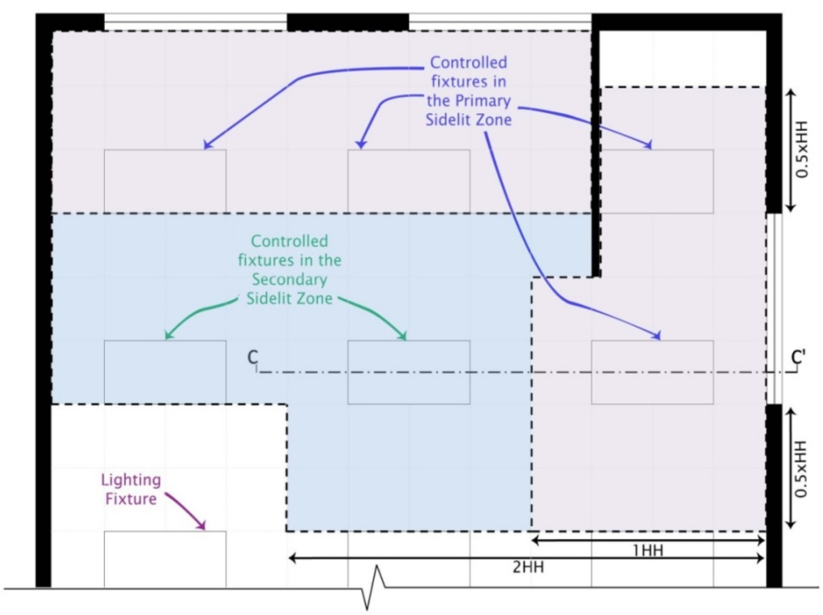


Figure 5-13: Secondary Sidelit Daylit Zone Diagram 2



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 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 must be shown on the building plans.
   2. Luminaires in the skylit daylit zone must be controlled separately from those in the primary sidelit daylit zones.
   3. Luminaires that fall in both a skylit and primary sidelit daylit zone must be controlled as part of the skylit daylit zone.

5.4.4.4 **Automatic Daylighting Control Installation and Operation**

For luminaires in skylit daylit zones and primary sidelit daylit zones, automatic daylighting controls must be installed and configured to operate according to all of the following requirements:

1. Photosensors shall be located so 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 convenience allows one person with a light meter and the wireless calibration tool to be located at the edge of the daylit zone and make the calibration adjustments without having to run back and forth between taking the measurement and making the adjustment

2. Automatic daylighting controls must 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 re-circuited, the daylighting control is not required to 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, and that 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.

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 (and 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 must 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 or 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 can be 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 Lighting Controls

§130.1(e); §110.12 (new for 2019)

Nonresidential buildings larger than 10,000 sq. ft. must have lighting systems with demand responsive lighting controls.

Spaces with a lighting power density of 0.5 W/ft^2 or less do not count towards the 10,000 sq ft. threshold for triggering demand responsive lighting control requirements. Also, spaces not permitted by a health or life safety statute, ordinance, or regulation to be reduced, are exempted from the requirement.

See Appendix D of this compliance manual for guidance on compliance with the demand responsive control requirements.

5.4.6 Lighting Control Interactions - Considerations for Spaces With Multiple Lighting Control Types

§130.1(f)

In indoor spaces, there can be more than one type of lighting control installed in the space to meet the Energy Code requirement of lighting controls. In the 2019 standards, a new section, Section 130.1(f) has been added to clarify interactions between two lighting control types.

Example 5-3 Interaction between manual dimming and automatic daylighting controls

Question

Is any acceptance test required for testing the interaction between manual dimming and automatic daylighting controls?

Answers

No, the interaction between manual dimming controls and automatic daylighting controls is not required for acceptance testing. Acceptance testing is required for automatic daylighting controls though.

5.4.6.1 **Practical Considerations**

For a space with both daylighting controls and dimming controls, the daylighting controls are likely to be the primary control most of the time. When the building user/occupant wants to use the dimming control to adjust the light level, the user/occupant should be able to do so. User should be able to manually override the level of light provided by the lighting system with manual dimming and a scene feature (switching the lighting in the zone to the predefined level) according to the needs of the activity in terms of duration of the activity.

One method that could be employed would have the occupant use the dimmer control to lower or raise the upper bound on the amount of light provided by the electric lighting. The dimming control would temporarily set a total lighting level that the daylighting control could then achieve by balancing the amount of electric lighting with the daylighting available in the space. This method allows the occupant to receive the benefits of both controls, rather than one control locking out the use of the other. When the activity is over, the lighting system should be restored to automatic control operation.

There is another method for spaces with all three control types – dimming, shutoff, and daylighting. If the occupancy sensing control is the shut-off control, the lighting should restore to automatic control mode (the occupancy sensing controls is triggered within 20 minutes after the area has been vacated). If there are no occupancy sensing controls and if an override is initiated, the automatic control should be overridden for no more than 20 minutes. After that, the automatic control resumes and the light level should be set by the daylighting controls.

5.4.7 Lighting Control Functionality

§110.9(b)

All installed lighting controls listed in §110.9(b) must comply with the requirements listed below. Additionally, all components of the system (considered together as installed) must meet all applicable requirements for which they are installed as required in §130.0 through §130.5, §140.6 through §140.8, §141.0, and §150.0(k).

To ensure they are meeting the requirements of Section 110.9(b), designers and installers are advised to review features of their specified lighting control products as part of the code compliance process.

A. Time-Switch Lighting Controls

Time-switch lighting control products shall provide the functionality listed in Section 110.9(b)1 of the Energy Code.

B. Daylighting Controls

Daylighting control products shall provide the functionality listed in Section 110.9(b)2 of the Energy Code.

C. Dimmer

Dimmer products shall provide the functionality listed in Section 110.9(b)3 of the Energy Code.

D. Occupant Sensing Controls

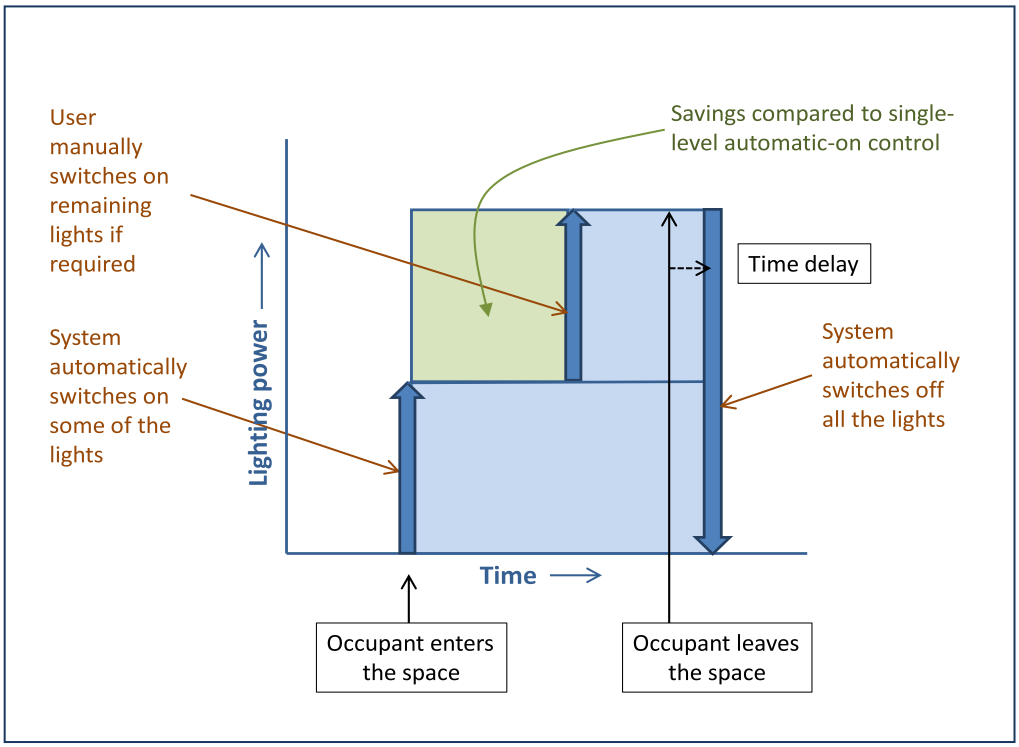
Occupant sensing control products (including occupant sensors, partial-on occupant sensors, partial-off occupant sensors, motion sensors, and vacancy sensor controls) shall provide the functionality listed in Section 110.9(b)4 of the Energy Code.

One important function is the capability to automatically turn lights either off or down within 20 minutes of an area being vacated.

EXCEPTIONS:

Occupant sensing control systems may consist of a combination of single or multi-level occupant, motion, or vacancy censor controls provided that components installed to comply with manual-on requirements are not capable of being converted from manual-on to automatic-on functionality by occupants.

Figure 5-14: Functional Diagram for Partial-ON Occupant Sensor



5.4.8 Track Lighting Limiter and Track Lighting Panel Functionality and Features

§110.9(c) and (d)

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, the track heads can be spread far apart and can use high efficacy sources to stay below the rated wattage of the current limiter. If the wattage exceeds the rated wattage of the current limiter, the limiter turns off current to the controlled lighting.

Track lighting integral current limiters must meet all of the requirements as specified in §110.9(c) and paraphrased below. The limiter

1. Must have the volt-ampere (VA) rating clearly marked so that it is visible for the enforcement agency's field inspection without opening coverplates, fixtures, or panels.
   - Must have the VA rating permanently marked on the circuit breaker.
   - Must have the VA rating printed on a factory-printed label permanently affixed to a non-removable base-plate inside the wiring compartment.
2. Must 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.

Each electrical panel feeding track lighting integral current limiters shall have a factory installed label prominently located.

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.

A track lighting supplementary overcurrent protection panel shall meet all of the requirements as specified in §110.9(d) and as paraphrased below:

1. Shall be listed as defined in Article 100 of the California Electric Code.
2. Shall be used only for line voltage track lighting.

Each track lighting supplementary overcurrent protection panel) shall have a factory installed label prominently located.

5.5 Other Prescriptive Daylighting Requirements – Daylighting, Daylighting Devices, and Secondary Sidelit Daylit Zones

This section contains daylighting requirements that are in addition to the mandatory automatic daylighting controls covered in Section 5.4 of this chapter.

They include the prescriptive requirements for daylighting in large enclosed spaces, for daylighting devices (clerestories, horizontal slats, light shelves) that are qualified for PAFs, and for automatic daylighting controls in secondary sidelit daylit zone.

5.5.1 Daylighting Devices (Clerestories, Horizontal Slat, Light Shelves) – Daylighting Design Power Adjustment Factors (PAFs)

§140.6(a)2L

Certain design features and technologies have the capacity to increase the daylighting potential of spaces. Some of these design features and technologies may be used in conjunction with automatic daylighting controls to receive PAFs from Table 140.6-A, or as a performance compliance option (PCO) in the performance method.

A careful analysis should be performed to ensure the avoidance of glare issues when including daylighting features in the design. An example where caution should be taken is specularly reflective (e.g. polished or mirror-finished) slats. These slats may redirect direct beam sunlight and cause uncomfortable glare. Since that is not the only consideration to make when considering daylighting design features, a careful daylighting analysis should be performed on a space-by-space, project-by-project basis.

For the PAF, daylight dimming plus off PAF and institutional tuning in daylit areas may be added to any of the daylighting design PAFs to create a combined total PAF.

In addition, the horizontal slat PAF can be added to the clerestory fenestration PAF if the requirements for both PAFs are met.

For the PCO, a variety of control strategies is available in the compliance software to take advantage of further savings.

For the PAF, at permit application, use form NRCC-LTI-E.

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.

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 ft^2.
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 5,000 sq ft. shall have at least 75 percent of the floor area within the 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.

$$\frac{Skylight\ Area}{Daylit\ Zone\ under\ skylights} \geq 3\,percent \quad (Equation\ 5-1)$$

$$Skylight\ Area \times VT \geq 1.5\,percent \times Daylit\ Zone\ under\ skylights \quad (Equation\ 5-2)$$

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 no 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.

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)6A). 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 according to several simulation studies.[2].

Example 5-4

Methods for buildings with large enclosed spaces in compliance with the minimum daylighting requirement

In buildings with large enclosed spaces that 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. Therefore, in a space having a ceiling height of 20 feet, the space will be fully skylit if the skylights are spaced so there is no more than 28 feet of opaque ceiling between the skylights.

Example 5-5

Large enclosed spaces in a warehouse building

A warehouse with 40,000 sq ft. area and a 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 at an increased cost since 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)x(32/1,024) = 0.0203 = 2.03 percent.

Example 5-6

Methods for complying with the mandatory daylight control requirements for a space with HID lighting

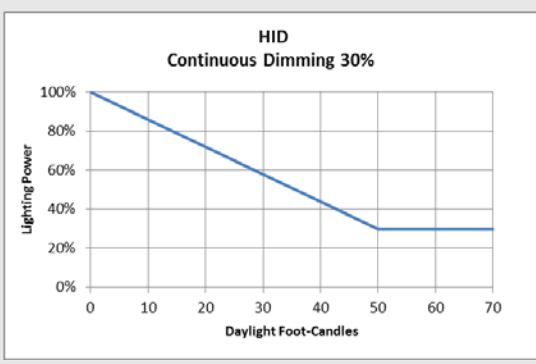
The Standards require that automatic daylighting controls shall provide functional multi-level lighting levels having at least the number of control steps specified in Table 130.1-A.

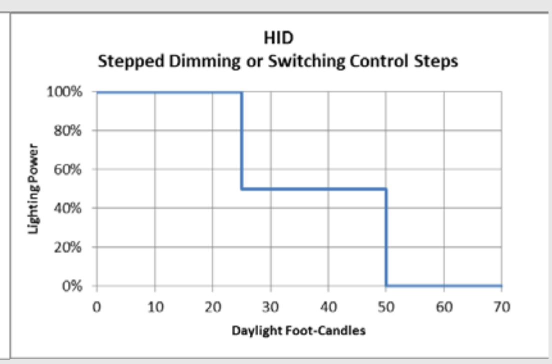
A space with HID luminaires that are greater than 20 watts, shall have a minimum of 1-step between 50 percent and 70 percent.

This can be achieved in one of the following 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 that there is one control step between 50 percent and 70 percent as noted above.





Example 5-7

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 daylit 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"

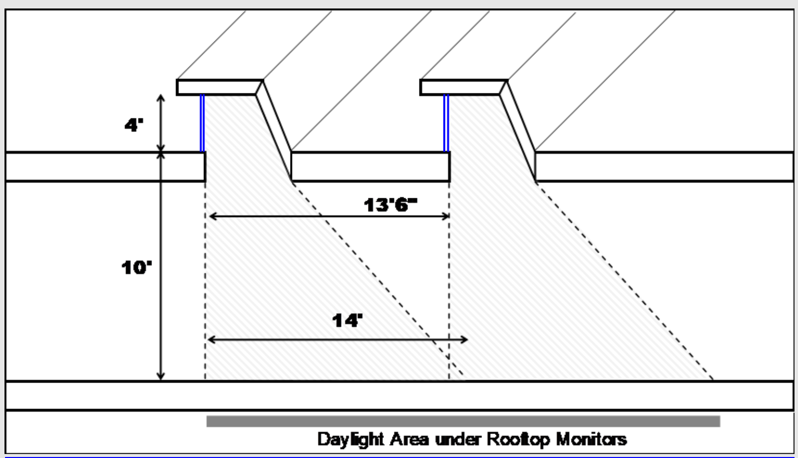
Example 5-8

Question

Draw the daylit zone for two roof top monitors with four 4-foot long windows projecting over a 10-foot tall roof. The two monitors are 13.5 feet 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.



5.5.3 Prescriptive Automatic Daylighting Control Requirements in Secondary Daylit Zones

§140.6(d)

The daylighting control requirements for secondary daylit zones are not mandatory but prescriptive.

All luminaires providing general lighting that is in, or at least half of the luminaires are in, a secondary sidelit daylit zone as defined in §130.1(d)1C, 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 daylit zone, the skylit daylit zone 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.

5.6 Prescriptive Compliance Approach for Indoor Lighting – Part 1, Adjusted Indoor Lighting Power

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 adjusted indoor lighting power of all proposed building areas combined, when calculated in accordance with §140.6(a), is no greater than the allowed indoor lighting power, calculated in accordance with §140.6(c).
2. The calculation of allowed indoor lighting power meets the general rules requirements in §140.6(b).
3. General lighting complies with the automatic daylighting controls in secondary sidelit daylit zones requirements in §140.6(d).

5.6.2 Calculation of Adjusted Indoor Lighting Power

The adjusted 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 indoor lighting power that must be reported. These adjustments are discussed below.

A. Power Adjustment Factors (PAFs) or Reduction of Wattage Through Controls

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 adjusted indoor lighting power, the installed watts of a luminaire providing general lighting in a functional area listed in Table 140.6-C may be reduced by multiplying the 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 are not met, the installation shall not be eligible to use 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 adjusted 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 adjusted 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 controlled luminaires must be within the skylit daylit or primary sidelit daylit 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 automatic daylighting 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 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 the following requirements, as applicable:

      i. Infrared sensors shall be equipped (either by the manufacturer or in the field by the installer) with lenses or shrouds to prevent them from being triggered by movement outside of the controlled area.

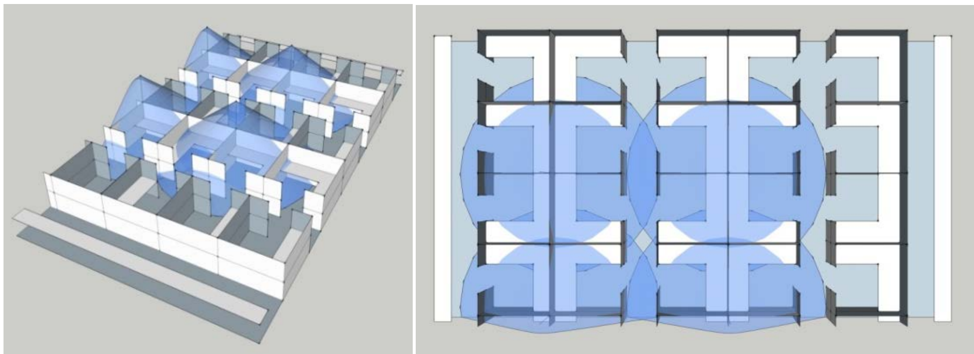
      ii. Ultrasonic sensors shall be tuned to reduce their sensitivity to prevent them from being triggered by movements outside of the controlled area.

      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 the square footage controlled by each occupant sensor.

Figure 5-15: To Qualify for the PAF for Occupancy Sensing Controls in Open-Plan Offices, Sensors Must be Tuned to the Controlled Area



10. The following requirements must be met to qualify the PAF for institutional tuning,:
    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 sq. ft. are required to have demand responsive controls, to qualify for the PAF, the building shall be 10,000 sq ft 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 the uniform level of illumination requirements in Table 130.1-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.
12. Daylighting devices for PAFs are newly introduced in the 2019 standards.

    To qualify for the PAF for daylighting devices (including clerestories, light shelves and horizontal slats in Table 140.6-A), the daylighting devices must meet the requirements in Section 140.3(d). Refer to Chapter 3 of the Nonresidential Compliance Manual about Section 140.3(d).

    Also note that the PAFs shall only apply to luminaires in the daylit areas adjacent to the daylighting devices, and to the lighting system meeting the automatic daylighting controls requirements of Section 130.1(d).

B. Luminaire Power Adjustment

Color-tunable LED lighting technologies are adopted for lighting applications including hospitality and healthcare and other built environments. Those luminaires offer the benefits of producing different correlated color temperatures (CCT) to match the functionality and occasions of a space.

Two categories of the color tunable luminaires -- tunable-white LED and dim-to-warm LED luminaires -- can be qualified for luminaire lighting power adjustment by a multiplier of 0.75 if the luminaires meet all of the requirements of Section 140.6(a)4B. The requirements are paraphrased below.

- Small Aperture – no wider than 4 inches for luminaires longer than 18 inches; no wider than 8 inches otherwise.
- Color Changing Capability– capable of color change greater than or equal to 2000K CCT for tunable-white LED luminaires; capable of color change greater than or equal to 500K CCT for dim-to-warm LED luminaires.
- Control Capability – the luminaires must be connected with controls enabling color-changing.

Figure 5-16 Dim-to-warm luminaires in Lighting Applications

Source: NORA Lighting

C. Portable Lighting in Office Areas

The Energy Standards (§140.6(a)) require that all planned portable lighting be counted toward the building's lighting energy use, regardless of when it is planned to be installed.

Because office cubicles (including their portable lighting) are typically not installed until after the building inspection is complete, the portable lighting power is accounted together with permanent lighting system as the adjusted lighting power for compliance purpose.

The Energy Standards define portable lighting as lighting with plug-in connections for electric power. That includes table and freestanding floor lamps; those attached to modular furniture; workstation task luminaires; luminaires attached to workstation panels; those attached to movable displays; or those attached to other personal property.

D. Two Interlocked Lighting Systems

I. Within the following five functional areas, as defined in §100.1, two lighting systems may be installed provided they are interlocked so that both lighting systems cannot operate simultaneously. All other functional areas are permitted to install only one lighting system.

1. Auditorium
2. Convention center
3. Conference room
4. Multipurpose room
5. Theater

II. No more than two lighting systems may be used for these five specifically defined functional areas, and if there are two lighting systems, they must be interlocked.

III. Where there are two interlocked lighting systems, the wattage of the lower system may be excluded from determining the adjusted 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 are not met, 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.

E. Lighting Wattage Not Counted Toward Building Load

The Energy Standards do not require lighting power of certain types of luminaires in specific functional 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 hotel are required to comply with all applicable requirements in §140.6. Also, lighting within guestrooms is regulated by the low-rise residential lighting standards.

The wattage of the following indoor lighting applications are not required to be counted toward the adjusted (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 multi-scene 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. That lighting must be separately switched from the general lighting system, switched independently at each dressing station, and 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.
- Exit way 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 sq. ft.
- Lighting in unconditioned agricultural buildings less than 2,500 sq. ft.
- 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 fewer vehicles: Lighting in nonresidential parking garages for seven or fewer 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 sq ft. shall comply with Title 20 Appliance Efficiency Regulations).
- Lighting in elevators where the lighting meets the requirements in §120.6(f).

5.7 Prescriptive Compliance Approach for Indoor Lighting – Part 2, Allowed Lighting Power

Following are the three methods permitted for the prescriptive compliance approach for calculating the allowed lighting power:

1. Complete Building Method
2. Area Category Method
3. Tailored Method

5.7.1 Complete Building Method (one of the Prescriptive Compliance Approaches)

§140.6(c)1

The Complete Building Method shall only be applied when lighting will be installed throughout the entire building. 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 the entire building shall be calculated as follows:

1. For a conditioned building, multiply the entire conditioned floor area of the building by the applicable lighting power density (LPD, watts per sq. ft.) provided in Table 140.6-B.
2. For an unconditioned building, multiply the entire unconditioned floor area of the building by the applicable LPD provided 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.)

The Complete Building Method shall be used only on projects involving:

a. Entire buildings with one type of use occupancy.

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).

A few more notes as follows:

- Use the Complete Building Method only when the applicant is applying for a lighting permit and submits plans and specifications for the entire building or the entire tenant space.
- Use the Complete Building Method only when the lighting power allotment in Table 140.6-B is available for the entire building. 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.
- For buildings including a parking garage plus another type of use listed in Table 140.6-B, the parking garage portion of the building and other type of use portion of the building shall each separately use the Complete Building Method.

Example 5-9 Mixed occupancy building – a parking garage building

Question

A building is to be constructed with 95 percent of it consisting of a parking garage, and the remaining 5 percent consisting of offices and support spaces such as an electrical room. What is the assumed building type under the complete building method?

Answer

Since parking garage makes up at least 90 percent of the entire building, the building shall be considered a parking garage when applying the Complete Building Method.

5.7.1.2 Definitions of Complete Building Types

When using the Complete Building Method, qualifying building types are 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), and which do not qualify as any other building occupancy type 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:

- **Assembly Building** is a building with meeting halls in which people gather for civic, social, or recreational activities. These include civic centers, convention centers and auditoriums.
- **Commercial and Industrial Storage Building** is a building with building floor areas used for storing items
- **Financial Institution Building** is a building with building floor areas used by an institution which collects funds from the public and places them in financial assets, such as deposits, loans, and bonds.

- **Industrial/Manufacturing Facility Building** is a building with building floor areas used for performing a craft, assembly or manufacturing operation.
- **Grocery Store Building** is a building with building floor areas used for the display and sale of food.
- **Gymnasium Building** is a building with building floor areas used for physical exercises and recreational sport events and activities.
- **Library Building** is a building with building floor area used for repository of literary materials, and for reading books, periodicals, newspapers, pamphlets and prints.
- **Office Building** is a building of CBC Group B occupancy with building floor areas in which business, clerical or professional activities are conducted.
- **Parking Garage Building** is a building with building floor areas, parking vehicles, and 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 with building floor areas used for assembly of people to worship.
- **Restaurant Building** is a building with building floor areas in which food and drink are prepared and served to customers in return for money.
- **Retail Store Building** is a building with building floor area used for the display and sale of merchandise except food.
- **School Building** is a building used by an educational institution. The building floor area can include 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.
- **Sports Arena Building** is a building with building floor areas used for public viewing of sporting events and activities. Sports arena are classified according to the number of spectators they are able to accommodate, as follows:

  Class I Facility is used for competition play for 5,000 or more spectators.

  Class II Facility is used for competition play for up to 5,000 spectators.

  Class III Facility is used for competition play for up to 2,000 spectators.

  Class IV Facility is normally used for recreational play and there is limited or no provision for spectators.
- **Motion Picture Theater Building** is a building with building floor areas used for showing motion pictures to audiences.
- **Performance Arts Theater Building** is a building with building floor areas used for hosting performing arts such as plays, music or dance to audiences.

Example 5-10 Calculating allowed lighting power using the Complete Building Method

Question

A 10,000-ft² healthcare facility building is to be built. What is the allowed lighting power under the complete building method?

Answer

From Table 140.6-B, a healthcare facility building is allowed 0.9 W/ft². The allowed lighting power for the entire building is 10,000 x 0.9 = 9,000 W.

5.7.2 Area Category Method (one of the Prescriptive Compliance Approaches)

§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. Under 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. For primary function areas not listed, selection of a reasonably equivalent type shall be permitted. 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 allowed lighting power 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 allowed lighting power 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 0.4 watts per sq. ft. 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 for each primary function area is the lighting power density value in Table 140.6-C multiplied by the square footage of the primary function area. The total allowed indoor lighting power for the building is the sum of the allowed indoor lighting power 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)2A thru F, the building may add additional lighting power allowances for qualifying lighting systems as specified in the Qualifying Lighting Systems column in Table 140.6-C under the following conditions:

1. Only primary function areas having a lighting system as specified in the Qualifying Lighting Systems column in Table 140.6-C and in accordance with the corresponding footnote of the table shall qualify for the additional lighting power allowances.
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:
   i. The lighting power density listed in the “Allowed Additional Lighting LPD” column in Table 140.6-C, times the sq. ft. of the primary function, or
   ii. the adjusted indoor lighting power of the applicable lighting.
7. In addition to the lighting power allowed under §140.6(c)2G(i through vi), up to 1.0 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:
   i. 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 are not met, the Additional Videoconference Studio Lighting installation shall not be eligible for the additional lighting power allotment.
   ii. 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.

iii. General lighting is controlled in accordance with Table 130.1-A.

iv. Wall wash lighting is separately switched from the general lighting system.

v. All of the lighting in the studio, including general lighting and additional lighting power allowed by §140.6(c)2Gvii is controlled by a multi-scene programmable control system (also known as a scene preset control system).

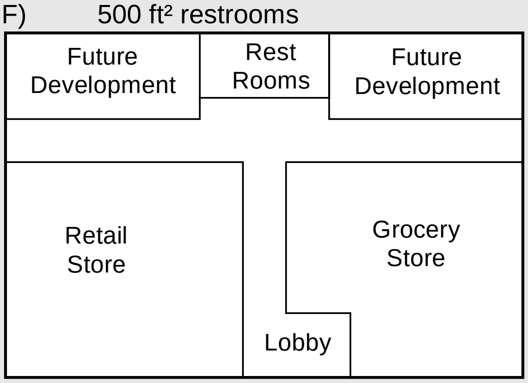
Example 5-11 Calculating the allowed lighting power using Area Category Method

Question

A 10,000-ft² multi-use building is to be built consisting of:

A) 500 ft² main entry lobby,
B) 1.500 ft² corridors,
C) 3,000 ft² grocery store (Grocery Sales),
D) 2,500 ft² retail store (Retail Merchandise Sales), and
E) 2,000 ft² future development.

F) 500 ft² restrooms



What is the allowed lighting power under the area category method?

Answer

Most of the functional area types can be identified from Table 140.6-C for their designated lighting power density values.

The future development area is unknown and with no built-out plan at the time of permitting and “All other” (with 0.4 W/ft²) is designated as its primary function area type.

Space		LPD	Area	Allowed Lighting Power
A)	Main Entry	0.85 W/ft²	500 ft²	425 W
B)	Corridors and Restrooms	0.6 W/ft²	1,500 ft²	900 W
C)	Grocery Store (Grocery Sales)	1.05 W/ft²	3,000 ft²	3,150 W
D)	Retail Store(Merchandise Sales)	1.00 W/ft²	2,500 ft²	2,500 W
E)	Restrooms	0.65 W/ft²	500 ft²	325 W
F)	Future Development (All other)	0.4 W/ft²	2,000 ft²	800 W
	TOTAL		10,000 ft²	8,100 watts

Example 5-12 Calculating allowed lighting power for spaces with display lighting and decorative lighting

Question

What if in the multi-use building (example 5-11), the retail store is planning floor displays and wall displays, as well as decorative chandeliers. How do you determine the allowed lighting power for the retail store with display lighting and decorative lighting?

Answer

A) As in the above example, determine the total area of the retails store (2,500 ft²)

B) As in the above example multiply the allowed LPD (1.0 W/ft²) X 2,500 ft² = 2,500 W (allowed lighting power)

C) Determine the additional allowed lighting power for display and accent lighting by multiplying the retail store size of 2,500 ft²by 0.2 W/ft² (Qualifying Lighting Column of Table 140.6-C) = 500 W

D) Determine the additional allowed lighting power for ornamental lighting (for chandeliers) by multiplying the retail store size of 2,500 ft² by 0.15 W/ft² (Qualifying Lighting Column of Table 140.6-C) = 350 W

E) Add the 2,500 W plus 500 W for display and 350 W for ornamental = 3,375 W

The allowed lighting power for this retail store, under the area category method, is 3,375 W.

Note: The allowed lighting power may be less than the theoretical 3,375 W since the display/accent lighting and ornamental lighting components are "use-it or-lose it". This means that the lesser of the adjusted additional lighting power for display/ornamental lighting and the calculated additional allowed lighting power (500 W and 375 W) is used. 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 in Table 140.6-C.

Example 5-13 Calculating additional lighting power for ornamental lighting

Question

What is the allowed lighting power for an ornamental chandelier with five 50 W lamps in a 300 ft² bank entry lobby?

Answer

The allowed lighting power for ornamental lighting is 0.3 W/ft² x 300 ft² = 90 W (0.3 W/ft² is based on Qualifying Lighting Column of Table 140.6-C.)

The wattage of the chandelier is 5 lamps x 50 W = 250 W.

If there are no applicable PAF or luminaire power reduction for the chandelier, the total wattage of the chandelier is the adjusted indoor lighting power or 90W.

The allowed lighting power for the chandelier is the smaller of the two values, or 90 W.

Example 5-14 Calculating additional lighting power for ornamental LED lighting

Question

What is the allowed lighting power for an LED chandelier with five 10 W LED lamps in a 300 ft² bank entry lobby?

Answer

The allowed lighting power for ornamental lighting is 0.3 W/ft² x 300 ft² = 90 W

The wattage of the chandelier 5 lamps x 10 W = 50 W.

If there are no applicable PAF or luminaire power reduction for the chandelier, the total wattage of the chandelier is the adjusted indoor lighting power or 50W.

The allowed lighting power for the chandelier is the smaller of the two values, or 50 W.

Example 5-15 Tunable-White and Dim-to-Warm Luminaires

Question

Which tunable-white and dim-to-warm luminaires qualify for the allowed additional lighting power for applications in healthcare facilities?

Answer

There are allowed additional lighting power for tunable-white and dim-to-warm luminaires for most of the healthcare/hospital function areas as specified in Table 140.6-C.

The qualified tunable-white luminaires shall be capable of color change ≥ 2000K CCT.

The qualified dim-to-warm luminaires shall be capable of color change ≥ 500K CCT.

A dim-to-warm luminaire product capable of color tune from 2700K to 1800K is acceptable and qualifies for the additional light power.

5.7.3 Tailored Method (one of the Prescriptive Compliance Approaches)

§140.6(c)3

5.7.3.1 Tailored Method Application and General Rules

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.

Use of Tailored Method could be helpful when more general lighting power is required for the listed primary function areas[1] in Table 140.6-D and for the listed area that has a high room cavity ratio (RCR).

In addition to providing a lighting power budget for general illumination, the tailored method 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 Complete Building Method of compliance is used.

[1]Definitions of the primary function areas can be found in Section 100.1.

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.

5.7.3.2 Determining Allowed General Lighting Power for Tailored Method

§140.6(c)3G thru 3H; Table 140.6-D, F, G

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, listed in Table 140.6-D. 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.

§140.6(c)3H shall be used to determine the general lighting power density allotments as follows:

1. Using Table 140.6-D and 140.6-G 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 nonresidential certificate of compliance 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 lighting power density value.

e. Multiply the allowed general lighting power density value by the square footage of the primary function area. The product is the allowed general lighting power for general lighting for that primary function area.

2. How to calculate Room Cavity Ratio (RCR)

- The room cavity ratio must be determined for any primary function area using the Tailored Lighting Method.
- 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.
- 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 length

- 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.
- 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.
- 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.

Example 5-15 Calculating Room Cavity Ratio (RCR)

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

5.7.3.3 Determine Additional Allowed Power for Tailored Method

§140.6(c)3G thru 3J; Table 140.6-D and E

When using the Tailored Method for lighting compliance, the additional allowed lighting power values and adjustment factor values are listed in Table 140.6-D, E, F, and G, for the special applications below:

- Wall display lighting,
- Floor display lighting and task lighting,
- Ornamental/special effects lighting, and
- Very valuable display case lighting.

These additional layers of lighting power are not available when using §140.6(c)3F 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.

Use the appropriate compliance form to document the additional lighting power for wall display lighting, floor display lighting and task lighting, ornamental/special effects lighting, and very valuable display case lighting.

A. Additional Wall Display Lighting Power:

Wall display lighting is defined 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, and 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 additional allowed power for wall display lighting shall be the smaller of:

   i. The wall display lighting power density values (Column 3 of Table 140.6-D) times the wall display length (determined from item #3);

   ii. The adjusted lighting power used for the wall display luminaires.

   Calculate the adjusted lighting power by multiplying the maximum rated wattage of the display luminaires with the appropriate mounting height adjustment factor from Table 140.6-E.

   Note that mounting height adjustment factor is available for wall display luminaires mounted at height greater than 10 feet 6 inches from the finished floor. Mounting height is the distance from the finished floor to the bottom of the luminaire.

2. To qualify for the additional wall display lighting power:

   i. The lighting system shall be a type that is appropriate for creating a higher level of illuminance on the wall display. Lighting systems appropriate for wall display 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 luminaires providing directional display lighting.)

ii. The qualifying wall display lighting shall be mounted within 10 feet of the wall having the wall display.

iii. The lighting system shall not be a general lighting system type.

Note: Lighting internal to display cases that are attached to a wall or directly adjacent to a wall are counted as wall display. All other lighting internal to display cases are counted as floor display lighting, or as very valuable display case lighting.

3. 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.

   Permanent full height interior partitions are those that meet the following conditions:

   i. Extend from the floor to within two feet of the ceiling or are taller than ten feet; and

   ii. Are permanently anchored to the floor.

4. The additional wall display lighting power is not available for the following:

   i. For any function areas using the Complete Building or Area Category methods of compliance.

   ii. General lighting systems.

   Note that floor displays shall not qualify for wall display lighting power allowances.

B. Additional Floor Display and Task Lighting Power:

Floor display lighting is defined 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.

Task Lighting is defined as lighting that specifically illuminates a location where a task is performed, but not general lighting.

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, for the listed primary function areas in Table 140.6-D.

Lighting internal to display cases that are not attached to a wall and not directly adjacent to a wall, shall be counted as floor display lighting or very valuable display case lighting.

1. The additional allowed power for the floor display and task lighting shall be the smaller of:

   a. The floor display and task lighting power density values (Column 4 of Table 140.6-D) times the square footage of floor display or task area.

   b. The adjusted lighting power used for floor display lighting or task lighting.

      Calculate the adjusted lighting power by multiplying the maximum rated wattage of the floor display or task luminaires with the appropriate mounting height adjustment factor from Table 140.6-E.

      Note that mounting height adjustment factor is available for floor display luminaires mounted at height greater than 10 feet 6 inches from the finished floor. Mounting height is the distance from the finished floor to the bottom of the luminaire.

2. To qualify for additional floor display lighting power:
   a. The floor display lighting system shall be mounted no closer than 2 feet to a wall. When track lighting is used for floor display 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 lighting power allowance.
   b. The floor display lighting system consists of only directional lamp types, such as PAR, R, MR, AR; or of luminaires providing directional display light.
   c. If track lighting is used, only track heads that are classified as directional lighting types.
3. To qualify for additional task lighting power:
   a. The task lighting system shall be located immediately adjacent to and capable of illuminating the task for which it is installed.
   b. The lighting system shall be of a type different from the general lighting system.
   c. The lighting system shall be separately switched from the general lighting system
4. 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.
5. The additional power for floor display and task lighting are not available for the following:
   a. For any function areas using the Complete Building or Area Category methods of compliance.
   b. Displays that are installed against a wall shall not qualify for the floor display lighting power allowances.
   c. 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.
6. 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.

C. Additional Ornamental/Special Effects Lighting Power:

Special effects lighting is defined as lighting installed to give off luminance instead of providing illuminance.

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.

Additional allowed power for ornamental/special effects lighting may be used only for the listed primary function areas in Table 140.6-D.

1. The additional allowed power for ornamental/special effects lighting shall be the smaller of:
    a. The allowed ornamental/special effects lighting power values (Column 5 of Table 140.6-D) times the square footage of the floor areas having ornamental/special effects lighting;
    b. The adjusted lighting power used for ornamental/special effects lighting.
2. Additional ornamental and special effects lighting power is not available for any function area using the Complete Building or Area Category methods of compliance.
3. Additional ornamental/special effects lighting power shall be used only in areas having ornamental/special effects lighting.

    Any floor area not designed to have ornamental or special effects lighting shall not be included for the ornamental/special effects lighting allowance.

D. Additional Very Valuable Display Case Lighting Power:

Case lighting is defined 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.

Additional allowed lighting power for very valuable display case lighting shall be available only for display cases in retail merchandise sales, museum, and religious worship areas.

1. The additional allowed power for very valuable display case lighting shall be the smallest of:
    a. The product of the area of the primary function and 0.55 watt per sq. ft.; or
    b. The product of the area of the display case and 8 watts per sq. ft.; or
    c. The adjusted lighting power used for very valuable display case lighting.
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. The additional very valuable display case lighting is not available for any function areas using the complete building or area Category methods of compliance.
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.

Example 5-17 Ornamental lighting and very valuable display lighting - Tailored Method (Five parts) (Part 1)

Question

A 5,500-ft² retail store has:

5,000 ft² of gross retail sales area (merchandise sales) 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 light sources

As part of the retail scheme in the sales floor area, the following lighting is being used.

- Wall display lighting of 300 linear feet of perimeter wall including closeable openings;
- Floor display lighting;
- Ornamental/special effects lighting.

What are the allowed lighting power for general lighting in this store using the Tailored Method?

Answer

The general illumination for merchandise sales and showroom area in retail is 500 Lux per column 3 of Table 140.6-D.

Per Table 140.6-G, the Lighting Power Density (LPD) is 1.05 W/ft² for a 500 Lux space with an RCR of 2.5. Therefore, the allowed general lighting power for the retail store is 1.05 W/ft² X 5,000 ft² = **5,250 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/ft² of LPD for corridors and 0.65 W/ft² for restrooms. *(RCR is irrelevant 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 0.65 W/ft² = **130 W**.

The allowed power for the corridors is 300 ft² x 0.6 W/ft² = **180 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 5-18 Wall display lighting – Tailored method (Continue – Part 2)

Question

If the adjusted lighting power of the floor display luminaires is 3,000 watts, what is the allowed wall display lighting power for the retail sales area in this store?

Answer

The wall display lighting is computed from the entire wall perimeter, including all closeable openings, times the wall display power allowance. Therefore, the wall display lighting is 300 ft. x 11.8 W/ft. = **3,540 W**. The allowed lighting power density value of 11.8 W/ft. is taken from column 3 of Table 140.6-D.

Note that in the Tailored Method, it is a use-it-or-lose-it allowance.

The additional allowed power for wall display lighting is the smaller of:

- The wall display lighting power of 3,540W, as calculated from above;
- The adjusted lighting power used for the wall display lighting, 3,000W.

Since the smaller of 3,540W and 3,000W is 3,000W, the additional allowed power for wall display lighting is 3,000W for the retail sales area in this store.

Example 5-19 Floor display lighting – Tailored method (Continue – Part 3)

Question

If the adjusted lighting power of the floor display luminaires is 4,000 watts, what is the allowed floor display lighting power for this store?

Answer

The floor display allowance is computed from the area of the entire space with floor displays multiplied by the floor display lighting power density. Therefore, the allowed wattage is 5,000 ft² x 0.8 W/ft² = **4,000 W**. The allowance is taken from column 4 of Table 140.6-D.

Note that in the Tailored Method, it is a use-it-or-lose-it allowance.

The additional allowed power for floor display lighting is the smaller of:

- the floor display lighting power of 4,000W, as calculated from above;
- the adjusted lighting power used for the floor display lighting, 4,000W.

Since the smaller of 4,000W and 4,000W is 4,000W, the additional allowed power for floor display lighting is 4,000W for the retail sales area in this store.

Example 5-20 Ornamental/special effect lighting – Tailored method (Continue – Part 4)

Question

If the adjusted lighting power of the ornamental/special effect luminaires is 4,000 watts, what is the allowed ornamental/special effect lighting power for this store?

Answer

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 0.4 W/ft² = **2,000 W**. The allowance is taken from column 5 of Table 140.6-D.

Note that in the Tailored Method, it is a use-it-or-lose-it allowance.

The additional allowed power for ornamental/special effect lighting is the smaller of:

- The ornamental/special effect lighting power of 2,000W, as calculated from above;
- The adjusted lighting power used for the ornamental/special effect lighting, 4,000W.

As the smaller of 2,000W and 4,000W is 2,000W, the additional allowed power for ornamental/special effect lighting is 2,000W for the retail sales area in this store.

The ornamental/special effect luminaires have to be re-selected for a lesser adjusted wattage so that it is no more than 2,000W.

Example 5-21 Very valuable display lighting – Tailored method (Continue – Part 5 of 5)

Question

What are the allowed very valuable display lighting power for this store?

Answer

The allowed wattage for very valuable display case top is smaller of the product of 0.55 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 allowed lighting power is the smaller of 0.55 W/ft² X 5,000 ft² = 2,750 watts, or 8 W/ft² X 100 ft² = 1,200 watts. Therefore, the maximum allowed power is **1,200 W**.

Because the floor display and very valuable display allowances are use-it-or-lose-it allowances, the maximum power allowed is the smallest of primary function area lighting power (2,750 W) and very valuable display case lighting power (800 W) or the adjusted lighting power for very valuable display case lighting (1,200 W). Therefore, the allowed watts for very valuable display lighting is 800 W.

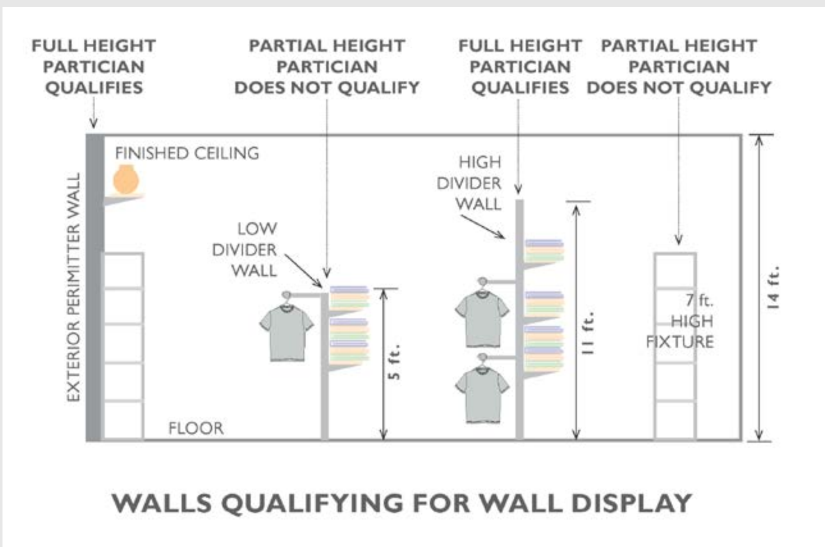
Example 5-22 Retail space – determination on partitions

Question

A large retail store with a sales area that has a 14-foot 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

The sketch below shows full height partitions and non-full height partitions.

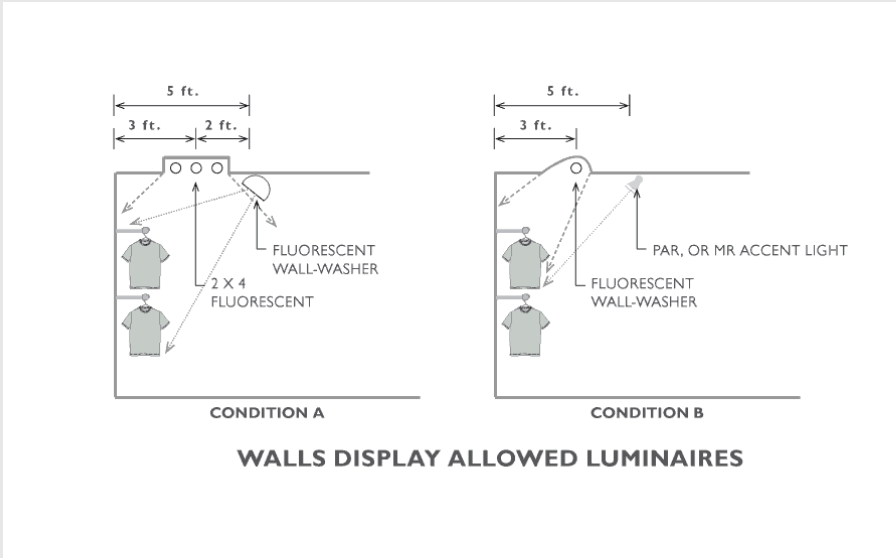


Example 5-23 Wall display lighting in a retail store– Tailored Method

Question

In this question, Condition A has 2 x 4 troffers placed 3 feet from a perimeter sales wall as well as fluorescent wall-washers 5 feet from the sales wall. Condition B has fluorescent wall-washers 3 feet from the wall and PAR adjustable accent lights 5 feet 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 feet of the wall and must be an appropriate wall lighting luminaires. (Luminaires with asymmetric distribution toward the wall or adjustable –directed toward the wall).

CONDITION A

While both luminaires are within 10 feet of the wall only the wall-washer qualifies for the wall display allocation. The 2 x 4 troffer is a general lighting luminaire with symmetric distribution and does not qualify for the allocation.

CONDITION B

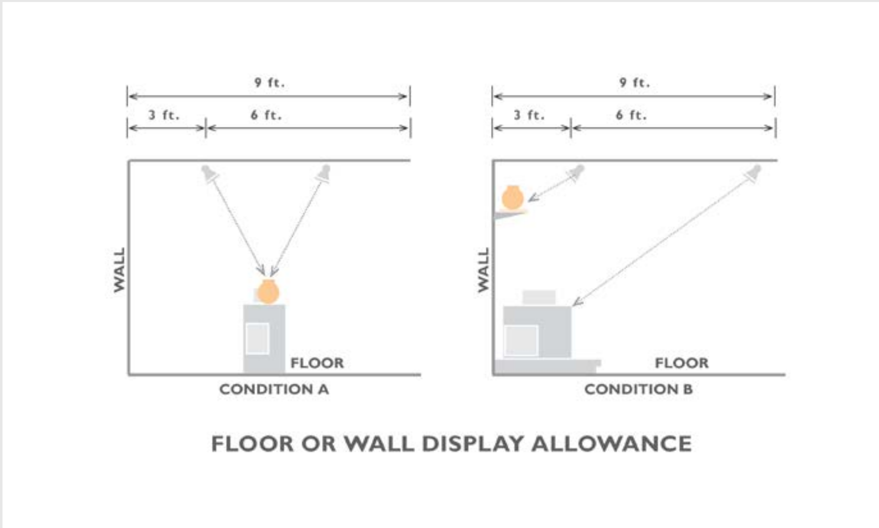
Both luminaires are within 10 feet of the wall and both qualify for the wall display allocation. The fluorescent wall-washer has an asymmetric distribution and the PAR accent light at 5 feet from the wall provides directional light.

Example 5-24 Display lighting in a museum – Tailored Method

Question

A museum space has directional accent lighting luminaires on a track mounted to the ceiling. The first track is 3 feet from the perimeter wall of the exhibit space and the second track is 9 feet from the wall. There is a third track (not shown) that is 15 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)3G & 3H, wall display luminaires must be within 10 feet of the wall and directional, and floor display luminaires 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

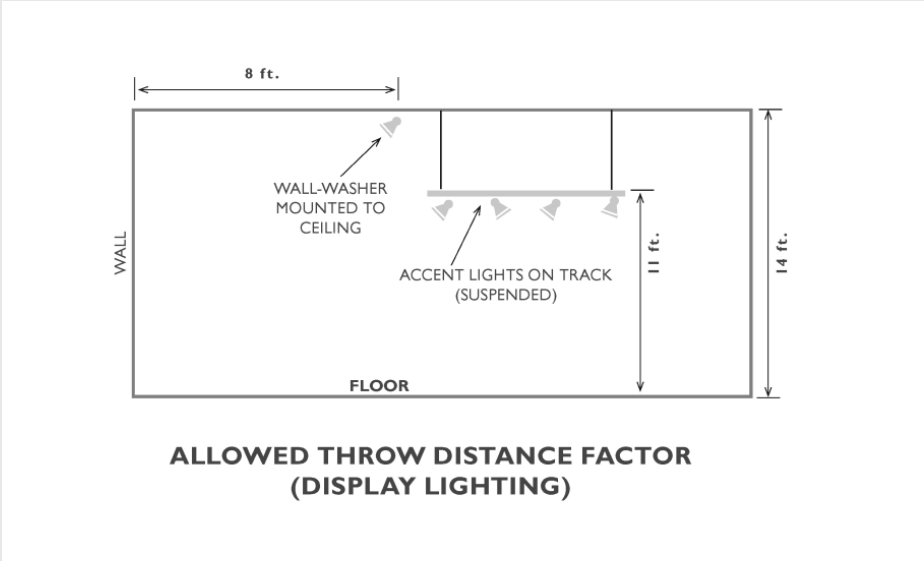
Both sets of luminaires (3 feet and 9 feet away from the wall) shown are at least 2 feet away from the wall and are directed onto a floor exhibit (display) therefore they both qualify for the floor display allocation. The third track (15 feet away from the wall) with directional luminaires also can qualify as floor display.

CONDITION B

Both sets of luminaires shown are closer than 10 feet 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 feet from the wall) does not qualify for wall display, only floor display.

Note: Luminaires within a 2 foot to 10 foot 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 5-25 Lighting Power 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 14-foot high ceiling, does the display lighting qualify for a mounting height factor adjustment?

Answer

Per §140.6(c) 3Giv and 3Hviii, both the wall-washers and accent lights qualify for the mounting height adjustment as they are mounted at height greater than 10 feet 6 inches and they also provide directional light.

If the track is suspended at 10 feet instead of 11 feet, it is excluded from an adjustment factor and must use the default factor of one with the allowed LPD as shown in column four in Table 140.6-E.

5.8 Performance Compliance Approaches

The performance approach is an alternative to the prescriptive approach. The allowed lighting power is calculated as part of the energy budget for the proposed design building. A building complies with the performance approach if the energy budget calculated for the proposed design building is no greater than the energy budget calculated for the standard design 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 2019 Nonresidential ACM Reference Manual for additional information.

5.9 Lighting Control Installation and Acceptance Requirements – for Installers and Acceptance Test Technicians

With the onset of the construction phase of projects, two types of documentation have to be prepared for showing compliance to the Energy Standards - certificate of installation and certificate of acceptance (for acceptance tests).

The following sections layout their scope and the related parts of the Nonresidential Appendix which contains the acceptance test procedures. Refers to Section 5.11 for a list of the certificate mentioned.

5.9.1 Lighting Installation Certificate Requirements (§130.4(b))

The person who is eligible under Division 3 of the Business and Professions Code to accept responsibility for the installation or construction of features, materials, components, or manufactured devices shall sign and submit the Certificate of Installation for installation of the following items, before any of the following applications will be recognized for compliance with the lighting requirements,

1. Lighting Control System.
2. Energy Management Control System.
3. Interlocked lighting systems service a single space.
4. Lighting controls installed to earn a lighting Power Adjustment Factor (PAF).
5. Additional lighting wattage available for a videoconference studio.

If any of the requirements in the Certificate of Installation are not met, that application shall not be recognized for compliance with the Energy Standards.

5.9.2 Lighting Control Acceptance Requirements (§130.4(a))

Acceptance testing must be performed by a certified lighting controls acceptance test technician.to certify the, indoor and outdoor lighting controls serving the building, area, or site for meeting the acceptance requirements.

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 tuning power adjustment factor comply with §140.6(a)2J and Reference Nonresidential Appendix NA7.7.6.2.

5.10 Additions and Alterations

5.10.1 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 panel board and luminaires; or that replace lighting control panels, panel boards or branch circuit wiring.

5.10.2 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 §110.0; §110.9, §130.0 through §130.5, §140.3, and §140.6.

When using the performance approach, the indoor lighting in the addition must meet the lighting requirements of §110.0; §110.9; §130.0 through §130.5; and one of the following two options of the performance requirements :

1. The addition alone with §140.1; or
2. The existing building plus the addition plus the alteration.

5.10.3 Alterations – General Information

§141.0(b)

5.10.3.1 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:

i. Comply with the requirements for additions, or
ii. Comply with the Prescriptive lighting requirements, or
iii. Comply with the Performance approach.

An alteration is defined by the Energy Standards as follows:

i. 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
ii. Any regulated change to an outdoor lighting system that is not an addition; and
iii. Any regulated change to signs located either indoors or outdoors; and
iv. 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.

5.10.3.2 **Indoor Lighting Exceptions**

The following indoor lighting alterations are not required to comply with the lighting requirements in the Energy Standards:

1. Alterations where less than 10 percent of existing luminaires are being altered.
2. Alteration of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.
3. In an enclosed space where there is only one luminaire.
4. Disturbance of asbestos directly caused by any alterations, unless the alterations are made in conjunction with asbestos abatement.
5. One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.
6. Alteration limited to addition of lighting controls or replacing lamps, ballasts, or drivers

5.10.3.3 **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.

5.10.3.4 **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.

5.10.3.5 **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.

5.10.4 Lighting Alterations

§141.0(b)2I, §141.0(b)2J

The 2019 edition of Title 24, Part 6 restructured the lighting alterations language to improve clarity. The three previous types of lighting alterations (entire luminaire, luminaire component, and wiring) have been unified into a single section (Section 141.0(b)2I), and the three compliance options have been clearly stated.

Alterations to the lighting systems must comply with the requirements in Section 141.0(b)2I when 10 percent or more of the luminaires serving an enclosed space are altered. Three types of alterations are covered by the standard:

- Entire luminaire alterations 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.

- Moving or modifying the walls or ceilings of the space along with modifying the space's lighting system.

Luminaire component modifications 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. Wiring alterations add a circuit feeding luminaires; replace, modify, or relocate wiring between a switch or panel board and luminaires; or replace lighting control panels, panel boards, or branch circuit wiring.

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 2019 Energy Standards allow the same three options for meeting the installed power and associated control requirements as the 2016 standards, and specify a set of requirements for lighting power allowance and controls for each of the following cases:

1. The altered lighting power that does not exceed Table 140.6-C,
2. The altered lighting power that is equal to or less than 80 percent of Table 140.6-C, or
3. Where the alteration is within a building or tenant space of 5,000 sq. ft. or less, and the total rated power of the existing luminaires in the occupancy, have 40 percent lower power than the pre-alteration total luminaire rate power.

Altered lighting systems must meet one of the three requirements above. Option 3 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. Options 2 and 3 are likely to result in a lower lighting power than option 1, and therefore multi-level lighting controls (Section 130.1(b)), daylighting controls (Section 130.1(d)), and demand responsive controls (Section 130.1(e)) are not required for these options. The control requirements for each option are described in Table 5-4.

Alterations to indoor lighting systems should be such that they do not prevent the operation of existing, unaltered controls, and do not alter controls to remove functions specified in Section 130.1. Alterations to indoor lighting systems are not required to separate existing general, floor, wall, display, or ornamental lighting on shared circuits or controls. New or completely replaced lighting circuits shall comply with the control separation requirements of Section 130.1(a)4 and 130.1(c)1D.

Table 5-2 (Modified Table 141.0-F): Control Requirement for Indoor Lighting Alterations

Control Specifications		**Projects complying with Section 141.0(b)2Ii**	**Projects complying with Sections 141.0(b)2Iii and 141.0(b)2Iiii**
Manual Area Controls	130.1(a)1	Required	Required
	130.1(a)2	Required	Required
	130.1(a)3	Only required for new or completely replaced circuits	Only required for new or completely replaced circuits
Multi-Level Controls	130.1(b)	Required	Not Required
Automatic Shut Off Controls	130.1(c)1	Required; 130.1(c)1D only required for new or completely replaced circuits	Required; 130.1(c)1D only required for new or completely replaced circuits
	130.1(c)2	Required	Required
	130.1(c)3	Required	Required
	130.1(c)4	Required	Required
	130.1(c)5	Required	Required
	130.1(c)6	Required	Required
	130.1(c)7	Required	Required
	130.1(c)8	Required	Required
Daylighting Controls	130.1(d)	Required	Not Required
Demand Responsive Controls	130.1(e)	Required	Not Required

The following lighting alterations are not required to comply with §141.0(b)2I:

1. Alterations where less than 10 percent of existing luminaires are altered (such as removed and reinstalled, or modified).
2. Alterations of portable luminaires, luminaires affixed to moveable partitions, or lighting excluded by §140.6(a)3.
3. Alterations in an enclosed space with only one luminaire.
4. Alterations that would directly cause the disturbance of asbestos, unless the alterations are made in conjunction with asbestos abatement.
5. One-for-one luminaire alteration of up to 50 luminaires either per complete floor of the building or per complete tenant space, per annum.
6. Lamp replacements alone, ballast or driver replacements alone, and addition of lighting controls are exempted. Such alterations shall not be considered a modification of the luminaire provided that the replacement lamps, ballasts, drivers, or controls are installed and powered without modifying the luminaire.

The acceptance testing requirement of §130.4 is not required for alterations where lighting controls are added to control 20 or fewer luminaires.

Example 5-26 Luminaire Alterations

All light fixtures are being replaced in one enclosed room of a commercial tenant space of less than 5,000 sq. ft. The entire tenant space has a total of 100 light fixtures. The altered room will receive a total of 40 new light fixtures. Which Energy Standards requirements must we comply with?

Answer

Since all existing luminaires (fixtures) within the enclosed area (room) are being replaced with 40 new ones, the project must comply with one of the two requirements of i, or ii of §141.0(b)2I. Since this is not a one-for-one alteration, section iii of §141.0(b)2I is not available as an option for compliance.

Example 5-27 Example Warehouse Lighting Alteration (example compliance with the 40 percent lighting power reduction option)

Question

The existing metal halide luminaires in a warehouse facility of 5,000 sq. ft. are proposed to be replaced by LED luminaires (shown below). There are 100 existing metal halide luminaires that use 250 watts each, all of which will be replaced. The replacement LED luminaires use 150 watts each. 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

The power reduction option requires a 40 percent reduction in installed lighting power. Thus, enter the number and wattage of the existing luminaires into NRCC-LTI, and use the form to calculate both the existing installed lighting power (100 x 250 = 25,000) and the maximum allowance based on a 40 percent reduction (25,000 x 0.6 = 15,000). Enter the number and wattage of the new luminaires into NRCC-LTI, just like any other project; if this is a one-for-one replacement, then the total lighting power of the new luminaires would be at the allowance (100 x 150 = 15,000).

Since the lighting power reduction is at 40 percent, only manual area controls and automatic shutoff controls are mandatory as specified in Section 141.0(b)2Iii and summarized in Table 5-4.

Example 5-28 Lighting Wiring Projects

Question

If the lighting system is being rewired as part of a lighting alteration project, which Energy Standards requirement must be complied with?

Answer

Note that alterations to lighting wiring are considered alterations to the lighting system; the requirements for wiring alterations and lighting alterations are the same.

When the alteration involves a wiring alteration, it must comply with the control requirements as specified in §130.1(a)3 and 130.1(c)1D.

The acceptance test requirement is triggered if controls are added to control more than 20 luminaires.

Example 5-29 Alterations Projects with both lamps and ballasts of the luminaire being replaced

Question

There are 100 lighting fixtures in an existing office space. For 20 fixtures, the internal components (lamps and ballasts) are being replaced with new kits.

Which Energy Standards requirements apply?

Answer

Because 20 out of 100, or 20 percent (more than 10 percent of the trigger threshold), of the luminaires are altered and also both lamps and ballast are replaced (removed and replaced with retrofit kits), the alteration shall meet one of the requirements of i, ii, or iii of Section 141.0(b)2I, "Altered Indoor Lighting Systems".

Example 5-30 Alterations in enclosed spaces with one luminaire

Question

A project includes more than 50 luminaires with one-for-one alteration on a floor, but a portion of those altered luminaires are in enclosed spaces containing one luminaire.

How are the luminaires in the enclosed spaces counted toward the trigger threshold of 50 luminaires under §141.0(b)2I (one-for-one luminaire alteration)?

Answer

Yes, the Exception 2 to §141.0(b)2I exempts enclosed spaces with one luminaire from the requirements of Section 141.0(b)2I, but does not reduce the total luminaire count on a floor or a tenant space. Therefore, the altered luminaires on the floor other than those one-luminaire spaces are required to meet one of the three requirements of i, ii, or iii of Section 141.0(b)2I.

Example 5-31 Lamp replacements as part of a project

Question

A single-story retail store has 50 T12 linear fluorescent strip luminaires 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 luminaires are being retrofitted with T8 lamps and premium ballasts. In the track luminaires the screw-in and pin-based incandescent lamps are being replaced with equivalent screw-in and pin-based LED lamps. There are no other alterations done to the lighting system of that tenant space in the calendar year.

What are the Energy Standards requirements for this job?

Answer

There is a total of 70 luminaires (50+10+10 = 70 luminaires).

The Energy Standards are not triggered for this project because fewer than 50 fixtures are being modified.

Out of the 70 fixtures included in the project, the 20 incandescent fixtures have lamp replacement and they do not count toward the trigger threshold of 50 luminaires under §141.0(b)2I (one-for-one luminaire alteration). Only 50 luminaires are being altered in this job.

Example 5-32 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)2I (Indoor Lighting 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)2I.

Example 5-33 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-foot 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 feet. In this example the area with a ceiling height greater than 15 feet is 16,000 ft²; therefore there are mandatory skylight requirements. (Note: skylight requirements do not apply in climate zones 1 and 16).

Example 5-34 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.

5.11 Indoor Lighting Compliance Documents

5.11.1 Overview

This subchapter describes the documentation (compliance forms) required for compliance with the nonresidential indoor lighting requirements of the Energy Standards.

5.11.2 Submitting Compliance Documentation

At the time a building permit application is submitted to the enforcement agency, the applicant also submits building 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 building plans and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance.

5.11.3 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 forms are required to be separately completed for conditioned and unconditioned spaces.

5.11.4 Compliance Documentation Numbering

Following is an explanation of the 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.
- E Primarily used by enforcement authority.
- A Primarily used by acceptance tester.

5.11.5 Certificate of Compliance Documents

There is only one nonresidential indoor lighting Certificate of Compliance documentation (form) required to be filled out for each project.

- NRCC-LTI-E; Certificate of Compliance; Indoor Lighting.

5.11.6 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, Lighting Control Systems.
- 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), have been installed to comply with any of the lighting control requirements.

- 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

5.11.7 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 certifying 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.

5.12 For Manufacturers and Installers

5.12.1 Luminaires Labeling

130.0(c)1

Luminaires shall be labelled with its wattage as follows.

1. The maximum rated wattage or relamping rated wattage of a luminaire shall be listed on a permanent, preprinted, factory-installed label, as specified by UL 1574, 1598, 2108, or 8750, as applicable; and
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. The luminaires can accommodate a range of lamp wattages without changing the luminaire housing, ballast, transformer or wiring.
   b. They have a single lamp.
   c. They have 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 (does 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.

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6. Outdoor Lighting

This chapter covers the requirements for nonresidential outdoor lighting systems for compliance to Title 24 California Code of Regulations, Part 6 (California Energy Code, or the Energy Standards) and it is related to lighting design and installation, luminaires and lighting controls.

It is addressed primarily to lighting designers, electrical engineers, installers, manufacturers and building officials responsible for lighting.

Chapter 5 addresses nonresidential indoor lighting requirements and covers lighting in parking garages.

Chapter 7 addresses sign lighting requirements.

6.1 Overview

What's New for the 2019 California Energy Code

The significant changes for outdoor lighting systems in the 2019 update to the Energy Standards include:

- Changes to outdoor lighting power allowances with the allowance values based on LED lighting technologies. Revisions to the general hardscape lighting values in Tables 140.7-A and the specific lighting application values in Table 140.7-B for all Lighting Zones (LZ) – Lighting Zone 1 thru Lighting Zone 4.
- Add separate lighting power allowance values for concrete-surfaced and for asphalt-surfaced hardscape lighting application in Table 140.-7A.
- Add new lighting power allowances for narrow band spectrum light sources used in applications for minimizing outdoor lighting impacts on professional astronomy and nocturnal habitat. (Table 140.7-A)
- Revision and streamlining outdoor lighting control requirements. (§130.2(c))
- Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) have to comply with the Energy Standards including the outdoor lighting requirements for all outdoor areas of healthcare facilities.

6.2 Scope, Approach and Applications

This chapter applies to all outdoor lighting, whether attached to buildings, poles, structures or self-supporting- including but not limited to: lighting for hardscape areas such as parking lots, lighting for building entrances; lighting for all outdoor sales areas; and lighting for building facades.

The outdoor lighting part of the Energy Standards sets minimum control requirements, maximum allowable power levels, minimum efficacy requirements, and cutoff (uplight and glare) zonal lumen limits for outdoor luminaires.

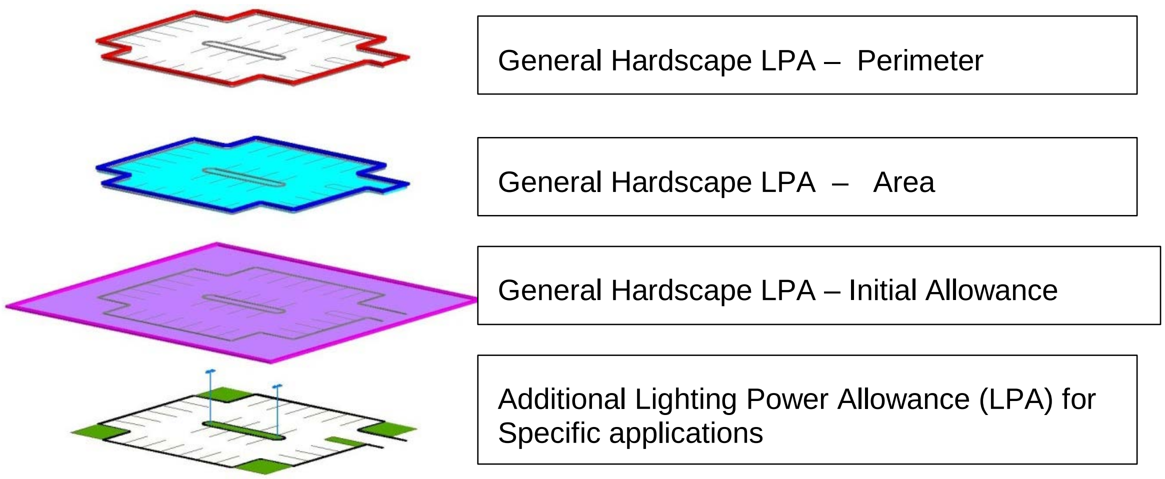
The Energy Standards only permit one type of trade-offs on outdoor lighting power. Refers to Section 6.2.2.1 for details.

All Section (§) and Table references in this Chapter refer to sections and Tables contained in the Energy Standards or California Energy Code.

6.2.1 Outdoor Lighting Approach

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.

Figure 6-1: Concept of a layered lighting approach for outdoor lighting - Lighting Power Allowance (LPA)



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.

6.2.2 Trade-offs

The Energy Standards do not allow trade-offs between outdoor lighting power allowances and indoor lighting, sign lighting, heating, ventilation, and air-conditioning (HVAC) system, 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 Tunnels 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, Healthcare Facilities, 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 outdoor lighting Required and regulated by FAA Required and 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 and wheelchair elevator lifts For ramps that are not 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 unregulated lighting applications.		

6.2.3 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). Refers to the rightmost column of Table 6-1 for a quick reference to the lighting applications that are exempted. Also the Energy Standards clarify that at least 50 percent of the light from the luminaire must fall within an application in order to qualify as being installed for that application.

6.3 Outdoor Lighting Zones

The basic premise of the Energy Standards is to base allowable outdoor lighting power on the brightness of the surrounding conditions. The Energy Standards contain lighting power allowances for new lighting installations and specific alterations that are dependent on the lighting zone in which the project is located.

Five categories of outdoor lighting zones are defined and they are LZ0, LZ1, LZ2, LZ3 and LZ4. Lighting zones with lower numbers are darker from LZ0 which is in national parks and other areas intended to be very dark at night to LZ4 for high intensity nighttime use, such as entertainment or commercial districts or areas with special security considerations requiring very high light levels. 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. Providing greater power than is needed potentially leads to debilitating glare and an increasing spiral of brightness as over-bright projects populate surrounding conditions causing future projects to unnecessarily require greater power resulting in wasted energy. 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.

The following summarizes the default locations for outdoor lighting zones as specified in §10-114:

- Lighting Zone 0 areas are undeveloped areas of government designated parks, recreation areas, and wildlife preserves;
- Lighting Zone 1 areas are developed portions of government designated parks, recreation areas and wildlife preserves;
- Rural areas are Lighting Zone 2;
- 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.

Details of 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 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, a Lighting Zone 2 designation can be adopted if the area is surrounded by rural areas (as defined by the U.S. Census Bureau). Similarly, 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. All adjustments in lighting zone 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 may designate certain areas as either Lighting Zone 3 or Lighting Zone 4 if it is determined 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 lighting zone 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 as Lighting Zone 4 for high intensity nighttime use, such as entertainment, commercial districts, or areas with special security considerations requiring very high light levels. All adjustments in lighting zone 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 deemed appropriate.

Table 6-2: 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

6.3.1 Determining the Lighting Zone for an Outdoor Lighting Project

Permit applicants may determine the lighting zone for a particular property using the following steps:

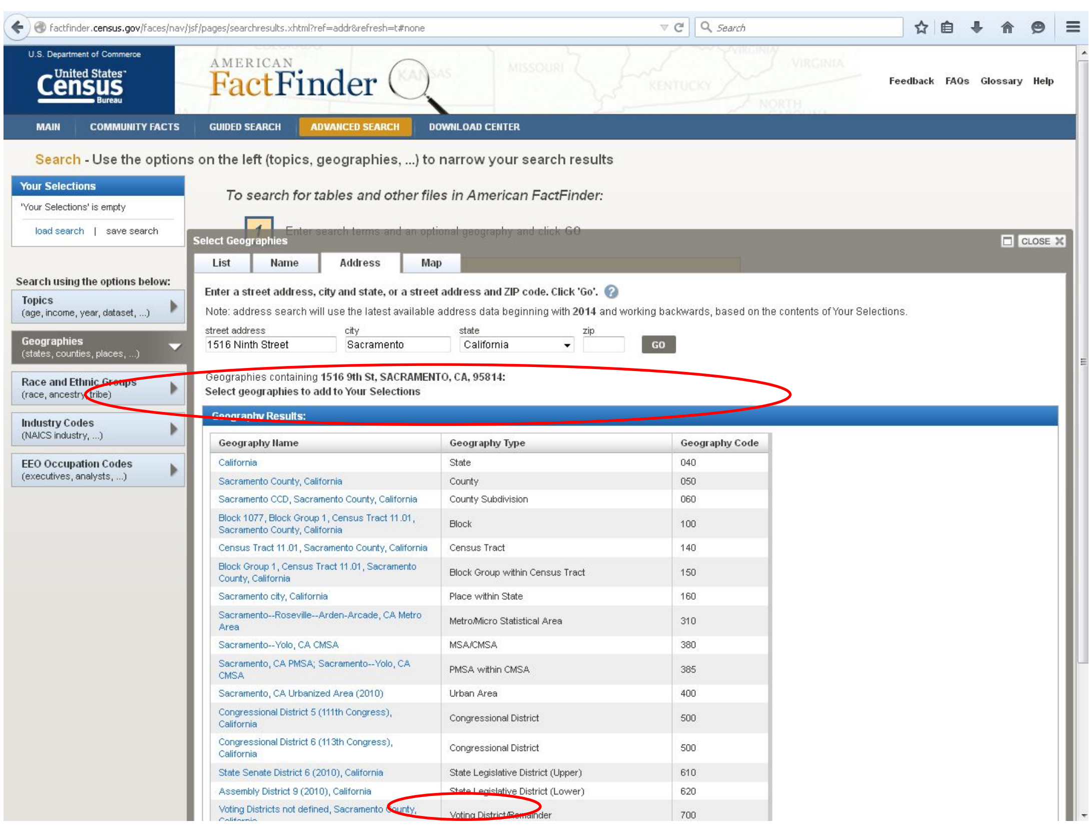
- Local jurisdiction – Check with the local jurisdiction having authority over permitting of the property. The local jurisdiction will know if the property is a government designated park, recreation area, or wildlife preserve, and therefore in default Lighting Zone 0 or 1. The local jurisdiction also 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 CEC website whether or not a locally-adopted change has been submitted to the Commission.

U.S. Census – The outdoor lighting zones of urban and rural areas as well as the legal boundaries of wilderness and park areas are based on the 2010 U.S. Census Bureau boundaries.

- 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.
  - o According to the US Census Bureau, there are two types of urban designations, 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.
  - o There is an address search tool provided by the US Census Bureau. Enter the address to look up 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)
  - o 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 results will designate this; otherwise you are in a rural geography.
- Energy Commission website – Check CEC 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.

Figure 6-2: Example of US Census Bureau Information



6.3.2 Lighting Zone Adjustments by Local Jurisdictions

§10-114

Energy Standards Table 10-114-A

The CEC 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 CEC 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 CEC 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.

6.3.3 Lighting Zone Examples of Using 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 beginning point and 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 description, such as along a certain watercourse or public road way.

The following examples use 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.

Example 6-1 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 how to petition to have the default outdoor lighting zone officially adjusted.

6.4 Mandatory Requirements

The mandatory features and devices must be included in all outdoor lighting projects when they are applicable. Mandatory requirements for outdoor lighting are specified in §110.9, §130.0, and §130.2. These are similar to the mandatory requirements 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. The Certificate of Acceptance document for outdoor lighting controls shall also be submitted to the local enforcement agency to prove the installed outdoor lighting controls pass the acceptance test.

6.4.1 Luminaire Cutoff Requirements

§130.2(b)

The 2019 Standards include a new threshold metric based on initial luminaire lumens for the BUG rating requirement. All outdoor luminaires that emit 6,200 lumens or greater must comply with Backlight, Uplight, and Glare ("BUG") requirements contained in Section 5.106.8 of the CalGreen Code (Title 24, Part 11).

The BUG ratings assume that the light emitted from the luminaire is providing useful illuminance on the task surfaces rather than scattering the light in areas where the light is not needed or intended, such as toward the sky. These BUG ratings also increase visibility because high amounts of light shining directly into observer’s eyes are reduced, thus decreasing glare. Additionally, light pollution into neighbors’ properties is reduced. The BUG requirements vary by outdoor lighting zones and outdoor lighting zones are described in Section 6.2.2.

Luminaire manufacturers are aware of the technical details of the BUG ratings and can typically provide to designers and contractors the BUG ratings for their luminaires. In the rare occasions where the luminaire manufacturer cannot provide the BUG rating, the BUG rating of the luminaire can be calculated with outdoor lighting software if the luminaire photometric data is available.

Luminaires are exempted from the BUG rating requirements for the following applications as these applications are desirable to project light sideways or upwards.

- 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 that does not persist beyond 60 consecutive days or more than 120 days per year.
- Replacement of existing pole mounted luminaires that are spaced more than 6 times the mounting height of the existing luminaires and the replacement luminaire wattage is less than the wattage of the original luminaires. In addition:
    - Where the existing luminaire does not meet the luminaire uplight and glare zonal lumen limits.
    - Where no additional poles are being added to the site.
    - Where new wiring to the luminaires is not being installed.
- Luminaires that are intended to light the right of way on publicly maintained roads, sidewalks, or bikeways.

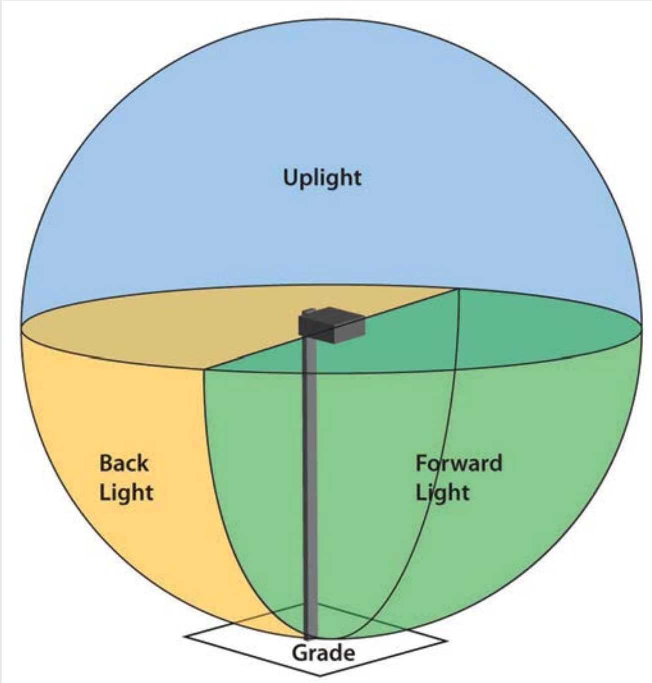
Example 6-2 Luminaire Classification for Outdoor Luminaires

Question

What is the IES BUG system for outdoor luminaires?

Answer

Illuminating Engineering Society (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.



Luminaire Classification System for Outdoor Luminaires as defined in IES TM-15-11

Image Credit: From ANSI/IES RP-8-14 Roadway Lighting with permission from the Illuminating Engineering Society

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 Wallpacks and Zonal Lumen Limits

Question

A new parking lot adjacent to a building is being designed to be illuminated by wall packs rated at 7,000 initial luminaire lumens. The wall packs are mounted on the side of the building and their main purpose is for parking lot illumination. But they are also illuminating the façade of the building. Do these wall packs have to meet the backlight, uplight and glare (BUG) rating limits?

Answer

Yes, these 7000-lumen wall packs will have to meet the BUG rating requirements 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 BUG rating 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 rated less than 6,200 initial luminaire lumens are not required to meet the Backlight, Uplight and Glare (BUG) requirements in the Energy Standards.

Example 6-4 Tilted Luminaires meeting the BUG Requirements

Question

If a low BUG rating luminaire is mounted at a tilt does it still meet the BUG requirements?

Answer

It depends. Luminaires that meet the zonal lumen limits when mounted at 90° to nadir may or may not comply with the BUG rating 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. There are lighting design software available to produce a BUG rating for a tilted luminaire, or this can be provided by the manufacturer.

Example 6-5 Defining the Property Line for the Purpose of BUG Rating Compliance

Question

Where is the property line if the area under construction is located next to a public road?

Answer

For property line that abuts a public roadway or transit corridor, the property line may be considered to be the centerline of the public roadway or transit corridor.

For property lines about public walkways, bikeways, plazas and parking lots, the property line may be considered to be 5 feet beyond the actual property line.

Example 6-6 Mounting Height from the Property Line

Question

How are the BUG rating of a luminaire determined by mounting height from the property line?

Answer

If the luminaire is mounted more than 2 mounting heights away from the property line, then there is no limit on the backlight rating. Otherwise, for locations less than 2 mounting height away, the luminaire must meet backlight ratings listed in Table 5.106.8 (N).

For instance, a 6,600-lumen parking lot luminaire rated with a B2-U0-G1 BUG rating is installed on a 20-foot pole. If this luminaire is located 2 mounting heights (40 feet) away from the closest property line, it is acceptable for use in a lighting zone 2 (LZ2) or higher lighting zone (LZ3 or higher) location.

The luminaire lumen output and BUG ratings can be obtained from the manufacturer or may be calculated from photometric data.

6.4.2 Requirements of Outdoor Lighting Controls

§130.2(c)

The primary requirements for outdoor controls are as follows:

1. **Lights Off During Daytime**: All outdoor lights shall be automatically controlled so that lights are turned off when daylight is available. [§130.2(c)1]
2. **Scheduling Controls**: All outdoor lights shall be automatically controlled by a time-based scheduling controls. [§130.2(c)2]
3. **Motion Sensing Controls**: Outdoor luminaires greater than 40 watts and mounted less than 24 ft. and above the ground shall be motion controlled, so that the lighting power of each luminaire shall be automatically reduced by at least 50 percent. This applies to luminaires providing general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting. [§130.2(c)2]

Exceptions to all outdoor lighting controls. All lighting control requirements do not apply to any of the following lighting applications:

1. Lighting where a health or life safety status, ordinance, or regulation prohibits outdoor lighting to be turned OFF or reduced.
2. Lighting in tunnels required to be illuminated 24 hours per day and 365 days per year.

Example 6-7 Circuiting of Non-outdoor Lighting Load

Question

Can irrigation controllers be on the same power circuit as lighting?

Answer

Maybe, it depends.

If there is any outdoor lighting load on the same power circuit, the outdoor lighting load must be independently controlled from all other non-outdoor lighting loads.

More information of each lighting controls are laid out in the following sections.

A. Daylight Availability

§130.2(c) 1

All installed outdoor lighting must be controlled by a photocontrol, astronomical time-switch control, or other controls that automatically turns off the outdoor lighting when daylight is available.

- A photocontrol measures the amount of ambient light outdoor and when the light level outside is high enough to indicate it is daytime, the control turns the lights off.
- Astronomical time clocks require an initial setup of the time clock device and the setup may include the entry of the current date and time (and time zone), site location (by longitude and latitude) and others (daylight saving time). The clock calculates sunrise and sunset times (which vary by factors such as day of the year), turns the lights off near sunrise and keeps them off until sunset.
- A part-night outdoor lighting control has a light sensor and a timing mechanism to control lights relative to measured sunrise and sunset times.

  The appropriate product of astronomical time clocks or part-night outdoor lighting controls can be used for both daylight availability and scheduling control.

B. Automatic Scheduling Controls

§130.2(c) 2

All installed outdoor lighting shall be controlled by an automatic scheduling control that reduces lighting power according to a schedule.

Further, automatic scheduling controls are required to have the capability of programming at least two nighttime periods (a scheduled occupied period and a scheduled unoccupied period) with different light levels (lighting power of 40 to 90 percent from full power) if desirable by the building design and operation. More than two nighttime periods are allowed for a building, as desirable for its activities or operations.

For the scheduled unoccupied period, the scheduling controls shall have the capability of reducing power between 50 percent and 90 percent and can also turn the lights off. Automatic scheduling controls are flexible to suit changes in building activities. If new actives warrant different operation schedules or different amounts of light is needed for the period, the building operator can adjust the settings of the automatic scheduling controls. The intent is to require the automatic scheduling controls to be capable of providing different amounts of outdoor lighting depending upon time of night. This also provides the capability to reduce lighting power when the outdoor space is not occupied or in use.

There are applications in which there are benefits to employ both motion sensing controls and automatic scheduling controls. It is the intent to allow both types for meeting the outdoor lighting control requirements. See example below.

Example 6-8 Using Automatic Scheduling Controls Plus Some Other Controls

Question

Can motion sensing controls be used together with automatic scheduling controls?

Answer

Some applications require the installation of motion controls. For these applications, automatic scheduling controls are required in addition of motion sensing controls. During the occupied period, motion sensing controls can detect vacancy of an outdoor space and the controls can reduce the lights to a reduced state, per the initial setup.

Example 6-9 Using Automatic Scheduling Controls for Buildings of 24x7 operation

Question

Is the automatic scheduling control requirement applicable to a building occupied 24 hours per day, seven days per week?

Answer

Yes, automatic scheduling controls are required for buildings that are occupied 24 hours per day, seven days per week.

Business activities can change over time as business models and hours of operation evolve. The required nighttime periods of a scheduled occupied period and a scheduled unoccupied period are decided by the building owner or the building operator, as appropriate, to suit the business needs.

Acceptance Tests Required for Automatic Scheduling Controls

Outdoor automatic scheduling controls are required to have acceptance test conducted to confirm the appropriate schedules are programmed and controls have been enabled. The acceptance test procedures are detailed in Reference Nonresidential Appendix NA7.8.7 and NA7.8.8. Refer to Section 6.6.5 of this manual for details about outdoor lighting controls acceptance test.

C. Motion Sensing Controls

§130.2(c) 3

Outdoor luminaires greater than 40 watts, where the bottom of the luminaire is mounted 24 ft. or less above the ground, shall be operated with motion sensing controls if they are used in the following applications:

1. General hardscape lighting including parking lot lighting
2. Vehicle service station hardscape lighting and canopy lighting
3. Wall pack lighting installed for building façade, ornamental hardscape, or outdoor dining lighting

The motion sensing controls shall:

1. reduce the lighting power of each luminaire by at least 50 percent and no more than 90 percent, or be capable of turning the luminaire off during unoccupied periods.
2. be capable of reducing the lighting to its dim or off state within 15 minutes of vacancy detection.
3. control no more than 1,500 watts of lighting power by a single sensor.

Exceptions to all motion sensing control requirements.

- The motion control requirements do not apply to applications listed as exceptions to Section 140.7(a). These application exempted from the motion controls requirements of Section 130.2(c)3 when more than 50 percent of the light fails in the application. The applications include temporary outdoor lighting, lighting for public roadways, and lighting for public monuments – the complete listing can be found in Section 140.7(a). A short version of the listing is also provided on the rightmost column of Table 6-1.

In addition, luminaires serving the following applications are not required to have motion sensing controls:

1. Lighting for Outdoor Sales Frontage, Building Facades, Ornamental Hardscape and Outdoor Dining;
2. Luminaires rated 40 watts or less;
3. Lighting subject to health or life safety statute, ordinance or regulation may have a minimum time-out period longer than 15 minutes or a minimum dimming level above 50 percent.

Acceptance Tests Required for Motion Sensing Controls

Motion sensing controls are required to have an acceptance test conducted to confirm the sensor can sense activity within the detection zone and turn the lights to their occupied lighting power levels within the timeout period. The acceptance test procedures are detailed in Reference Nonresidential Appendix NA7.8.1 and NA7.8.2. Refer to Section 6.6.5 of this manual for details about outdoor lighting controls acceptance test.

6.4.3 Lighting Control Functionality

§110.9(b)

All installed lighting controls listed in §110.9(b) shall comply with the requirements listed below. In addition, 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).

Designers and installers are advised to review features of their specified lighting control products for meeting the requirements of Section 110.9(b) as part of the code compliance process.

A. Time-Switch Lighting Controls
Time-switch lighting control products shall provide the functionality listed in Section 110.9(b)1 of the Energy Code.

B. Daylighting Controls

Daylighting control products shall provide the functionality listed in Section 110.9(b)2 of the Energy Code.

C. Dimmer

Dimmer products shall provide the functionality listed in Section 110.9(b)3 of the Energy Code.

D. Occupant Sensing Controls

Occupant sensing control products (including occupant sensors, partial-ON occupant sensors, partial-OFF occupant sensors, motion sensors, and vacancy sensor controls) shall provide the functionality listed in Section 110.9(b)4 of the Energy Code.

One important functionality is the capability to automatically turn lights either off or down within 20 minutes after the area has been vacated.

EXCEPTION to the requirement: 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 occupants from manual-on to automatic-on functionality.

E. Part-Night Outdoor Lighting Controls

Part-night outdoor lighting control products shall provide the functionality listed in Section 110.9(b)5 of the Energy Code.

Example 6-10 Manufacturer Responsibility for Certified Controls

Question

What is the responsibility of the manufacturer with regard to using lighting control products that are certified by the CEC and listed in the Commission’s directories?

Answer

It is the responsibility of the manufacturer to certify its lighting control products as required by the applicable California Appliance Efficiency Standards (also known as Title 20 Standards). The approved products will be listed in the CEC’s directories or in an appliance efficiency database.

Example 6-11 Designer Responsibility for Certified Controls

Question

What is the responsibility of the designer with regard to using lighting control products that are certified by the CEC and listed in the Commission’s directories?

Answer

It is the responsibility of the designer to specify only lighting control products that have been certified and listed in Energy Commission directories.

Example 6-12 Installer Responsibility for Certified Controls

Question

What is the responsibility of the installer with regard to using lighting control products that are certified by the CEC and listed in the Commission’s directories?

Answer

It is the responsibility of the installer to only install lighting control products that are certified by the CEC and listed in the Commission's directories. It is also the responsibility of the installer to sign the Installation Certificate.

6.5 Prescriptive Measures

6.5.1 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.

The area of the lighting application must be defined exclusive of any areas on the site that are not illuminated.

The allowed lighting power is determined by measuring the area or length of the lighting application and multiplying this area (in W/ sq. ft.) or length (in W/sq. ft. by the Lighting Power Allowance (in W) to arrive the allowed lighting power. The allowed lighting power must be calculated for the general hardscape lighting of the site and for specific applications if desired. (See §140.7(d))

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.

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)).

A. 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.

B. 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, mounting heights and 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, within a building, or areas beyond property lines.

The primary purpose for validating the illuminated area is to exclude any areas that are not illuminated. Areas that are illuminated by more than one luminaire shall not be double counted. An area is either 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.

6.5.2 General Hardscape Lighting Power Allowance

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. Calculation of Allowed Lighting Power - 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 are 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:

   a. Landscaped areas completely enclosed within the hardscape area, and with a width or length a minimum of 10 feet wide, shall have the perimeter of the landscaped areas or permanent planter added to the hardscape perimeter length.
   b. Landscaped areas completely enclosed within the hardscape area, and with a width or length less than 10 feet wide, shall not be added to the hardscape perimeter length.
   c. 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.

(Refer to Figure 6-1 for a concept layout of the general hardscape lighting allowance for area, and perimeter, as well as initial wattage allowance.)

Table 6-3: General Hardscape Lighting Power Allowance

Type of Power Allowance	Lighting Zone 0[3]	Lighting Zone 1[3]	Lighting Zone 2[3]		Lighting Zone 3[3]		Lighting Zone 4[3]
	Asphalt/Concrete	Asphalt/Concrete	Asphalt.	Concrete[2]	Asphalt	Concrete[2]	Asphalt/Concrete
Area Wattage Allowance (AWA)	No allowance[1]	0.018 W/sq. ft.	0.023 W/sq. ft.	0.025 W/sq. ft.	0.025 W/sq. ft.	0.03 W/sq. ft.	0.03 W/sq. ft
Linear Wattage Allowance (LWA)		0.15 W/lf	0.17 W/lf	0.4 W/lf	0.25 W/lf	0.4 W/lf	0.35 W/lf
Initial Wattage Allowance (IWA)		180 W	250 W	250 W	350 W	350 W	400 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 shall meet the maximum zonal lumen limits as specified in 130.2(b).

[2] Where greater than 50% of the paved surface of parking lot is finished with concrete. This does not extend beyond the parking lot, and does not include any other General Hardscape area.

[3] Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact, active professional astronomy or nocturnal habitat of special local fauna, shall be allowed a 2.0 lighting power allowance multiplier.

Table 140.7-A from the Energy Standards

The allowed lighting power for general hardscape lighting is calculated using the following components:

1. Area Wattage Allowance (AWA), which is the area of the illuminated hardscape, and is expressed in watts per sq. ft.
2. Linear Wattage Allowance (LWA), which is the length of the perimeter of the illuminated hardscape, and is expressed in watts per linear foot.
3. 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 6-13 Outdoor Lighting for Healthcare Facilities

Question

Is the parking lot outside of a healthcare facility ("I" occupancy) regulated by the Energy Standards?

Answer

Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) have to comply with California Energy Standards including the outdoor lighting requirements for all outdoor areas of healthcare facilities. For outdoor lighting, a licensed healthcare facility has to meet the outdoor lighting power requirements as specified in Section 140.7, as well as the outdoor lighting control requirements in Section 130.2.

Example 6-14 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.

Example 6-15 Power Allowance for a Parking Lot

Question

In a parking lot in front of a retail store, we are not using the full lighting power allowed according to Table 140.7-A. 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 6-16 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 sq. ft.

Example 6-17 Calculating the Illuminated Area

Question 1

If a pole has a height of 15 ft., what are the dimensions of the square pattern used for power calculations?

Answer 1

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 sq. ft. (150 ft. x 150 ft.), minus areas that are beyond the property line or other obstructions.

Question 2

If two poles in the center of an illuminated area are separated by a distance greater than 10 times the mounting height, will all of the square footage between them be included in the area?

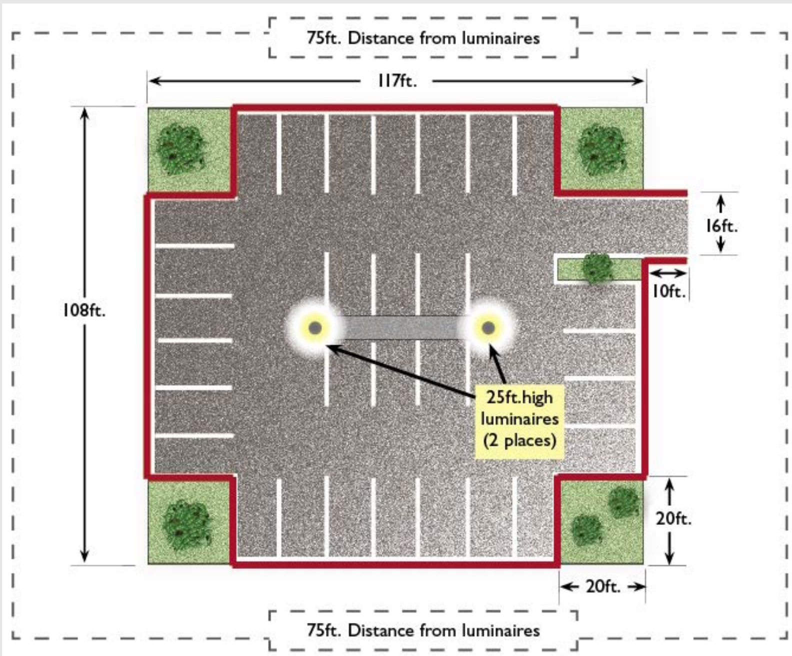
Answer 2

In most applications, such as 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, and the coverage squares do not overlap, then the non-illuminated areas between poles cannot be included in determining illuminated hardscape area.

Example 6-18 Calculating the Power Allowance for a Parking Lot

Question

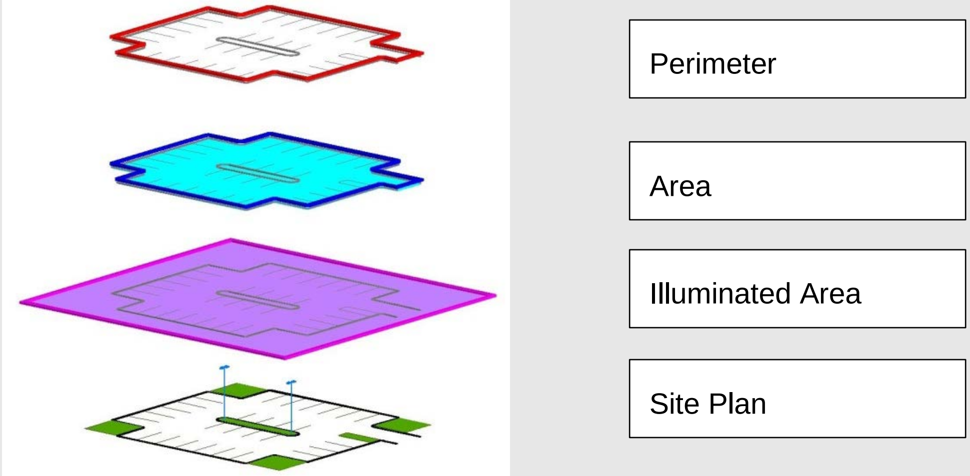
The parking lot with concrete surface as illustrated below has two luminaires that are mounted at a height of 25 ft. What is the illuminated hardscape area and what is the allowed lighting? The lot is located in Lighting Zone 3.



Poles are 40 ft. 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 sq. ft.. [(12,636 sq. ft. + 160 sq. ft. (driveway) – 1,600 sq. ft (cutouts)]. The perimeter of the hardscape is 470 ft. [(2 x 77 ft.) + (2 x 68 ft.) + (8 x 20 ft.) + (2 X10 ft.)].



Three allowances make up the total power allowance: Area, Linear, and Initial. All allowances are based on a concrete surface of Lighting Zone 3 and found in Table 6-4 (Table 140.7-A of the Energy Standards).

The area wattage allowance is equal to 335.9 W.

The linear wattage allowance is equal to 188 W.

The initial wattage allowance (IWA) is 350 W for the entire site.

The sum of these three allowances gives a total wattage allowance for the site of 873.9 W.

The calculation can also be tabulated as below.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Initial	350 W	-	350 W
Area	0.03 W/sq. ft.	11,196 sq. ft.	336 W
Perimeter	0.4 W/LF	470 ft.	188 W
	TOTAL POWER ALLOWANCE		**874 W**

Example 6-19 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 sq. ft. [(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/ sq. ft.	8524 sq. ft.	341 W
Perimeter	0.35 W/LF	380 ft.	133 W
	TOTAL POWER ALLOWANCE		**994 W**

Example 6-20 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 with asphalt surface?

Answer

The hardscape area for the roadway must first be calculated. If the entire roadway will be lit, 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 therefore is 15 ft. x 300 ft. or 4500 sq. ft. 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 an asphalt surface in Lighting Zone 2 and can be found in Table 6-4 (Table 140.7-A of the Energy Standards).

The area wattage allowance is equal to 103.5 W.

The linear wattage allowance is equal to 104.6 W.

The sum of these allowances gives a total wattage allowance for the roadway of 208.1 W.

The calculation can also be tabulated as below.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Initial	250W	-	not used
Area	0.023 W/sq. ft	4500 sq. ft.	103.5 W
Perimeter	0.17 W/LF	615 ft.	104.6 W
TOTAL POWER ALLOWANCE			**208.1 W**

B. Calculation of Allowed Lighting Power - Narrow Band Spectrum Light Source Applications

The 2019 Standards includes a lighting power provision for narrow band spectrum light source application to minimize the impact of electric light on local, active professional astronomy or nocturnal habitat of specific local fauna. The provision is in the format of lighting power multiplier as specified on the footnote of Table 140.7-A (footnote 3) which reads, "Footnote 3: Narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm – as mandated by local, state, or federal agencies to minimize the impact on local, active professional astronomy or nocturnal habitat of specific local fauna, shall be allowed a 2.0 lighting power allowance multiplier."

Example 6-21 Calculating the Illuminated Area of a Parking Lot

Question

The lighting system for an asphalt parking lot in Lighting Zone 2 is being designed next to an active, professional astronomical observatory. The parking lot is 800 sq. ft. with a perimeter of 280 linear feet. All lighting within 10 miles of the observatory is required by a local ordinance to use a narrow band spectrum light source with a wavelength above 580 nm to be compatible within the telescopes' ability to filter out stray light while capturing most of the wavelengths of light from the night sky. Spectral power distributions of two amber light sources are shown in the two images in Figure 6-21a.

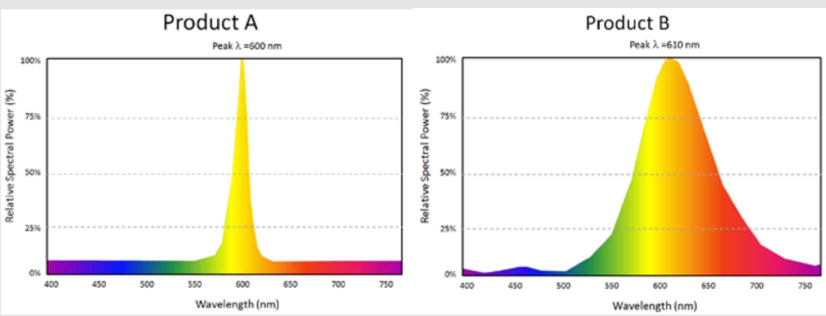


Figure 6-21a Spectral Distribution of Light Source Product A and B

Question 1: Which of these products meet criteria for "narrow band spectrum" light sources?

Question 2: What is the allowed lighting power for this parking lot with and without the use of a narrow band spectrum light source?

Answer

Answer 1: Narrow band spectrum light sources are those which have a spectral power distribution closely distributed around the wavelength of peak spectral power. There are no spectral power limitations on the wavelengths that are within 20 nm of the peak wavelength. As the spectrum diverges from the peak wavelength, the allowed relative spectral power declines rapidly.

Between 20 to 75nm from peak wavelength, the spectral power shall be no greater than 50% of the peak spectral power.

Beyond 75 nm the spectral power shall be no greater than 10% of the peak spectral power. This distribution is reflected in the narrow ban spectrum criteria line centered around the peak wavelength in Figure 6-21b.

As shown in the figure, Product A is a narrow band spectrum light source as it fits within the spectral power criteria, whereas Product B does not comply as the spectral power exceeds the narrow band criteria.

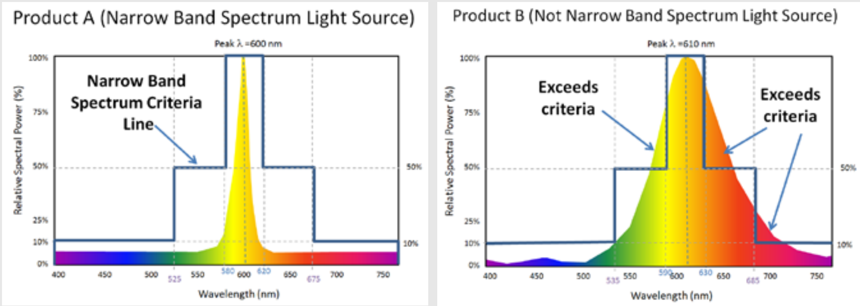


Figure 6-21b Spectral Distribution with Narrow Band Criteria Superimposed

Answer 2: To claim the two times multiplier for narrow band spectrum light sources, as described in footnote 3 to Table 140.7-A, the project has to comply with all three of the following criteria:

1. The light source has to have a narrow band spectrum (true for product A).

2. The dominant peak wavelength has to be greater than 580 nm (true for product A with a peak wavelength of 600 nm).

3. The narrow band spectrum and dominant peak wavelength of the light source has to be greater than 580 nm as mandated by local, state, federal agencies, to minimize the impact on local, active professional astronomy or on the nocturnal habitat of specific local fauna. (The credit is not available unless the ordinance specifically calls out a requirement for a narrow band spectrum.)

The allowed wattage without the narrow spectrum multiplier calculated as follows:

Allowed Wattage = (Area Wattage Allowance) x (Area, sq. ft.) + (Linear Wattage Allowance) x (Perimeter Length, linear ft.) + (Initial Wattage Allowance)

The asphalt parking lot is 800 sf with a perimeter of 280 linear feet and is in Lighting Zone 2. From Table 140.7-A in the asphalt column of Lighting Zone 2, the power allowance factors are:

Area Wattage Allowance = 0.023 W/sq. ft., Linear Wattage Allowance = 0.17 W/lf, and Initial Wattage Allowance = 250 Watts.

Allowed Wattage = (0.023 W/sq. ft) x (800 sq. ft.) + (0.17 W/lf) x (280 lf) + (250 W) = 316 Watts

If the design makes use of narrow band light sources and meets all three criteria of footnote 3 to table 140.7-A, the allowed wattage is allowed a 2.0 lighting power allowance multiplier.

Narrow Band Allowed Wattage = Allowed Wattage x 2 = 316 Watts x 2 = 632 Watts.

Example 6-22 Low Blue Content Light Source Design

Question

A lighting system is being designed for a similar parking lot as in Example 6-21 except that it is next to a wildlife refuge and all outdoor lighting near the refuge is required by a local ordinance to use low blue content light sources to minimize the lighting impact on nocturnal animals.

If the designer specifies a narrow band spectrum light source (such as Product A in Example 6-21), can the designer make use of the narrow band spectrum lighting power allowance multiplier in determining the lighting power allowance?

Answer:

To claim the two-times multiplier for narrow band spectrum light sources, as described in footnote 3 to Table 140.7-A, the project must comply with all three of the following criteria:

1. The light source has to have a narrow band spectrum.

2. The dominant peak wavelength has to be greater than 580 nm.

3. The narrow band spectrum and dominant peak wavelength of the light source be greater than 580 nm, as mandated by local, state, federal agencies to minimize the impact on local, active professional astronomy or on the nocturnal habitat of specific local fauna (The credit is not available unless the ordinance specifically calls out a requirement for a narrow band spectrum.)

For this example, the narrow band spectrum credit is not available since the local ordinance called for low blue light content without specifying this had to be accomplished with narrow band spectrum light sources with a dominant peak wavelength greater than 580 nm. As a result, the two-times multiplier for narrow band spectrum light sources cannot be used in calculating the lighting power allowance for this project.

6.5.3 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 6-4: 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, Healthcare Facilities, 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	20 watts	40 watts	57 watts	60 watts
Drive Up Windows. Allowance per customer service location. Luminaires must be within 2 mounting heights of the sill of the window.	Not applicable	16 watts	30 watts	50 watts	75 watts
Vehicle Service Station Uncovered Fuel Dispenser. Allowance per fueling dispenser. Luminaires must be within 2 mounting heights of the dispenser.	Not applicable	55 watts	77 watts	81 watts	135 watts
ATM Machine Lighting. Allowance per ATM machine. Luminaires must be within 50 feet of the dispenser.	Not applicable	100 watts for first ATM machine, 35 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	11 W/linear ft.	19 W/linear ft.	25 W/linear ft.
WATTAGE ALLOWANCE PER HARDSCAPE AREA (W/sq. ft.). 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	0.007 W/sq. ft.	0.013 W/sq. ft.	0.019 W/sq. ft.
WATTAGE ALLOWANCE PER SPECIFIC AREA (W/sq. ft.). 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	0.100 W/sq. ft.	0.170 W/sq. ft.	0.225 W/sq. ft.
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	0.060 W/sq. ft.	0.210 W/sq. ft.	0.280 W/sq. ft.	0.485 W/sq. ft.
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	0.006 W/sq. ft.	0.068 W/sq. ft.	0.138 W/sq. ft.	0.200 W/sq. ft.
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	0.220 W/sq. ft.	0.430 W/sq. ft.	0.580 W/sq. ft.	1.010 W/sq. ft.
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	0.470 W/sq. ft.	0.622 W/sq. ft.	0.740 W/sq. ft.

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	0.057 W/sq. ft.	0.137 W/sq. ft.	0.270 W/sq. ft.	0.370 W/sq. ft.
Guard Stations. Allowed up to 1,000 square feet 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, documentations, vehicle license plates, and vehicle contents. Qualifying luminaires shall be within 2 mounting height of a vehicle lane or the guardhouse.	Not applicable	0.081 W/sq. ft.	0.176 W/sq. ft.	0.325 W/sq. ft.	0.425 W/sq. ft.
Student Pick-up/Drop-off zone. Allowance for the area of the student pick-up/drop-off, 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 feet, times the smaller of the actual length or 250 feet. Qualifying luminaires shall be within 2 mounting heights of the student pick-up/drop-off zone.	Not applicable	No Allowance	0.056 W/sq. ft.	0.200 W/sq. ft.	No Allowance
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.	Not applicable	0.004 W/sq. ft.	0.030 W/sq. ft.	0.050 W/sq. ft.	0.075 W/sq. ft.
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.	Not applicable	0.004 W/sq. ft.	0.005 W/sq. ft.	0.010 W/sq. ft.	No Allowance

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 by multiplying the total length of the instance by 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, healthcare facilities, 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 by multiplying the total length of qualifying sales frontage by 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 by multiplying the total illuminated hardscape for the site by 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/ sq. ft.), 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 sq. ft. 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., multiplied by 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.

6.5.4 Further Discussion about Additional Lighting Power Allowance for Specific Applications

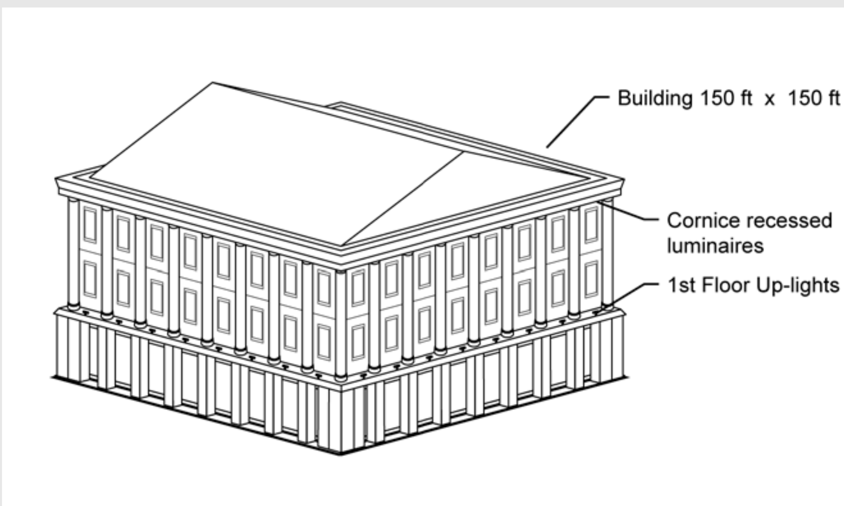
A. Building Facades

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.

Example 6-23 Calculating the Allowance for a Projected Area

Question



(Lighting Zone 3) A city wants to illuminate its city hall on two sides (two facades). 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

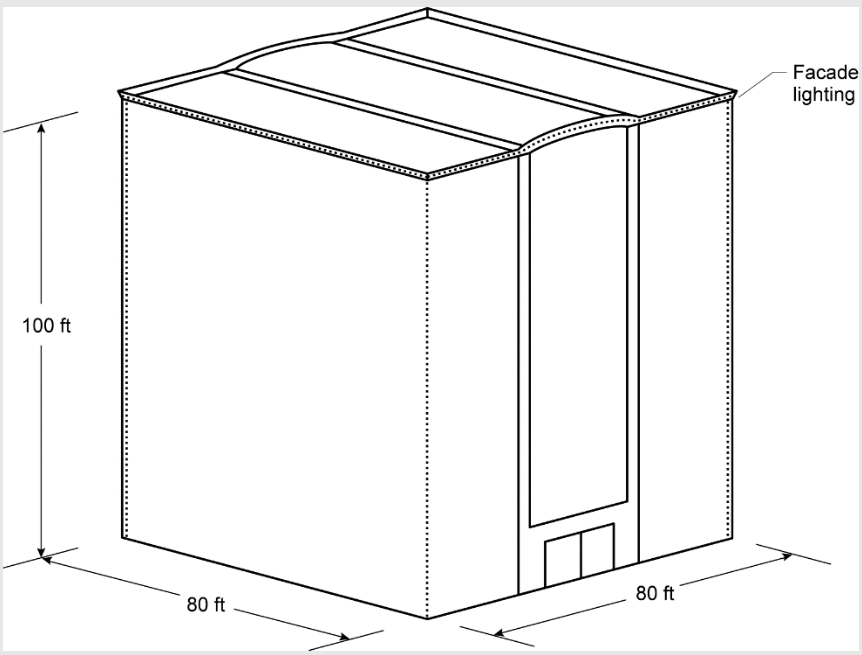
The area of the façade for the purposes of calculating the lighting allowance is the projected area of the illuminated façade. Architectural features such as columns, recesses, facets, etc. are ignored. The illuminated area for each façade is therefore 30 ft. x 150 ft. or 4,500 sq. ft. The façade allowance for Lighting Zone 3 is 0.17 W/sq. ft., so the total power allowed is 765 W per façade, or 1,530 W total.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.17 W/ sq. ft.	B. 4,500 sq. ft.	765 W per facade
TOTAL POWER ALLOWANCE			**1,530 W**

Example 6-24 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 7 W LED 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 sq. ft.. The total illuminated area is four times 8,000 sq. ft. or 32,000 sq. ft.. The Lighting Zone 3 allowance for façade lighting is 0.17 W/sq. ft. and the total power allowance for façade lighting is 5,440 W.

There are 100 ft. x 4 plus 80 ft. x 4 lamps (a total of 720 luminaires) on the building. Each luminaire is 7 W. The installed power is 720 luminaires times 7 W/luminaire or 5,040 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 0.1 W/sq. ft. or a total of 3,200 W. The lighting design would not comply in Lighting Zone 2.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.17 W/ sq. ft.	32,000 sq. ft.	5,440 W
	TOTAL POWER ALLOWANCE		**5,440 W**

Example 6-25 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 ft.^{2} of fenestration in the front wall that is illuminated by the façade lighting. Signs cover another 500 ft.^{2} of the front wall, and another 400 sq. ft. is not illuminated at all. What is the allowed front façade lighting power?

Answer

The gross wall area is 2,400 sq. ft. (120 x 20). However, we must subtract all those areas that are not illuminated. Note that because the 250 sq. ft. 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 sq. ft. of signs + 400 sq. ft. of unlighted façade = 900 sq. ft.

Net wall area used for façade lighting: 2,400 sq. ft. – 900 sq. ft. = 1,500 sq. ft.

From Table 6-5 (Table 1407-B of the Energy Standards), the allowed façade lighting power density in Lighting Zone 3 is 0.17 W/ sq. ft.

The calculated allowed power based on net wall area is 1,500 sq. ft. x 0.17 W/ sq. ft. = 255 W.

The allowed power is therefore the smaller of actual wattage used for façade lighting or 255 W.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Facade	0.17 W/ sq. ft.	1,500 sq. ft.	255 W
	TOTAL POWER ALLOWANCE		**255 W**

Example 6-26 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 6-27 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 6-28 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.

C. 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 by multiplying the total length of qualifying sales frontage by 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

D. 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 fueling 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 6-3: Service Station Hardscape Areas

Source: AEC Photographer: Tom Bergstrom

Example 6-29 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.

E. 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 6-4: Canopy Lighting

Source: AEC Photographer: Tom Bergstrom

Example 6-30 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 sq. ft. 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 $ft.^2$ used for the flower cart, news-stand and shoe shine stand is considered a sales canopy and the allowance is 0.622 W/ sq. ft. or a total of 933 W. The other 1,500 sq. ft. is a non-sales canopy and the allowance is 0.270 $W/ft.^2$ or a total of 405 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. 270W/ sq. ft.	1,500 sq. ft.	405 W
Sales Canopy	0.622 w/ sq. ft.	1,500 sq. ft.	933 W
TOTAL POWER ALLOWANCE			**1,338 W**

F. 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 by multiplying the total illuminated hardscape for the site by 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 30 watts or less and not providing general and task lighting, they qualify as ornamental lighting)

Example 6-31 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.

G. 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 6-6: Drive-up Windows

Source: AEC Photographer: Tom Bergstrom

Example 6-32 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, 30 W is allowed for each drive-up window.

H. 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 sq. ft. 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 6-33 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 ft.². 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 ft.² times 0.176 W/ft.² is 105.6 W, in addition to the general hardscape lighting power allowance.

Example 6-34 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.

6.6 Alterations and Additions for Outdoor Lighting

§141.0(b)2L

The Energy Standards apply to alterations and additions to outdoor lighting systems, and the application of the Energy Standards to alterations depends on the scope of the proposed improvements.

Lighting alterations generally refers to replacing the entire luminaire.

Example 6-35 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.

6.6.1 Outdoor Lighting Alterations – With an Increase of Lighting Loads

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.

Example 6-36 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 luminaire cutoff requirements.

6.6.2 Outdoor Lighting Alterations – With no Increase of Lighting Loads, and small changes to existing luminaires

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).

Example 6-37 BUG Requirements for Lighting Alterations

Question

We are replacing 20 percent of the existing HID 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 luminaire cutoff (“BUG”) requirements; however, luminaires that are not being replaced are not required to be upgraded to meet the luminaire BUG requirement. §141.0 (b)2L specifies that all altered luminaires must meet applicable mandatory requirements, including the BUG requirements for replacements luminaires. Therefore, replacement luminaires that are greater than 6,200 initial luminaire lumens must meet the luminaire BUG requirements, even if less than 5 luminaires or 10 percent of the luminaires on site are replaced.

6.6.3 Outdoor Lighting Alterations – With no Increase of Lighting Loads, and sizable changes to existing luminaires

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.

Example 6-38 Requirements for Replacing more thatn 50 percent of 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 §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.

There is an exception (to Section 141.0(b)2Liii) for the alteration in which the replacement luminaires are at least 40 percent more efficient in lighting power than the existing luminaires.

Example 6-39 Exemption from lighting power allowance requirements

Question

Fifty 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 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.

6.6.4 Outdoor Lighting Alterations – With no Increase of Lighting Loads, and other small changes to existing luminaires

For alterations that do not increase connected lighting load and replace less than 5 luminaires or less than 10 percent of the existing luminaires, the requirements to comply are minimal – comply with the luminaire cutoff (“BUG”) requirements of Section 130.2(b) and applicable installation and acceptance requirements of Section 130.4.

Example 6-40 Outdoor Lighting Alteration Triggers

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 calculate the lighting power allowance for the hardscape area, or you can list the quantity 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 or must achieve a 40 percent reduction in lighting power.

6.6.5 Outdoor Lighting Additions– Mandatory and Lighting Power Requirements

§141.0(a)1. §130.0, §130.2

Outdoor lighting additions are treated similarly as newly constructed buildings, and must comply with all mandatory lighting control and lighting power requirements.

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, outdoor luminaire and control requirements apply as follows:

- Outdoor luminaires that emit 6200 lumens or greater must comply with backlight, uplight and glare (“BUG”) requirement. (Refer to Section 6.3.1 for the outdoor luminaire BUG requirement.)
- Outdoor lighting control requirements including automatically turning off lighting when daylight is available. [§130.2(c)1]
- All outdoor lights shall be automatically controlled by a time-based scheduling controls. [§130.2(c)2]
- Outdoor luminaires greater than 40 watts and mounted less than 24 feet and above the ground shall be motion controlled, so that the lighting power of each luminaire shall be automatically reduced by at least 50 percent. This applies to luminaires providing general hardscape lighting, outdoor sales lot lighting, vehicle service station hardscape lighting, or vehicle service station canopy lighting. [§130.2(c)3].

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.

6.6.6 Outdoor Lighting Additions and Alterations– More Examples

Example 6-41 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 sq. ft. 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 0.050 W/sq. ft. Multiplying this allowance by 400 sq. ft. yields 20 W.

Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Outdoor Dining	0.050 W/ sq. ft.	400 sq. ft.	20 W
TOTAL POWER ALLOWANCE			20 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 6-42 Power Allowance for Additional Outdoor Dining (Outside Illuminated Area)

Question

A strip mall in Lighting Zone 3 with a common asphalt parking lot has the parking lot lighting system designed and installed. A restaurant moves into one of the buildings and designates 400 $ft.^2$ 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 sq. ft.. 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.

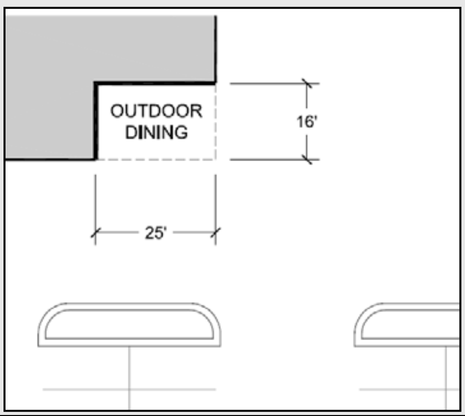
As shown in the figure below, the perimeter length is 41 ft. (25 ft. + 16 ft.). In LZ3 the asphalt AWA is 0.025 W/sq. ft. and the LWA is 0.25 W/ft. The additional allowance for the outdoor dining area for specific applications (Outdoor Dining) as contained in Table 140.7-B is 0.05 W/sq. ft.. Thus for a perimeter length of 41 ft. and an area of 400 sq. ft., the total lighting wattage allowance is:

Hardscape LWA of 0.25 W/ sq. ft. x 41 ft. = 10.3 W

Hardscape AWA of 0.025 W/sq. ft. x 400 sq. ft. = 10 W

Specific Allowance Outdoor Dining 0.05 W/sq. ft.. x 400 sq. ft. = 20 W

Total allowance = 40.3 W



Type of Allowance	*Allowance*	*Area/Perimeter Value*	*Power Allowance*
Outdoor Dining	0.050 W/ sq. ft.	400 sq. ft.	20 W
Area	0.025 W/ sq. ft.	400 sq. ft.	10 W
Perimeter	0.25 W/LF	41 ft.	10.3 W
TOTAL POWER ALLOWANCE			40.3 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.

6.7 Outdoor Lighting Compliance Documents and Acceptance Tests

This section contains information about the Certificate of Compliance, Certificate of Installation, and Certificate of Acceptance needed for compliance with the nonresidential outdoor lighting requirements of the Energy Standards.

6.7.1 Overview

At the time a building permit application is submitted to the enforcement agency, the applicant also submits plans and energy compliance documentation including the Certificate of Compliance. The enforcement agency plan checkers examine these documents for compliance with the Energy Standards

The person responsible for the construction of the lighting system should submit the Certificate of Installation and Certificate of Acceptance to the local building department or the enforcement agency after the installation and before receiving the building occupancy permit.

6.7.2 Compliance Documentation and Numbering Scheme

Nonresidential outdoor lighting Certificate of Compliance documents are listed below:

- NRCC-LTO-E; Certificate of Compliance: Outdoor Lighting

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.

6.7.3 Certificate of Installation Documents

The Certificates of Installation is 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.

6.7.4 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:

- Certifying plans, specifications, installation certificates, and operating and maintenance information to meet the requirements of the Energy Standards.
- Certifying 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. See the following chapters about compliance and enforcement, and acceptance requirements.

- Chapter 2 - Compliance and Enforcement
- Chapter 13 - Acceptance Requirements

6.7.5 Acceptance Tests

The primary purpose of outdoor lighting acceptance tests is to assure the lighting controls are configured properly and are functioning as expected in meeting the energy code requirements.

The procedures for performing the lighting acceptance tests are documented in Reference Nonresidential Joint Appendix. See the following sections for the outdoor lighting controls acceptance tests.

- NA7.8.1 and NA7.8.2 for Motion Sensor (aka Motion Sensing Controls)
- NA7.8.3 and NA7.8.4 for Photocontrol
- NA7.8.5 and NA7.8.6 for Astronomical Time-Switch Controls
- NA7.8.7 and NA7.8.8 for Automatic Scheduling Controls

Often, the building occupancy schedule is not known at the time the acceptance test is performed as it is before occupancy. If this is the case, a default schedule of midnight to 6 am - as the normally unoccupied period - could be used for the acceptance test of the installed automatic scheduling controls to verify that the outdoor lighting power could be reduced by at least 50 percent during the unoccupied period.

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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 Scope and Application

The 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.

7.1.2 Summary of Requirements

§110.9, §130.0, §130.3, §140.8 and §141.0

7.1.2.1 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.

7.1.2.2 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/ft^2 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, §110.12, §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 Using Lighting Control to Comply with the Energy Standards

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.

B. Lighting Control Functionality:

All Installed Lighting Controls listed in §110.9(b) shall comply with the requirements listed below. In addition, 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).

Designers and installers are advised to review features of their specified lighting control products for meeting the requirements of Section 110.9(b) as part of the code compliance process.

1. Time-Switch Lighting Controls

   Time-switch lighting control products shall provide the functionality listed in Section 110.9(b)1 of the Energy Code.

2. Daylighting Controls

   Daylighting control products shall provide the functionality listed in Section 110.9(b)2 of the Energy Code.

3. Dimmer

   Dimmer products shall provide the functionality listed in Section 110.9(b)3 of the Energy Code.

4. Occupant Sensing Controls

   Occupant sensing control products (including occupant sensors, partial-ON occupant sensors, partial-OFF occupant sensors, motion sensors, and vacancy sensor controls) shall provide the functionality listed in Section 110.9(b)4 of the Energy Code.

   One important functionality is to be capable of automatically turning the lights either off or down within 20 minutes after the area has been vacated.

   EXCEPTION to the requirement: 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 occupants from manual-on to automatic-on functionality.

5. Part-Night Outdoor Lighting Controls

   Part-night outdoor lighting control products shall provide the functionality listed in Section 110.9(b)5 of the Energy Code.

7.2.2 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 other than exit 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.

Sign lightings installed at healthcare facilities are not required to meet sign lighting control requirements in §130.3.

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 options:
    1. A photo control 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

§110.12(d)

Electronic Message Centers (EMCs) that have a connected lighting load greater than 15kW must that have demand responsive controls unless a health or life safety statute, ordinance, or regulation does not permit EMC lighting to be reduced. See Appendix D of this manual for guidance on compliance with the demand responsive control requirements.

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.

   Exit signs are required to meet the requirements of the Appliance Efficiency Regulations.

3. Traffic Signs.

   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). For double-faced signs, only the area of a single face shall be used to determine the allowed lighting power (see Figure 7-3).

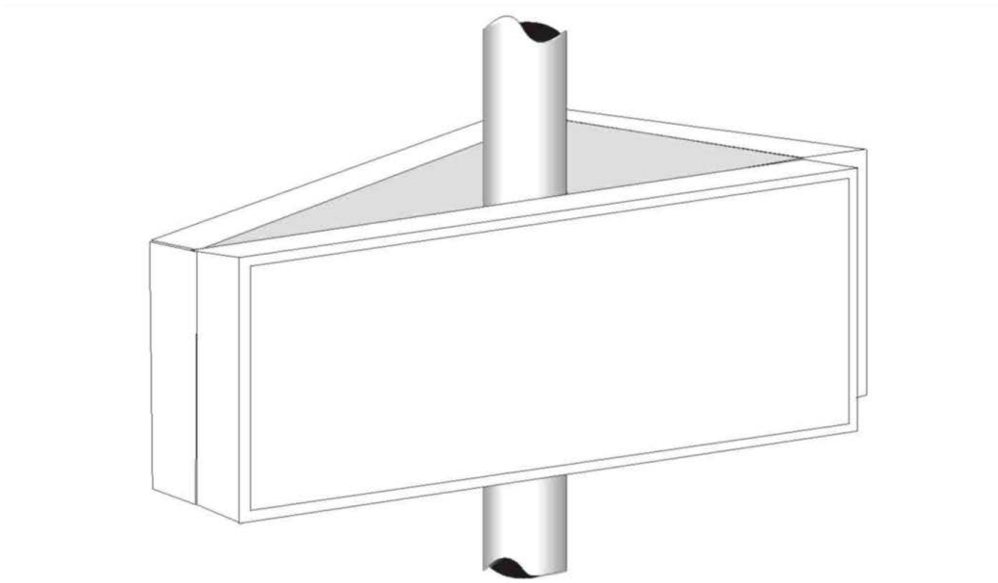
   Internally illuminated signs are defined in the Energy Standards as signs that are illuminated by a light source that is contained inside a sign where the message area is luminous, including cabinet signs and channel letter signs.

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.

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

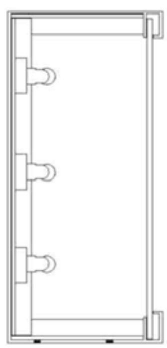
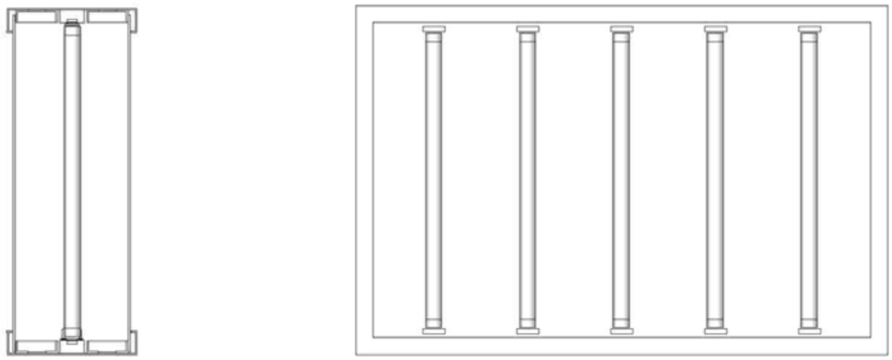


Figure 7-3: Double-faced Internally Illuminated Cabinet Sign with Fluorescent Lamps and Translucent Faces



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 referenced *lamp* power *divided by the* ballast *input* power *when tested according to ANSI C82.6*-2015*.*
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

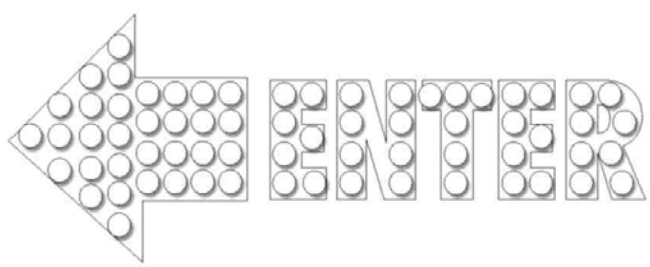
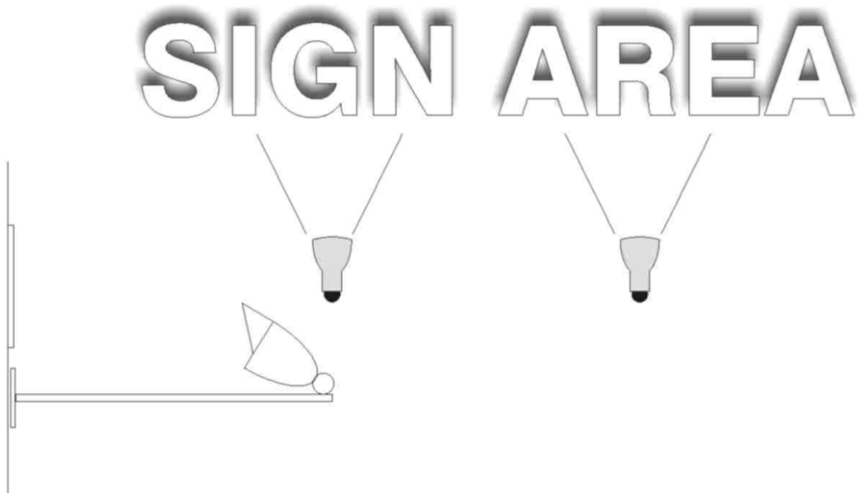


Figure 7-5 shows an externally illuminated sign using flood lighting, which is regulated by the Energy Standards. The power (wattage) used for these lighting components must comply with the watts per square foot approach, or use only lighting technologies approved according to §140.8(b).

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?

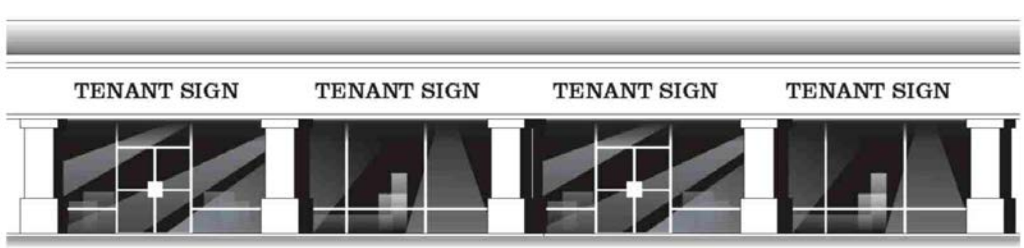
Answer

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.”

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-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 the 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 5.11.5 of this manual for information about the Certificate of Compliance, and Section 5.11.6 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)
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

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 sign lighting controlled by a lighting control system or by an EMCS, the NRCI-LTS-E shall be used as a Certificate of Installation submitted for signs.

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8. Electrical Power Distribution

This chapter describes the Title 24, Part 6, Building Energy Efficiency Standards (California Energy Code or the Energy Standards) requirements in Section 130.5 (§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 What's New for 2019 California Energy Code?

The significant changes for electrical power distribution systems in the 2019 update to the Energy Standards include:

A. Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) having to comply with the applicable requirements of §130.5 for electrical power distribution systems. There are exemptions added for healthcare facilities to avoid potentially conflicting requirements for healthcare facilities. The exceptions may be revisited for changes in future code cycles.

B. Relocated requirements related to demand responsive controls from §130.5 to a new Section 110.12.

8.1.2 Scope and Applications

The following requirements for electrical power distribution systems apply to all nonresidential, 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 Section 141.0(b)2P of the Energy Standards.

For alterations with new or replacement electrical service equipment, the requirements of §130.5(a) must be met. For alterations with entirely new or complete replacements of electrical power distribution systems, the requirements of §130.5(b) and (d) must be met. An electrical power distribution system can encompass service equipment, disconnecting means, overcurrent protection devices, feeders, circuit feeders, luminaires, receptacles, and electrical equipment such as switchboards, step-down transformers, and panelboards. For example, a building rehabilitation project where the entire electrical power distribution system is demolished and replaced with new is required to meet the requirements of §130.5(b) and (d).

For alterations of feeders and branch circuits, which include adding, modifying, or replacing feeders and branch circuits, the voltage drop requirements of §130.5(c) must be met. See Section 8.6 of this manual and Section 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 kilovolt-ampere (kVA) as specified in Table 130.5-A and stated below:

1. For electrical service rated at any kVA, the meter must be able to indicate instantaneous kW demand and kWh for a user-defined period.
2. For electrical service rated more than 250 kVA, the meter must be able to measure historical peak demand in kilowatts.
3. For electrical services rated more than 1,000 kVA, 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 the requirements of this section 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:

1. "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.
2. “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 California Electrical Code.

This is not a requirement to install meters 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.

- For the 2019 Standards, healthcare facilities are exempted from the requirement of Section 130.5(a), Service Electrical Metering. Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) are brought into the scope of Title 24 Part 6 for the first time. This exemption is to avoid potentially conflicting requirements for healthcare facilities.

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. It provides the required kW and kWh information, and I intend to use 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 tenant space is served by separate 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 Separation of Electrical Circuits requirement sets 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 set up and implemented without significant physical changes to the electrical installations. The 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. Further analysis of such energy information can help facilitate energy efficiency and related measures to improve building energy performance for building owners and operators.

For the 2019 Standards, healthcare facilities are exempted from the requirement of Section 130.5(b), Separation of Electrical Circuits for Electrical Energy Monitoring. Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) are brought into the scope of Title 24 Part 6 for the first time, and this exemption avoids potentially conflicting requirements for healthcare facilities.

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 50 kVA, 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.

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, rather than prescriptive requirements, the 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 (See Example 8-6):** Switchboards, motor control centers, or panelboards loads can be disaggregated for each load type, allowing energy measurement of each load type independently and readily. 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 for taking energy measurement of each load type, as each 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 (See Example 8-7):** Switchboards, motor control centers, or panelboards may supply other distribution equipment with the associated 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 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 to obtain the energy usage of each load type.

C. **Method 3 (See Example 8-8):** Switchboards, motor control centers, or panelboards may supply more than one load type as long as each branch circuit serves a single load type and the equipment includes provisions for adding branch circuit monitoring in the future. For example, neighboring branch circuits in a panelboard may serve receptacles and fans respectively, but any circuit of that panelboard cannot serve a mixed type of loads. Also, there is no mandatory requirement to include branch circuit monitoring at this time.

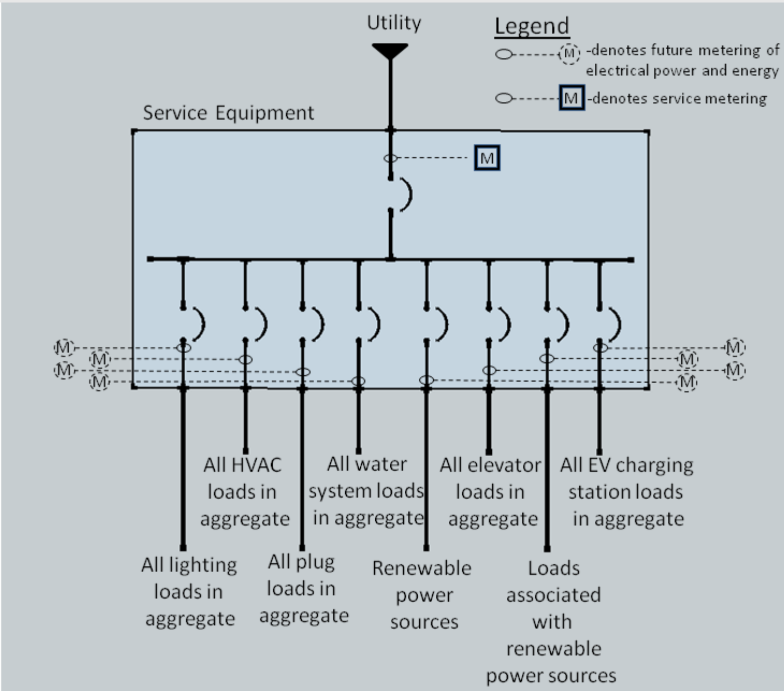
D. **Method 4:** Buildings for which a complete metering and measurement system is provided so that it can measure and report the loads by type.

This method allows a complete metering system to be used to meet the requirements of §130.5(b), provided that at a minimum the system 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. It provides benefits for building owner and operators by giving them a readily available tool for assessing the building energy usage as soon as the facility is turned over to them.

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 50 kVA. Following is the proposed concept layout of separation of circuits for connecting different load types to the service equipment. Does this concept meet the requirements of the Energy Standards?



Answer:

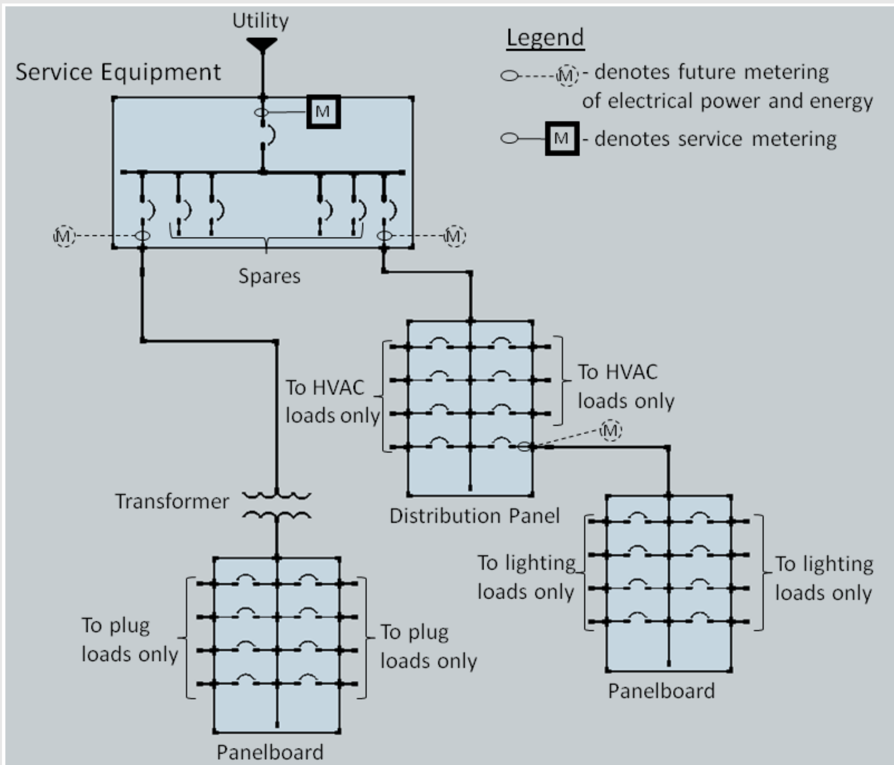
The proposed design meets the separation of electrical circuit requirement of §130.5(b) as there are separations of circuits for connecting different load types to the service equipment. There should be provisions including physical spaces for future setup of measurement devices for energy monitoring 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?



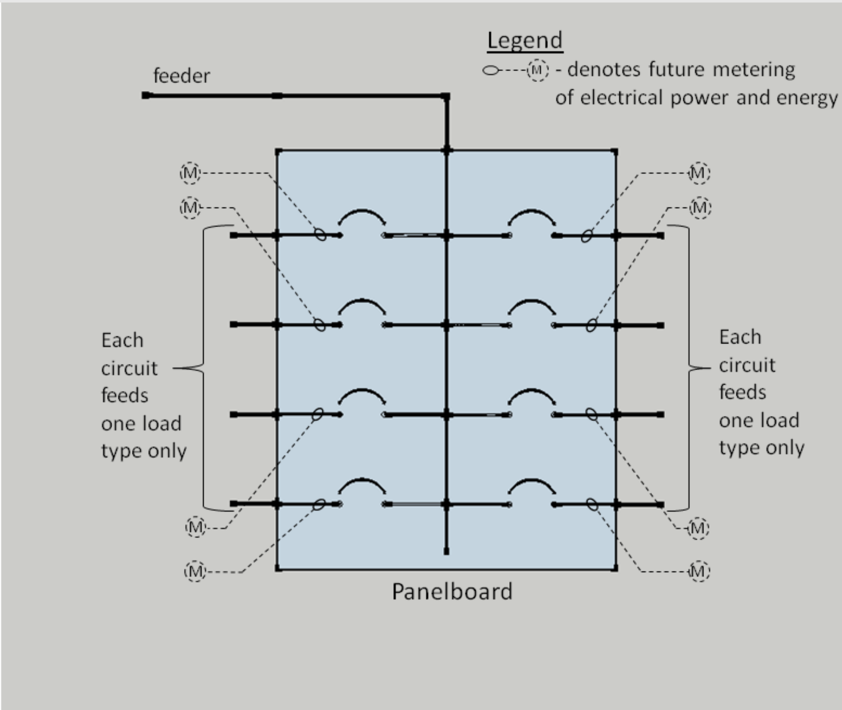
Answer:

The proposed design meets the separation of electrical circuit requirement of §130.5(b) as each load type 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 be 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 size of 50 kVA or less, separation of electrical loads is not required for the building loads, except for any renewable power sources (solar PV systems) and electric vehicle charging stations installed at the building.

In buildings with a larger service between 50 kVA and 250 kVA, separate risers for lighting, receptacles/equipment, and HVAC are allowed to be used for meeting the separation of electrical circuits requirement. 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 buildings with 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 provision to allow for future metering for each load type – metering data available can further be organized, compiled, and viewed with software or mobile apps for each load type).

In a multistory 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, and so forth) or by the type of light fixture (metal halide vs. fluorescent, dimmable vs. fixed output). So, for instance, 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 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 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 5 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

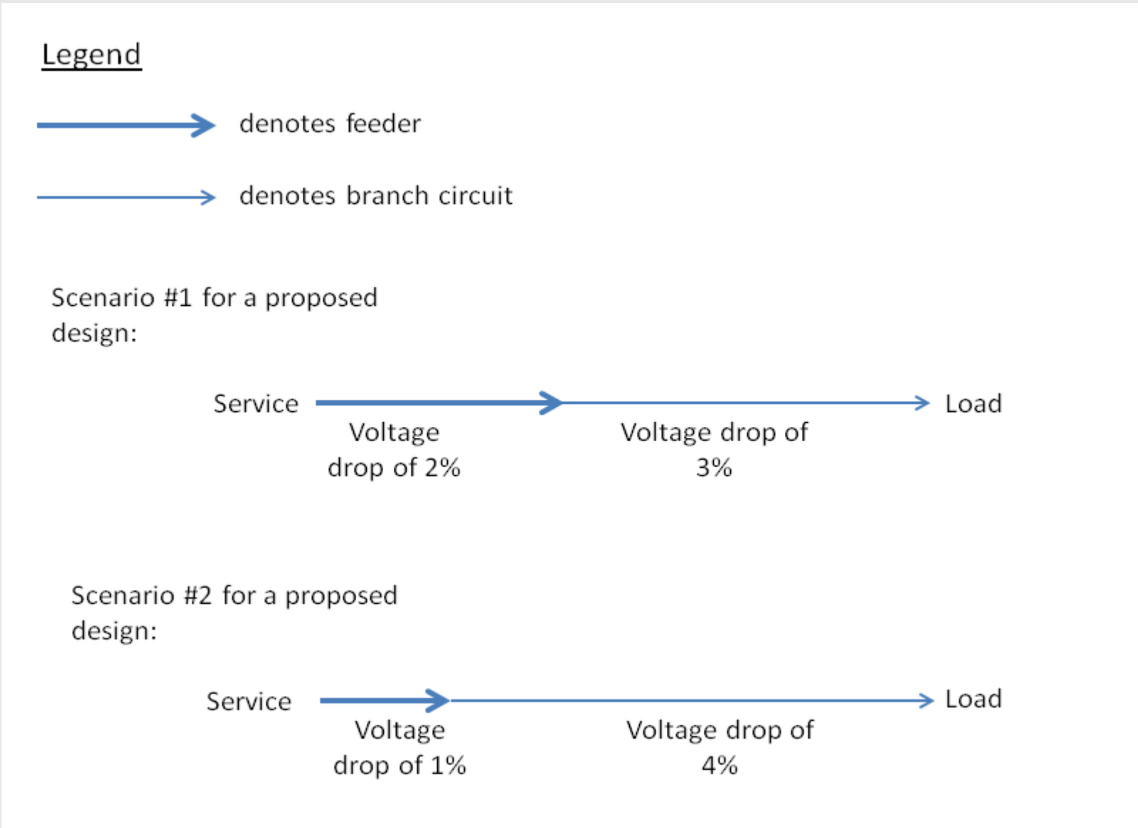
However, the informational note about voltage drop in Article 210, Branch Circuits, of the California Electrical Code is not part of the requirements of the Energy code, nor is the informational note about voltage drop in Article 215, Feeders.

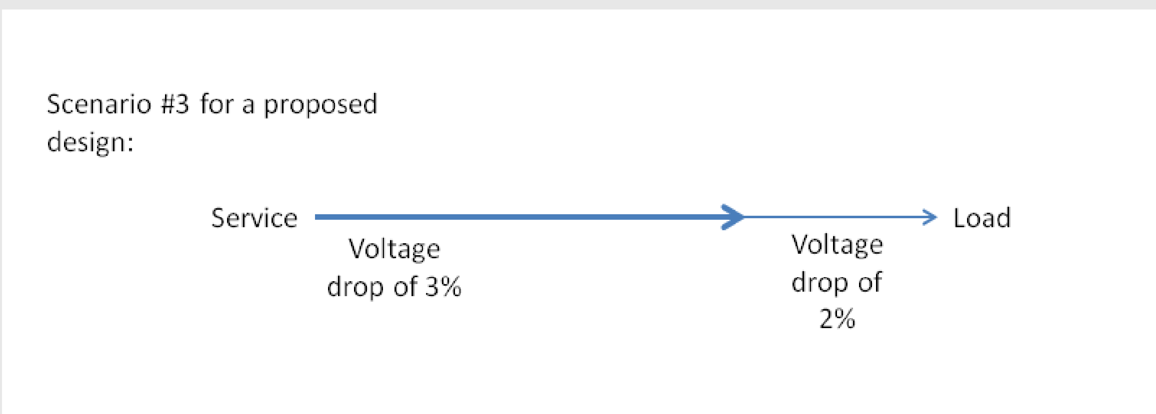
Voltage drop represents energy lost as heat in the electrical conductors. The loss is called "I^2R" (I-squared-R) loss, meaning that the loss is directly proportional to the conductor resistance and to the current squared. Because of I^2R loss, it is advantageous to distribute utilization power at the 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

Question: 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.

Example 8-10

Question: Do healthcare facilities have to comply with the voltage drop requirement?

Answer:

Healthcare facilities have to meet the voltage drop requirement in Section 130.5(c).

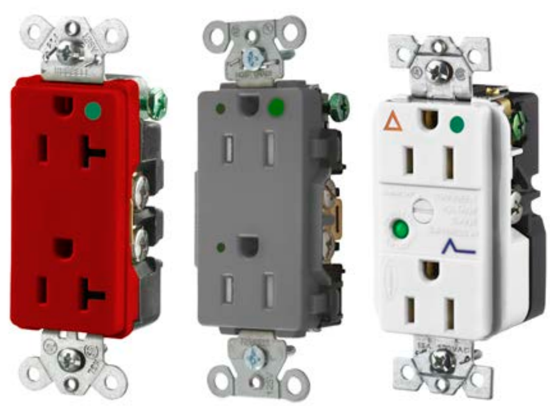
8.5 Circuit Controls and Controlled Receptacles for 120-Volt Receptacles

§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 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.

For the 2019 Standards, receptacles in healthcare facilities are exempted from the requirement of Section 130.5(d), Circuit Controls for 120-Volt Receptacles and Controlled Receptacles. Healthcare facilities overseen by the California Office of Statewide Health Planning and Development (OSHPD) are brought into the scope of Title 24 Part 6 for the first time; the purpose of this exemption is to avoid potentially conflicting requirements for healthcare facilities.

Figure 8-1: Samples of Receptacles for Hospital Applications



Source: Hubbell Wiring Devices - Kellems

All controlled receptacles must be marked to differentiate them from uncontrolled receptacles.

Either circuit controls or controlled receptacles for 120-volt receptacles can be used for meeting the requirements of Section 130.5(d).

Methods for meeting requirements include the following:

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. See next section, “Application Considerations,” for example approaches of using automatic means for shutting off controlled receptacles. 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 to meet 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. (The receptacle must be mounted 6’ or more above the floor to meet this exception.)
3. Receptacles in copy rooms specifically for **network** copiers, fax machines, audio-visual equipment, 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 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. 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 automatic shut-off system of the building 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)

When demand-response controls are installed at the power distribution system level (for example, circuit-level controls), the controls must comply with §110.12(a) and may need to comply with additional requirements if they are specifically intended to control HVAC or lighting systems. See Appendix D of this manual for guidance on compliance with the demand-responsive control requirements.

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.

A summary of requirements for alterations of electrical power distribution systems is as 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.

   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.

   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 8-11

Question:

I have an existing building with multiple tenant spaces, and each 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 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 8-12

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 entire electrical power distribution system; therefore, separation of electrical circuits would not typically be required.

Another example is a project with a portion of the system upgraded with greater capacity and the work scope includes replacement of panelboards, associated feeders and overcurrent protection devices – it is not considered to be complete replacement or entirely new electrical power distribution system, as other existing equipment are not changed or replaced. This is not a complete replacement and not an entirely new electrical power distribution system.

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 efficiency regulations, and both medium-voltage dry-type and liquid-immersed transformers are included in the Appliance Efficiency Regulations.

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 the 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
13. Welding transformers.

8.8 Electrical Power Distribution Systems Compliance Documents

8.8.1 Overview

This section describes the compliance documentation (compliance form[s]) required for compliance with the requirements of the Energy Standards regarding 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 is as follows; the documents are downloadable from California Energy Commission website under the "Compliance Manuals and Compliance Documents" section.

- NRCC-ELC-E, Certificate of Compliance, Electrical Power Distribution Systems
- NRCI-ELC-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 person who is eligible under Division 3 of the Business and Profession Code to accept responsibility for the building design can sign the compliance form

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9. Solar Ready

§110.10

This chapter of the nonresidential compliance manual addresses solar-ready requirements for hotels/motels, nonresidential, and high-rise multifamily buildings. These requirements are in §110.10 and §141.0 and are mandatory for newly constructed buildings, and for additions where the total roof area is increased by at least 2,000 square feet.

The solar ready requirement is implemented when designing the building's rooftop and associated equipment. The intent is to reserve a penetration-free and shade-free portion of the roof for the potential future installation of a solar energy system. There are no requirements to install panels, conduit, piping, or mounting hardware.

9.1 Overview

The solar ready provisions are mandatory; "trade-offs" are not allowed. There are exceptions to the "solar zone" requirements, and these are described in the corresponding sections of this chapter. Because Solar Ready is mandatory, NRCC-SRA-E compliance form must be submitted with the building permit application, even when using an allowable solar zone exception.

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.
- See Example 9-3.

Mixed Occupancy Buildings: The Energy Standards apply to mixed occupancy buildings. Buildings with nonresidential space on the ground floor and multi-family residential floors above are common examples.

9.3 Solar Zone

§110.10(b)

The solar zone is a suitable place where solar panels can be installed at a future date - if the owner chooses to do so. A solar zone area is designed with no penetrations, obstructions or significant shade. The solar zone must comply with the access, pathway, smoke ventilation, and spacing requirements in Title 24 Part 9. Requirements from the other parts of Title 24, and those adopted by a local jurisdiction should also be incorporated in the solar zone design.

The solar zone can be located at any of the following locations:

- Roof of building.
- Overhang of the building.

- Covered parking installed with the building project.
- 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.

Other structures include, but are not limited to, trellises, arbors, patio covers, carports, gazebos, and similar accessory structures.

Multifamily buildings: Solar Ready requirements for low-rise multifamily buildings are located in both the Residential and Nonresidential Compliance Manuals. In the 2019 Energy Standards, the solar zone requirements for low-rise multifamily buildings are grouped with high-rise multifamily, hotel/motel and nonresidential in §110.10(b)1B.

9.3.1 Solar Zone Minimum Area and Exceptions

§110.10(b)1

Total Area: The solar zone must have a total area of at least 15% of the total roof area, after subtracting any skylights. See Example 9-4.

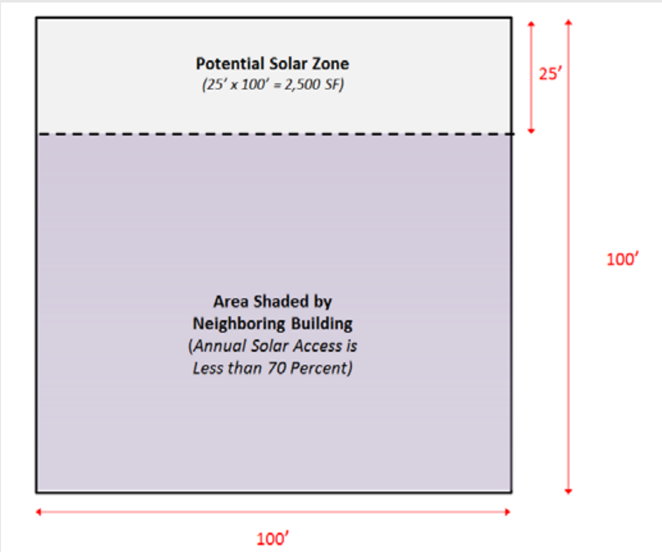
Multiple areas: The solar zone may be composed of multiple subareas if they meet the following minimum size specifications:

1. Each subarea dimension must be at least five feet.
2. If the total roof area is equal to or less than 10,000 square feet, each subarea must be at least 80 square feet.
3. If the total roof area is greater than 10,000 square feet, each subarea must be at least 160 square feet.

Example 9-1

Question:

A roof with no skylights has an area of 10,000 sq. ft. A neighboring building shades the roof, so 7,500 sq. ft 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 sq. ft, or 15 percent of the total roof area (10,000 sq. ft.). However, the since the potential solar zone is 2,500 sq. ft, the minimum solar zone can be reduced to half the area of the potential solar zone, or 1,250 sq. ft.

Example 9-2

Question:

The total roof area is less than 10,000 sq. ft., but the potential solar zone is less than the minimum size requirements for any subarea (less than 80 sq. ft. 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 sq. ft. (if roof is less than or equal to 10,000 sq. ft) or 160 sq. ft. (if roof is greater than 10,000 sq. ft), 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?

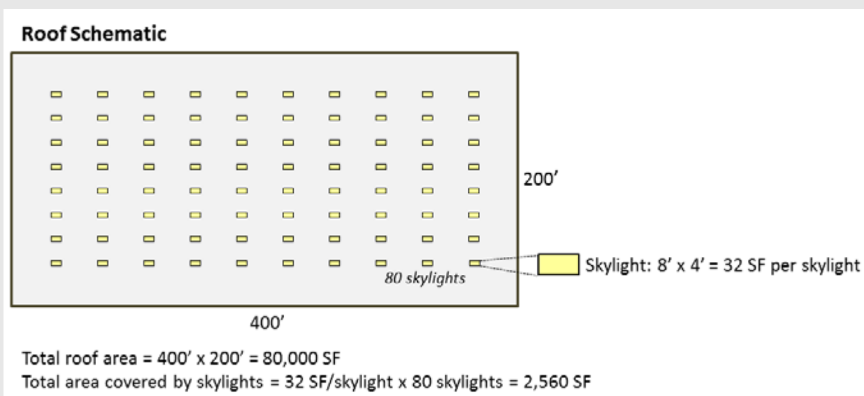
Answer:

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 sq. ft. Skylights cover 2,560 sq. ft. of the total roof area. What is the minimum solar zone area?



Answer:

The minimum solar zone area would be 11,616 sq. ft

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ \ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{11,616\ sq.ft} = \ 15\%\ x\ (80{,}000\ sq.ft - 2{,}560\ sq.ft)$$

Example 9-5

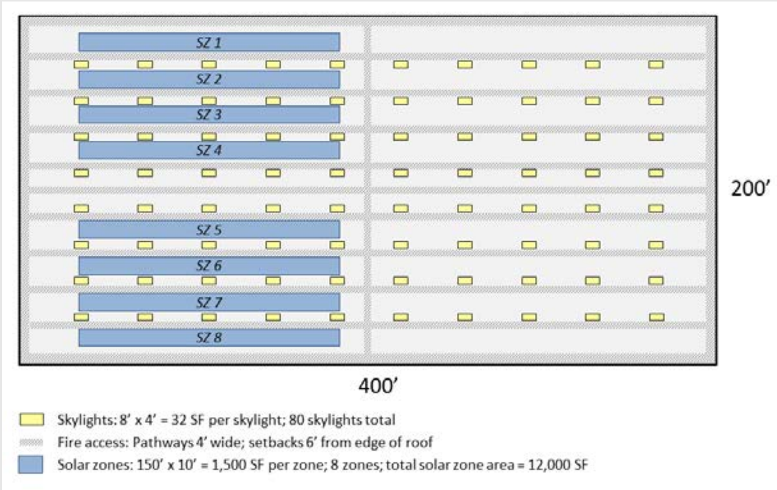
Question:

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 sq. ft or less, each subarea must be at least 80 sq. ft. If the total roof area is greater than 10,000 sq. ft, each subarea must be at least 160 sq. ft.

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 sq. ft. 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.



9.4 Solar Zone Exceptions

There are five exceptions to the solar zone area requirement described in §110.10(b)1B. Some exceptions are limited to certain buildings, as noted in the individual exception details below. Submit an NRCC-SRA-E, the "Solar Ready Areas" Certificate of Compliance to the enforcement agency for all building projects subject to Solar Ready, even if using a Solar Zone Exception.

Exception 3 allows a reduced-size solar zone when solar access is limited by certain circumstances.

Exceptions 1, 2, 4 and 5 allow alternate efficiency measures instead of a solar zone, so the requirements for zone shading, azimuth and design load; interconnection pathway, and owner documentation do not apply either. Any installations must be inspected and verified prior to final approval by the enforcement agency.

Exception 1: A compliant solar electric system is permanently installed on high-rise multifamily, hotel/motel, and nonresidential buildings. The system must have a nameplate direct current (DC) power rating of no less than 1 watt per sq. ft of roof area. The nameplate rating must be measured under Standard Test Conditions. See Example 9-6. To verify compliance with this exception, NRCI-SPV-01-E Certificate of Installation: Solar Photovoltaic System must be submitted as a condition of final approval.

Exception 2: A solar hot water system (SWH) is permanently installed on high-rise multifamily, hotel/motel, and nonresidential buildings. The SWH system must comply with §150.1(c)8Biii, the prescriptive solar requirements for a system serving multiple dwelling units. To verify compliance with this exception, submit NRCI-STH-01-E Certificate of Installation: Solar Water Heating System.

Exception 3: Reduce the solar zone area when the roof is shaded by objects that are not part of the building project, and therefore beyond the designer's control. The designated solar zone may be reduced to ≥ 50 percent of the potential solar zone area when solar access is limited as described below. When the "potential" solar zone is smaller than the 250 sq. ft minimum, the solar zone can be reduced to half the area of the potential solar zone. The reduced-size solar zone is called the "designated" solar zone.

Exception for Reduced Solar Zone

Step 1: Determine the Annual Solar Access: For the solar ready requirements, solar access is the ratio of solar insolation including shading to the solar insolation without shading. Annual solar access is most easily determined using specialized software.

$$\text{Solar Access} = \frac{\text{Solar Insolation Including Shading}}{\text{Solar Insolation Without Shading}}$$

Solar access does not take into account shading from objects that are included in the building project because the designer has control of potential obstructions. Objects that are not part of the building project cannot be moved or modified as part of the project and include existing buildings, telephone poles, communication towers, trees, or other objects. Objects that are considered part of the building project are objects constructed as part of the building project and include the building itself, its HVAC equipment, outdoor lights, landscape features and other similar objects.

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 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).

Step 2: Determine the Potential Solar Zone Area: On low-sloped roofs, the potential solar zone is the area where annual solar access is ≥ 70 percent.

On steep-sloped roofs the potential solar zone is the area where the annual solar access is ≥ 70 percent on the portion oriented between 90 and 300 degrees of true north.

Step 3: Determine the size of the designated solar zone. The designated solar zone must be ≥ 50% of the potential solar zone area. If the roof is shaded such that there is no potential solar zone area, then no solar zone is required. Document the method/tools used to demonstrate that the solar access is less than 70 percent in the compliance form NRCC-SRA-E (Minimum Solar Zone Area Worksheet).

Exception 4: Allowed for multifamily buildings only. The solar zone, interconnection pathway, and documentation requirements do not apply when compliant thermostats and other energy efficiency features are installed during construction.

In each dwelling unit, the thermostats must have demand responsive (DR) controls that comply with Section 110.12(a). The thermostats must be installed in the dwelling units before the local enforcement agency grants the occupancy permit.

§110.12 is a new section in the 2019 Energy Standards that specifies capabilities for demand responsive controls. A "demand responsive control" is defined in §100.1 as an "automatic control capable of receiving and automatically responding to a demand response signal." The technical specifications for compliant demand responsive control thermostats are detailed in JA5.

In addition to the demand responsive thermostats, choose option A or option B (below).

A. Each dwelling unit must have one of the following four measures (1 – 4):

1. Install a dishwasher that meets or exceeds the ENERGY STAR® program requirements with either a refrigerator that meets or exceeds the ENERGY STAR program requirements or a whole-house fan driven by an electronically commutated motor.
2. Install a home automation system that complies with §110.12(a) and capable of, at a minimum, controlling the appliances and lighting of the dwelling and responding to demand response signals.
3. Install alternative plumbing piping to permit the discharge from the clothes washer and all showers and bathtubs to be used for an irrigation system. It must comply with the California Plumbing Code and local ordinances.
4. Install a rainwater catchment system that uses rainwater flowing from at least 65% of the available roof area. It must comply with the California Plumbing Code and local ordinances.

B. Meet the Title 24 Part 11, Section A4, 106.8.2 requirements for electric vehicle charging spaces.

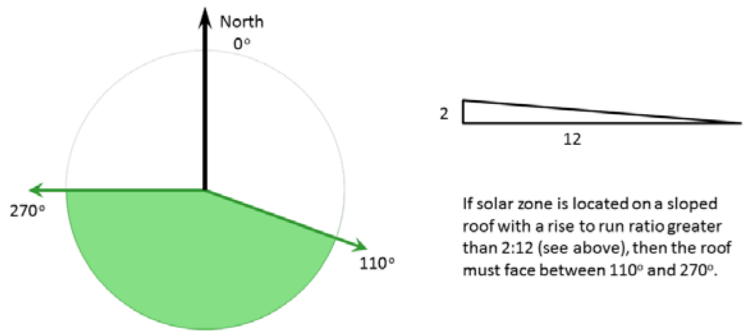
Exception 5: Applies to multifamily, hotel/motel, and nonresidential buildings. If the roof is designed and approved to be a heliport, or used for vehicular traffic or parking, no solar zone is required. Therefore, interconnection pathway and documentation requirements do not apply.

9.4.1 Solar Zone Azimuth

§110.10(b)2

If the solar zone is located on a steep-sloped roofs (the roof has a rise to run ratio 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 (the roof has a rise to run ratio less than 2:12), the orientation requirements do not apply.

9.4.2 Solar Zone 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: $D \geq 2H$

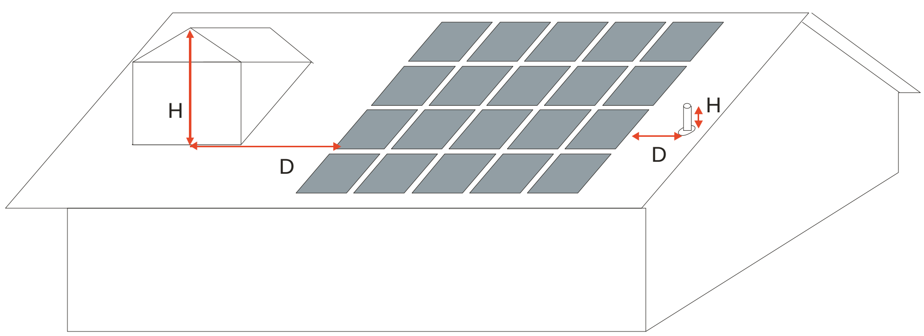


Figure 9-2: Schematic of Allowable Setback for Rooftop Obstructions

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.

9.4.3 Solar Zone 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 estimating the loads of possible future solar equipment.

9.5 Interconnection Pathways

§110.10(c)

All buildings that 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 could cover the entire solar zone.
2. A pathway for routing conduit from the solar zone to the point of interconnection with the electrical service. The design drawings must show where the conduit would be installed if a system were installed at a future date. There is no requirement to install conduit.
3. A pathway for routing plumbing from the solar zone to the water-heating system connection. The design drawings must show where the plumbing would be installed if a SWH system were installed at a future date. There is no requirement to install piping.

This requirement is not applicable if compliance is achieved by using Exceptions 1, 2, 4 and 5 in lieu of a designated solar zone.

9.6 Documentation for the Building Occupant

§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 document NRCC-SRA-E. The document copies are required so that the solar-ready information is available if the occupant decides to install a solar energy system in the future. This requirement is not applicable if compliance is achieved by using Exceptions 1, 2, 4 and 5 in lieu of a designated solar zone.

Example 9-6

Question:

An office building has a total roof area of 5,000 sq. ft. The total roof area covered by skylights is 200 sq. ft. 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 sq. ft. 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 sq. ft of roof area, or in this case 5 kW (see equation below).

$$Minimum\ PV\ System\ Power\ Rating\ = Total\ Roof\ \ Area\ x\ 1\ Watt\ per\ sq.ft$$

$$\mathbf{5,000W} = 5000\ sq.ft\ \times\ 1W/sq.ft$$

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 sq. ft would need to be allocated to complete the minimum solar zone requirement.

$$Minimum\ Solar\ Zone\ Area = 15\%\ x\ (Total\ Roof\ \ Area - Area\ Covered\ by\ Skylights)$$

$$\mathbf{720\ SF} = 15\%\ x\ (5{,}000\ sq.ft \times 200\ sq.ft)$$

9.7 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 sq. ft. (200 sq. meters).

9.8 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 ft. 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

9.9 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 to demonstrate compliance with the nonresidential solar ready requirements. Each document is briefly described below.

- NRCC-SRA-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 increase the roof area by more than 2,000 sq. ft. This form is required for all covered occupancies, including projects that use any of the solar zone exceptions.

- NRCI-SPV-01-E: Certificate of Installation – Solar Photovoltaic System
  This document is required when using solar zone Exception 1 to achieve compliance.
- NRCI-STH-01-E: Certificate of Installation – Solar Water Heating System
  This document is required when using solar zone Exception 2 to achieve compliance.

Table of Contents

10. Covered Processes

10.1 Introduction

This chapter of the Nonresidential Compliance Manual addresses covered processes for the *2019 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

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.

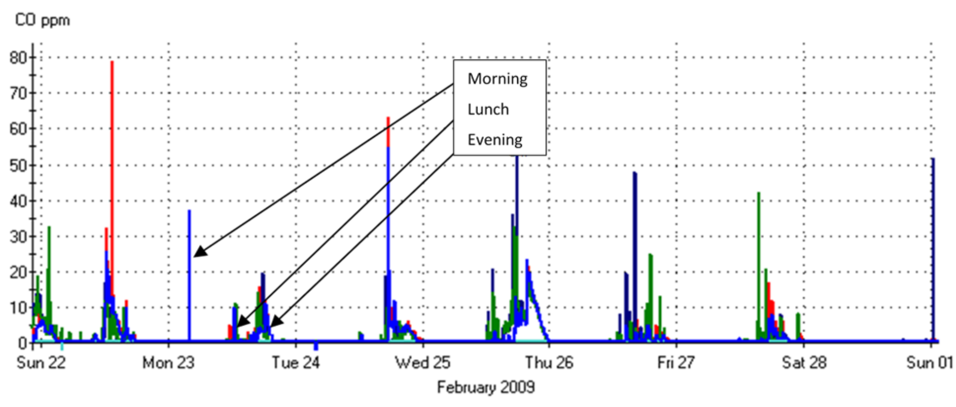
Under the prescriptive compliance approach, the project designer is responsible for completing the Process Compliance Forms & Worksheets. The project designer is required to complete all applicable sections of the NRCC-PRC-E. This form is required on plans for all submittals with covered processes. For the performance compliance approach this form will automatically be completed by the approved computer compliance program.

10.2 Enclosed Parking Garages

10.2.1 Overview

Garage 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 requirement 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 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 setpoint at all times.
- A minimum ventilation of 0.15 cfm/ft^2 when the garage is "occupied."
- The garage maintained at a neutral or negative pressure with respect to adjacent occupiable areas when the garage is scheduled to be occupied.
- CO sensors 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 sensor serves an area no more than 5,000 ft^2. Furthermore, the standard requires a minimum of two sensors per "*proximity zone*." *Proximity zones* are 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 toward 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:

a. Certified by the manufacturer to:
    1. Accuracy of +/- 5%.
    2. 5% or less drift per year.
    3. Require calibration no more than once per year.

b. Be factory calibrated

c. 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. At a minimum, the following must be monitored:
    1. If any sensor has not been calibrated according to the manufacturer's recommendations within the specified calibration period, the sensor has failed.
    2. During unoccupied periods, the system compares the readings of all sensors. For example, if any sensor is more than 15 ppm above or below the average of all sensors for longer than four hours, the sensor has failed.
    3. During occupied periods, the system compares the readings of sensors in the same proximity zone. For example, if the 30-minute rolling average for any sensor in a proximity zone is more than 15 ppm above or below the 30-minute rolling average for other sensor(s) in that proximity zone, the sensor has failed.

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:

1. Direct replacement of exhaust air limitations.
2. Type I exhaust hood airflow limitations.

3. Makeup and transfer air requirements.
4. 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:

1. A limitation on use of short-circuit hoods §140.9(b)1A
2. Maximum exhaust ratings for Type I kitchen hoods §140.9(b)1B

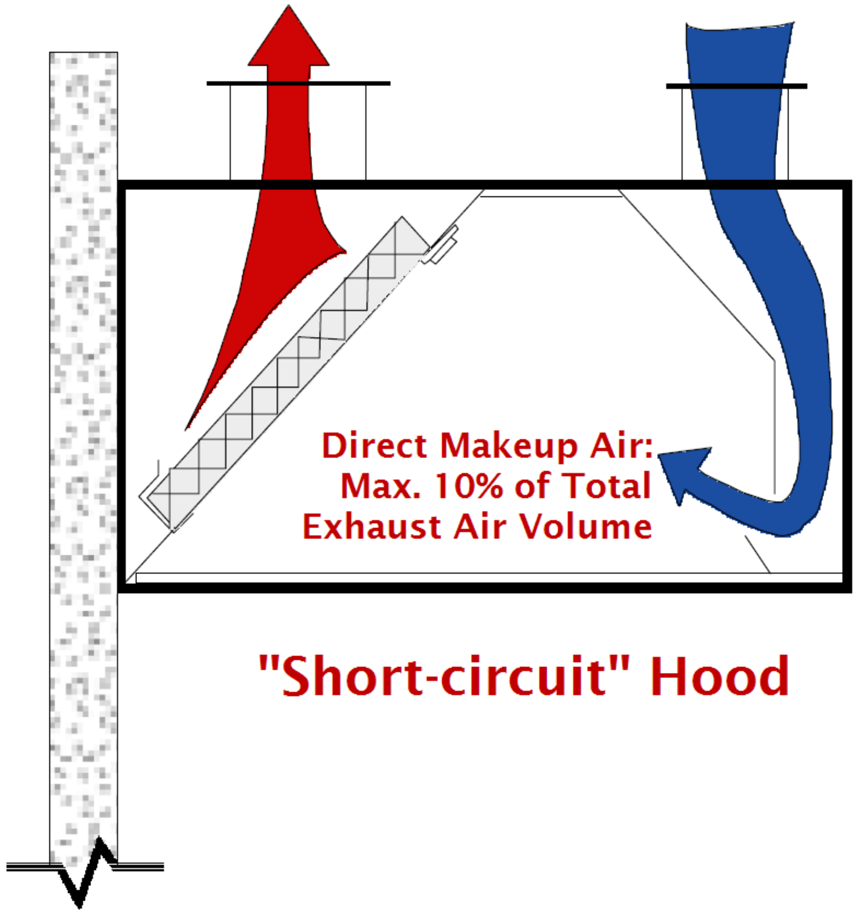
A. Limitation of Short-Circuit Hoods

§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 and 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 reduction 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 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: 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 (light-duty through extra-heavy-duty). The values in this table are typically less than the minimum airflow rates for hoods that are not Underwriter Laboratories (UL) specification listed products. These values are supported by ASHRAE research for use with UL-listed hoods. (For more detail see ASHRAE research project report RP-1202.) 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:

1. Limitations to the amount of mechanically heated or cooled airflow for kitchen hood makeup air §140.9(b)2A
2. 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:

a. ***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.

b. ***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.

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 the greater of:

1. The supply flow required to meet the space heating or cooling load.
2. 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. This amount includes 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.

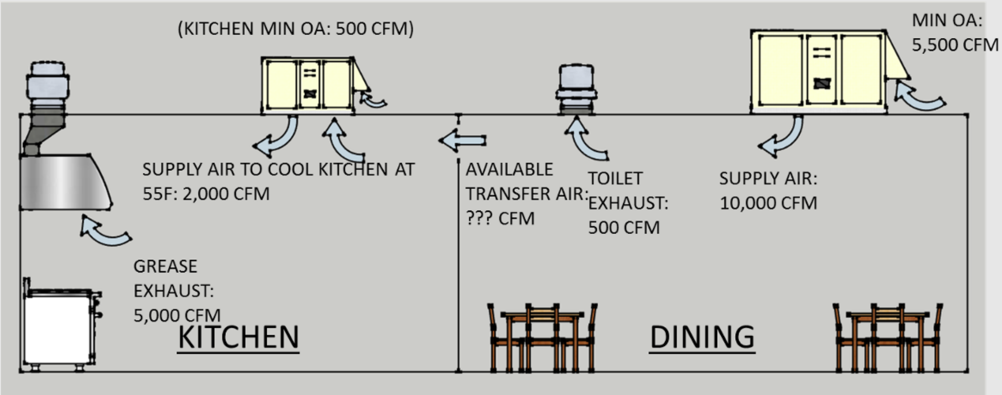
An exception is provided for existing kitchen makeup air units (MAU) that are not being replaced as part of an addition or alternation.

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 makeup 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, subtract 500 cfm for the toilet exhaust and 0 cfm for building pressurization.

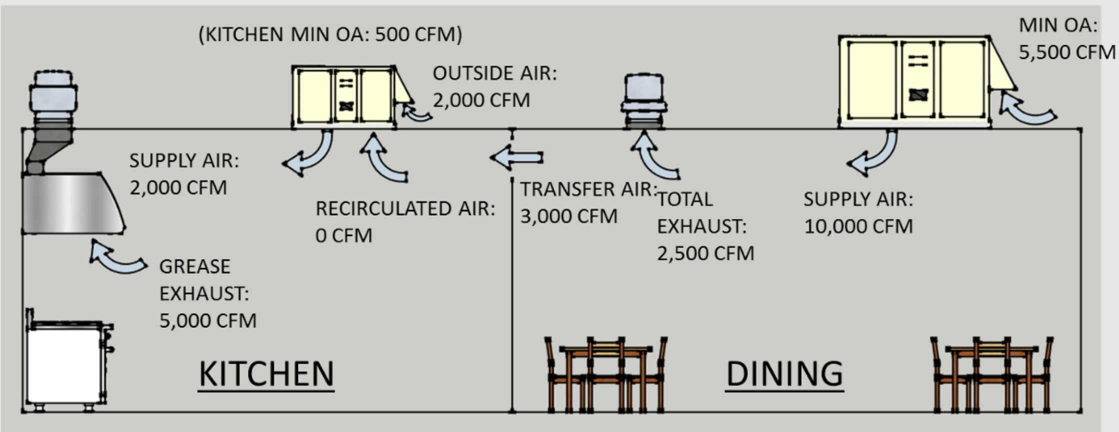
5,500 cfm – 500 cfm – 0 cfm = 5,000 cfm

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

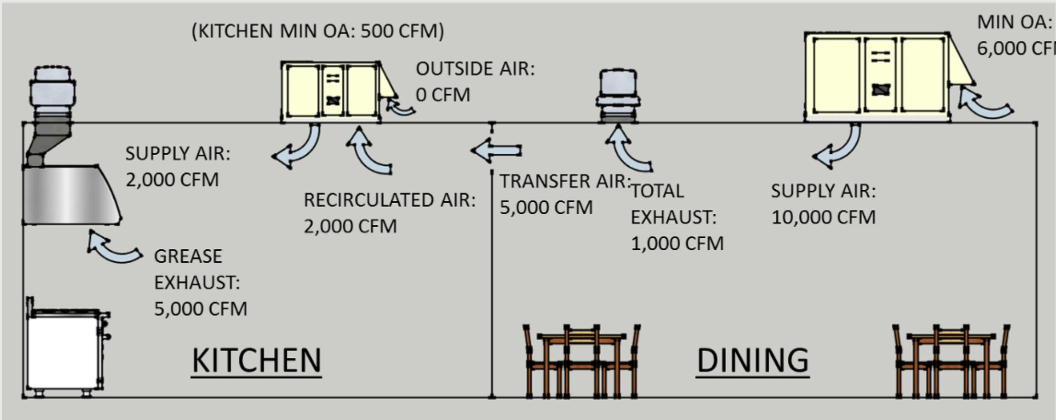
Yes. This example meets the first provision of §140.9(b)2A. The supply flow required to meet the cooling load is 2,000 cfm. Thus, up to 2,000 cfm of mechanically conditioned makeup air can be provided to the kitchen. The supply from the MAU, 2,000 cfm, is not as large as the hood exhaust, 5,000 cfm. 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. 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:

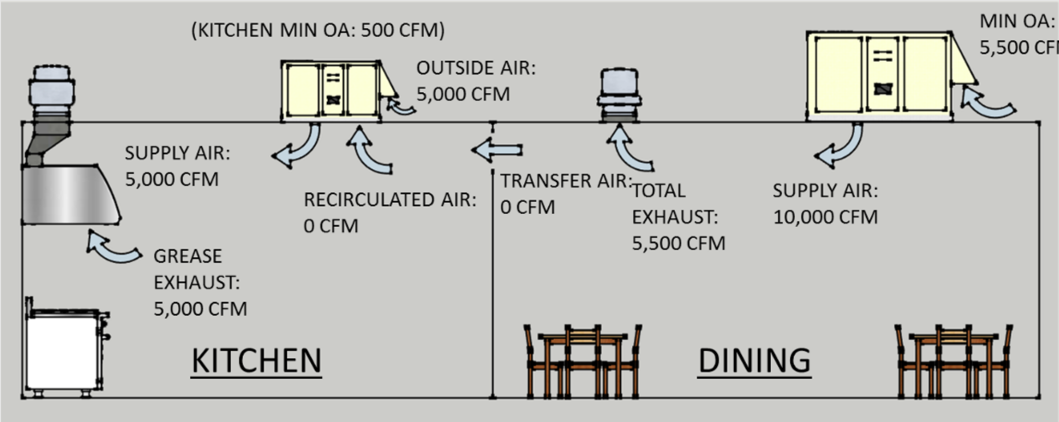
1. The total outside airflow to be conditioned has been reduced from 7,500 cfm in the previous example (2,000 cfm at the MAU and 5,500 cfm at the dining room unit) to 6,000 cfm.
2. The dining room exhaust fan has dropped from 2,500 cfm to 1,000 cfm reducing both fan energy and first cost of the fan.

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 is mechanically heated or cooled. Per §140.9(b)2A, the maximum amount of makeup air that can be mechanically heated or cooled cannot exceed the greater of:

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 (5,500 - 500 = 5000 cfm; from Example 10-2).

The 5,000 cfm of conditioned makeup air exceeds 2,000 cfm. This example assumes that the required exhaust for the dining space is 500 cfm of bathroom exhaust and the remaining 5,000 cfm of dining outdoor air is available for transfer to the kitchen.

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 and 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. The listed energy recovery devices have a sensible heat recovery effectiveness ≥40% on ≥50% of the total exhaust flow.
4. Seventy-five percent or more of the makeup air volume is:
   a. Unheated or heated to no more than 60°F.
   b. Uncooled or cooled without the use of mechanical cooling.

Exception to 140.9(b)2B: Existing hoods not being replaced as part of an addition or alteration.

Transfer Air: 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 the following characteristics:

a. 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.

b. Include failsafe controls that result in full flow upon cooking sensor failure.

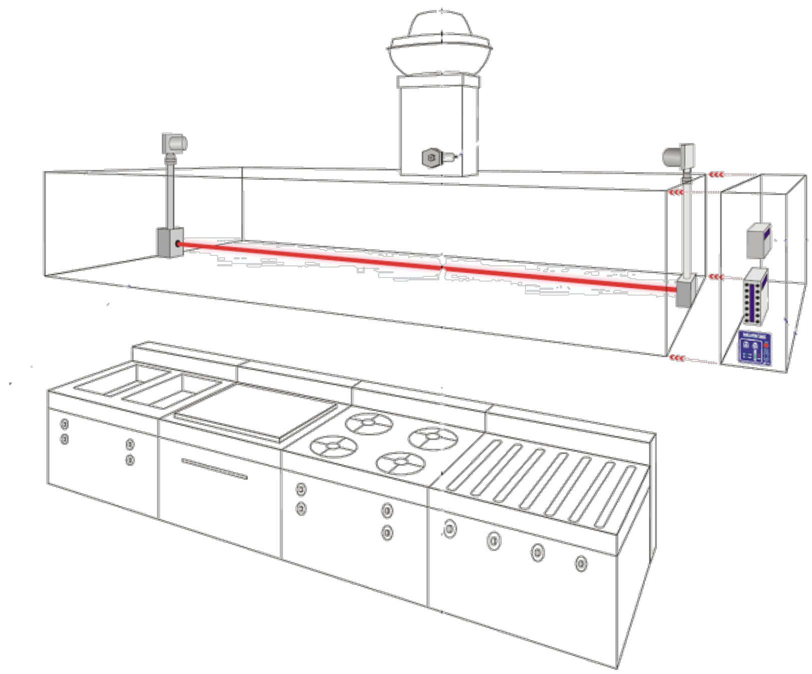
c. Include an adjustable timed override to allow occupants the ability to temporarily override the system to full flow.

d. Be capable of reducing exhaust and replacement air system airflow rates to the larger of:

1. 50% of the total design exhaust and replacement air system airflow rates.
2. The ventilation rate required in §120.1.

There are several off-the-shelf technologies that use smoke detectors that can comply with all 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) and less 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 set point to 60°F and to use evaporative (non-compressor) cooling or no cooling at all for 75% 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.

10.3.3.4 **Healthcare Facilities**

Healthcare facilities are not required to meet 140.9(b).

10.3.4 Additions and Alterations

See above sections for specific applications of these measures to additions and alterations.

10.4 Computer Rooms

10.4.1 Overview

Section 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."

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:

a. Air or water side economizer - §140.9(a)1

b. Restriction on reheat or recool - §140.9(a)2

c. Limitations on the type of humidification - §140.9(a)3

d. Fan power limitations - §140.9(a)4

e. Variable-speed fan control - §140.9(a)5, and

f. Containment - §140.9(a)6

10.4.3.1 **Economizers**

§140.9(a)1

This section requires integrated air or water economizers. 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 temperatures of 55°F drybulb (Tdb) with a coincident 50°F wetbulb (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 than the standard air economizer. Furthermore, air handlers with cooling capacity greater than 54 kBtuh and air economizers must be equipped with fault detection and diagnostic devices meeting §120.2(i).

If a water economizer is used to meet this requirement, it must be capable of providing 100% of the expected system cooling load at outside temperatures of 40°F drybulb with a coincident 35°F wetbulb.

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**: Computer rooms with cooling capacity <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 noncomputer rooms in two important ways. First, the computer room exception refers to the cooling capacity of all systems serving the computer room, whereas the noncomputer room regulation refers to each cooling system serving the building. Second, the computer room exception applies only 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 computer 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 using the performance approach. Ways to meet this requirement include:

   a. Provide the new capacity using a new cooling system that has a complying air or water economizer.
   b. 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 computer room up to a total of 20 tons of new cooling load in an existing building.

This is similar to the previous exception, but the capacity threshold is lower because you can locate a new space in a location suitable for 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 and complying air-side economizer that can fully condition the computer rooms on weekends and evenings when the other building spaces are unoccupied. This exception allows the computer rooms to be served by fan coils or split system direct expansion (DX) units as long as the following conditions are met:
   a. The economizer system on the central air-handling unit is sized sufficiently that all the computer rooms are less than 50% of the total airflow capacity.
   b. The central air-handling unit is configured to serve only the computer rooms if all the other spaces are unoccupied.
   c. The supplemental cooling systems for the computer rooms are locked out when the outside air drybulb temperature is below 60°F and the noncomputer room zones are less than 50% of the design airflow.

Example 10-5

Question

A new data center is built with a total computer room load of 1,500 tons. 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 drybulb and 35°F wetbulb. The design conditions in §140.9(a) would require a different heat exchanger and cooling towers than the conditions in §140.4(e) for nonprocess spaces for a given expected load. The load on the cooling towers, while in economizer-only mode, is lower than the design load even if the computer room load is constant because the towers do not have to reject the heat from the chillers. Furthermore, 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, then 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 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 drybulb temperature at 55°F.
- 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.
- The economizer system is provided with a high limit switch that complies with §140.4(e). Although fixed drybulb switches are allowed in §140.4(e) they are not recommended in this application as the setpoints were based on office occupancies. A differential drybulb switch would provide greater energy savings.

- Moreover, because the system economizer is separate from the air handler, FDD is not required.

Example 10-7

Question

A new office building has a central air system with an air-side economizer that complies with §140.4(e). This building has two Intermediate Distribution Frame (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 be served by the central air system economizer of the building. 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 they are also served by variable air volume (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), the VAV boxes must be shut so that the VAV system can serve only the IDF rooms.

Example 10-8

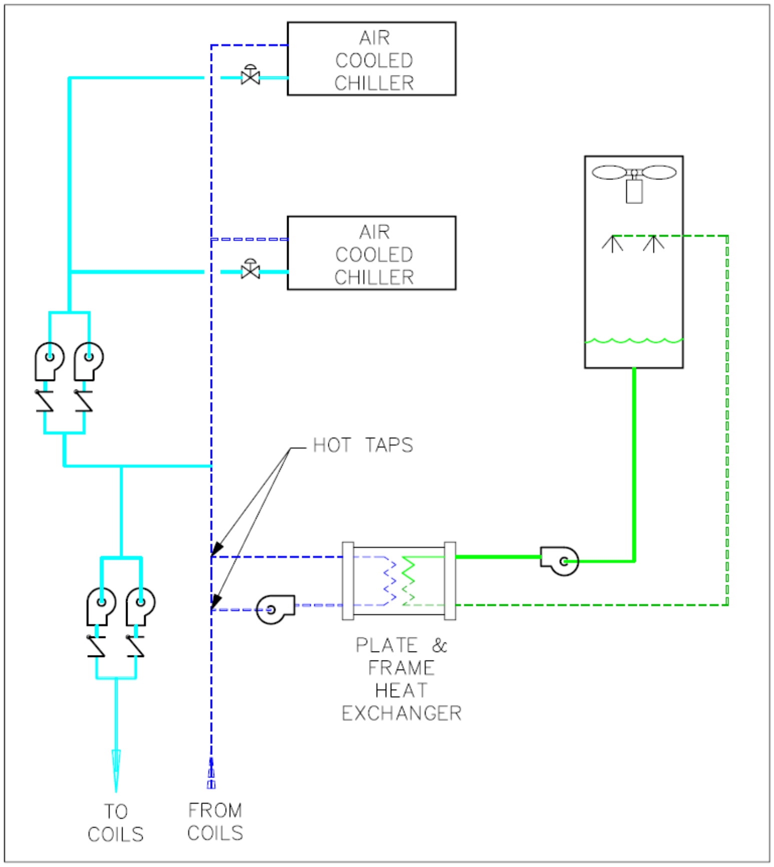
Question

A new data center employs rear door heat exchangers that are cooled entirely 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 *economizer* (both air and water) both have the phrase "to reduce or eliminate the need for *mechanical 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



10.4.3.1 **Reheat/Recool**

§140.9(a)2

§140.9(a)2 prohibits reheating, recooling or simultaneous heating and cooling in *computer rooms*. Furthermore, the definition of cooling includes both *mechanical cooling* and *economizers.* This provision is to prohibit use of CRAC and CRAH units with humidity controls that include reheat coils.

10.4.3.2 **Humidification**

§140.9(a)3

140.9(a)3 prohibits the use of nonadiabatic humidification for *computer 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 printed circuit board failure due to circuit board metallic filament formations known as conductive anodic filaments (CAF). For both of these issues, there is insufficient evidence that the risks are adequately addressed 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) because it was not effective and did not supplant the need for personal grounding. The

Energy Standards allows for humidification but prohibits the use of nonadiabatic 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.

10.4.3.3 **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* 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.

10.4.3.4 **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:

a. Expansions of existing *computer rooms* that don't already have containment.
b. Computer racks with a design load of < 1 kW/rack (e.g. network racks).
c. 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

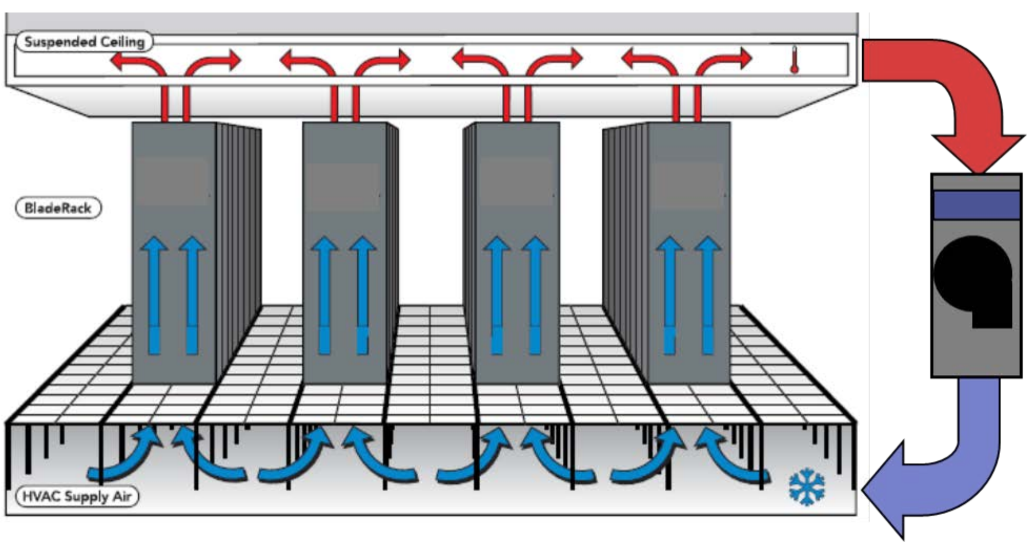


Figure 10-6: Example of Aisle Containment Using Hard Partitions and Doors

10.4.4 Healthcare Facilities

Healthcare facilities are not required to meet Section 140.9(a)

10.4.5 Additions and Alterations

The application to additions and alternations is 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 2019 Energy Standards

In the 2019 Energy Standards, adiabatic condenser efficiency and size requirements have been added. §120.6(b) 1D and 1E along with Table 120.6 – D have been updated with new requirements for adiabatic condenser systems using halocarbon refrigerant.

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 use either refrigerated display cases or walk-in coolers or freezers. 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 lineups 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 Condenser Mandatory Requirements

§120.6(b)1

This section addresses the mandatory requirements for condensers serving commercial refrigeration systems. These requirements apply only 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 the following conditions apply:

1. The total heat of rejection of the compressor system attached to the condenser or condenser system does not increase.

2. Less than 25% of the attached refrigeration system compressors (based on compressor capacity at design conditions) are new.
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, evaporative, or adiabatic 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 controlled. 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, usually no higher than 10-20%, the fans may be staged off to reduce condenser capacity. As load increases, fans should be turned back on before significantly increasing fan speed, recognizing a control band is necessary to avoid 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, the holdback valve is 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 that 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 (in other words the condenser control temperature difference). Fan speed is then modulated so that the measured saturated condensing temperature (SCT) 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 the ambient wetbulb temperature, and the SCT control setpoint for air-cooled condensers must be reset according to ambient drybulb temperature. The target SCT for adiabatic condensers when operating in dry mode must be reset according to ambient drybulb temperature. There is no requirement for SCT control during wet-mode (adiabatic) operation. Systems served by adiabatic condensers in climate zone 16 are exempted from this control requirement.

The condenser control TD is not specified in the Energy Standards. 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 use as much condenser capacity as possible without excessive fan power, the common practice is to optimize the control TD over a period such that the fan speed is in a range of around 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 using 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 use the average condensing temperature or the highest condensing temperature of the 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.

Air-cooled condensers with separately installed evaporative precoolers added to the condenser are not considered adiabatic condensers for this standard and must meet the requirements for air-cooled equipment, including specific efficiency and ambient-following control.

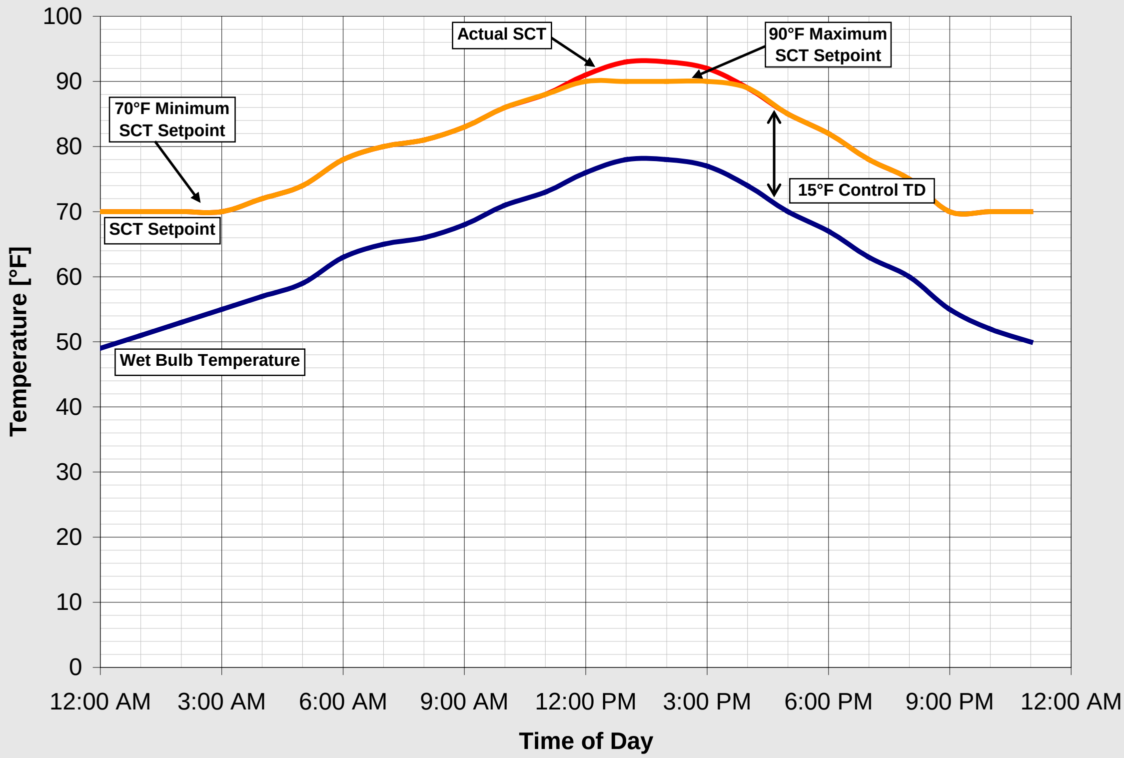
Example 10-12

Question

A new supermarket with an evaporative condenser is being commissioned. The control system designer has used a wetbulb-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 wetbulb 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 wetbulb-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 wetbulb 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 used 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, air-cooled condensers, and adiabatic 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
Adiabatic Dry Mode	45 Btuh/Watt (Halocarbon)	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 SCT and 70°F outdoor wetbulb temperature for evaporative condensers, and 105°F SCT and 95°F outdoor drybulb temperature for air-cooled and adiabatic (halocarbon refrigerant only) condensers. Total heat of rejection capacity for adiabatic condensers is based on dry mode ratings (i.e. no precooling of the air). 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 other is a set of "evaporator ton" capacity factors. Only the "heat rejection" capacity factors shall be used to calculate the condenser capacity at the efficiency rating conditions for determining compliance with this section.

For air-cooled and adiabatic 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 and adiabatic 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 original equipment manufacturer (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 or alteration.
3. If the condenser capacity is less than 150,000 Btuh 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 10 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 450 Watts = 4,500 Watts
fan motor

The specific efficiency of the condenser is therefore:

500MBH x 1,000 Btu/hr / 4,500Watts = 111Btu/hr/Watts
4,500 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 six-pole open fan motor, the minimum efficiency is 91.7%. For a 2 HP six-pole open pump motor, the minimum efficiency is 87.5%. The fan motor input power is calculated to be:

1 Motor x 10 HP x 746 watts x 100% assumed loading = 8,135 watts
Motor HP 91.7% efficiency

The pump motor input power is calculated to be:

$$1 \text{ Motor} \times \frac{2 \text{ HP}}{\text{Motor}} \times \frac{746 \text{ watts}}{\text{HP}} \times \frac{100\% \text{ assumed loading}}{87.5\% \text{ efficiency}} = 1{,}705 \text{ watts}$$

The combined input power is therefore:

8,135 watts + 1,705 watts = 9,840 watts

Note: Actual motor power should be used when available. (See note in text.)

Finally, the efficiency of the condenser is:

$$\left(2{,}105 \text{ MBH} \times \frac{1{,}000 \text{ Btuh}}{\text{MBH}}\right) / 9{,}840 \text{ watts} = 214 \text{ Btuh/watt}$$

214 Btuh per watt is higher than the 160 Btuh per watt requirement; this condenser meets the minimum efficiency requirements.

Example 10-15

Question

An adiabatic condenser is being designed for a new supermarket. The refrigerant is R-407A. The condenser manufacturer’s catalogue states that the subject condenser has a capacity of 550 MBH at 10°F TD between entering air drybulb temperature and saturated condensing temperatures with R-407A refrigerant when operating in dry mode. Elsewhere in the catalog, it states that the condenser has two 5 hp fan motors that draw 4.5 kW 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 rated 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:

2 fan motors x 4500 Watts = 9,000 watts

The specific efficiency of the condenser is therefore:

(550MBH x 1,000 Btu/hr/MBH) / 9000 watts = 61 Btu/hr/watts

This condenser has a specific efficiency of 61 Btuh per watt, which is higher than the 45 Btuh per watt minimum requirement. This condenser meets the minimum specific efficiency requirements.

10.5.2.3 **Condenser Fin Density**

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 use a microchannel 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.

10.5.2.4 **Adiabatic Condenser Sizing**

§120.6(b)1E

New adiabatic condensers on new refrigeration systems must follow the condenser sizing, fan control, and efficiency requirements as described in §120.6(b)1E.

Condensers must be sized to provide sufficient heat rejection capacity under design conditions while maintaining a specified maximum temperature difference between the refrigeration system 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 this requirement, reserve or backup compressors may be excluded from the calculations.

§120.6(b)1E provides maximum design SCT values for adiabatic condensers. For this section, designers should use the 0.5 percent design drybulb 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 adiabatic condensers is proportional to the temperature difference (TD) between SCT and DBT for operation in dry mode, regardless of the actual ambient temperature entering the condenser. For example, the capacity of an adiabatic 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 during dry mode operation, since the TD across the condenser is 10°F in both examples. Thus, similar to air-cooled condensers, the requirement for adiabatic condensers does not have varying sizing requirements for different design ambient temperatures.

However, the Energy Standards have different requirements for adiabatic condensers depending on the space temperatures served by the refrigeration system. The maximum design SCT requirements are listed in Table 10-5 below:

Refrigerated Load Type	Space Temperature	Maximum SCT (dry mode)
Cooler	≥ 28°F	Design DBT plus 30°F
Freezer	< 28°F	Design DBT plus 20°F

Often, a single refrigeration system and the associated condenser will serve a mix of cooler and freezer load. In this instance, the maximum design SCT shall be a weighted average of the requirements for cooler and freezer loads, based on the design evaporator capacity of the spaces served.

Example 10-16

Question

An adiabatic condenser is being sized for a system that has half of the installed capacity serving cooler space and the other half serving freezer space. What is the design TD to be added to the design drybulb temperature?

Answer

Using adiabatic condensers for coolers has a design approach of 30°F and for freezers a design approach of 20°F. 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 percentage of the total installed capacity dedicated to coolers by 30°F. Next, multiply the percentage of the total installed capacity dedicated to freezers by 20°F. 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 25°F.

(50% x 20 °F) + (50% x 30°F) = 10 °F + 15 °F = 25 °F

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

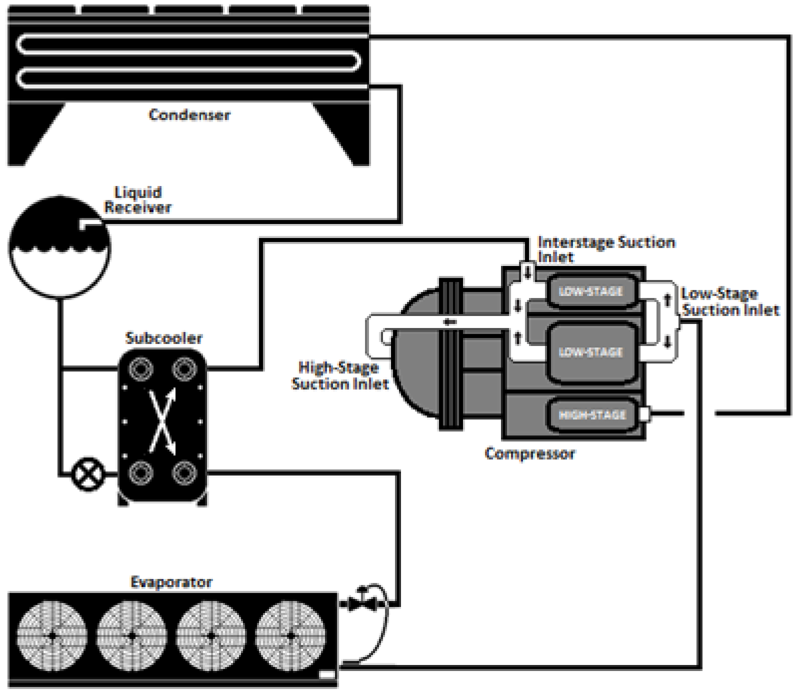


Figure 10-8: Cascade System

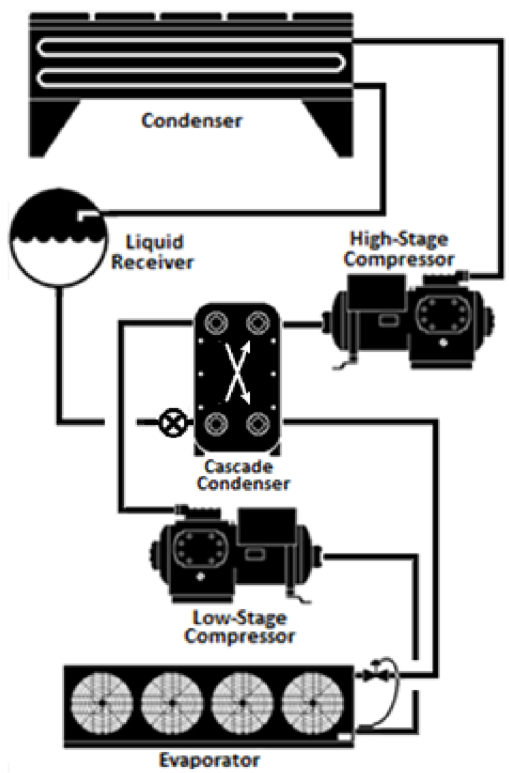
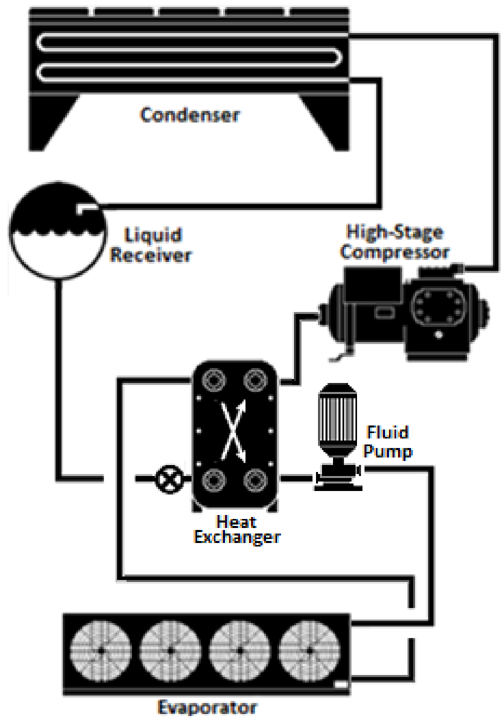


Figure 10-9: Secondary Fluid System



Example 10-16

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 that 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 10-17

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 10-18

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.

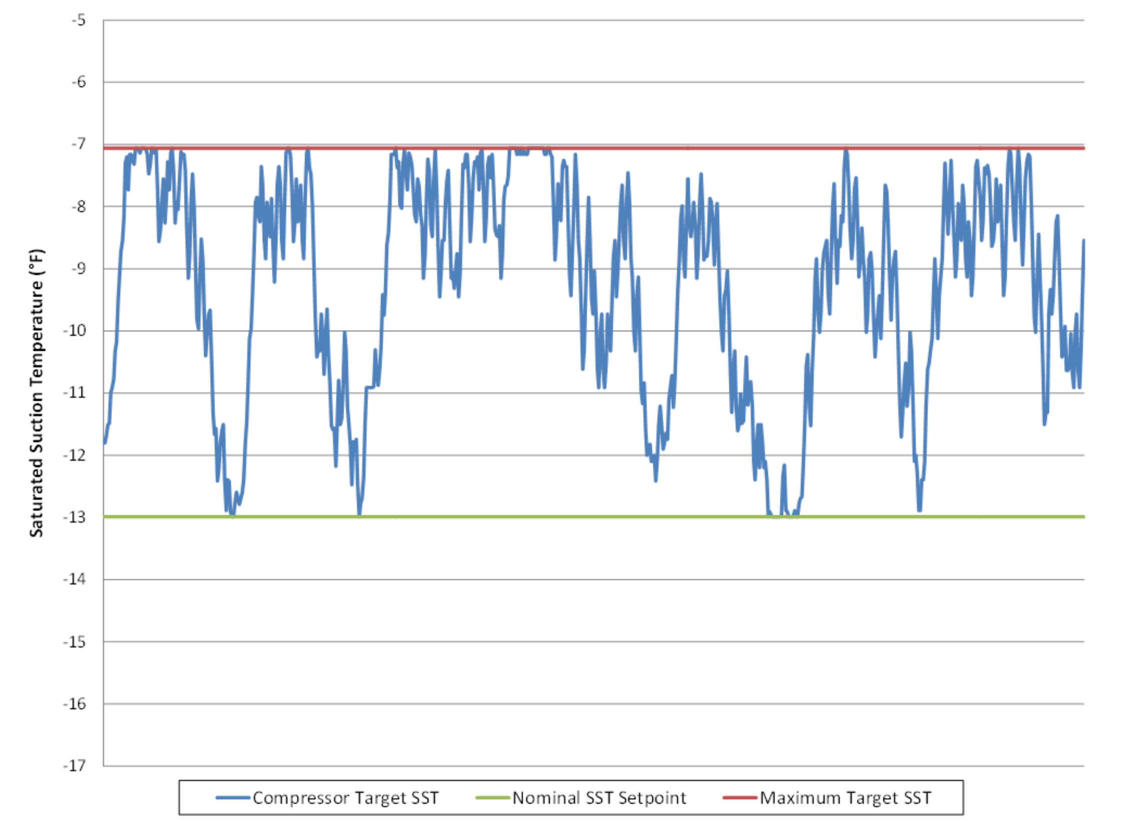
Cascade system: Only the low-temperature suction group of the system is required to have floating suction pressure control.

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 temperature (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 the lowest current SET requirement of any attached refrigeration load while maintaining target fixture temperatures, but not any higher. The controls are typically bound by low and high setpoint 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 one week, 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

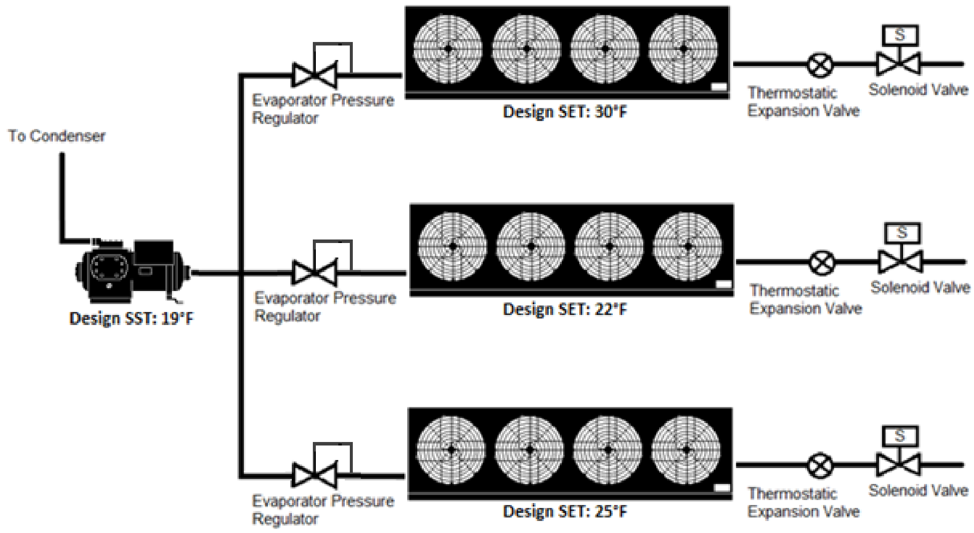
Mechanical evaporator pressure regulators (EPR valves) are often used on multiplex systems to maintain temperature by regulating the SET at each evaporator connected to the common suction group, and often to function as a suction stop valve during defrost. EPR valves throttle to maintain the pressure 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-1980'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



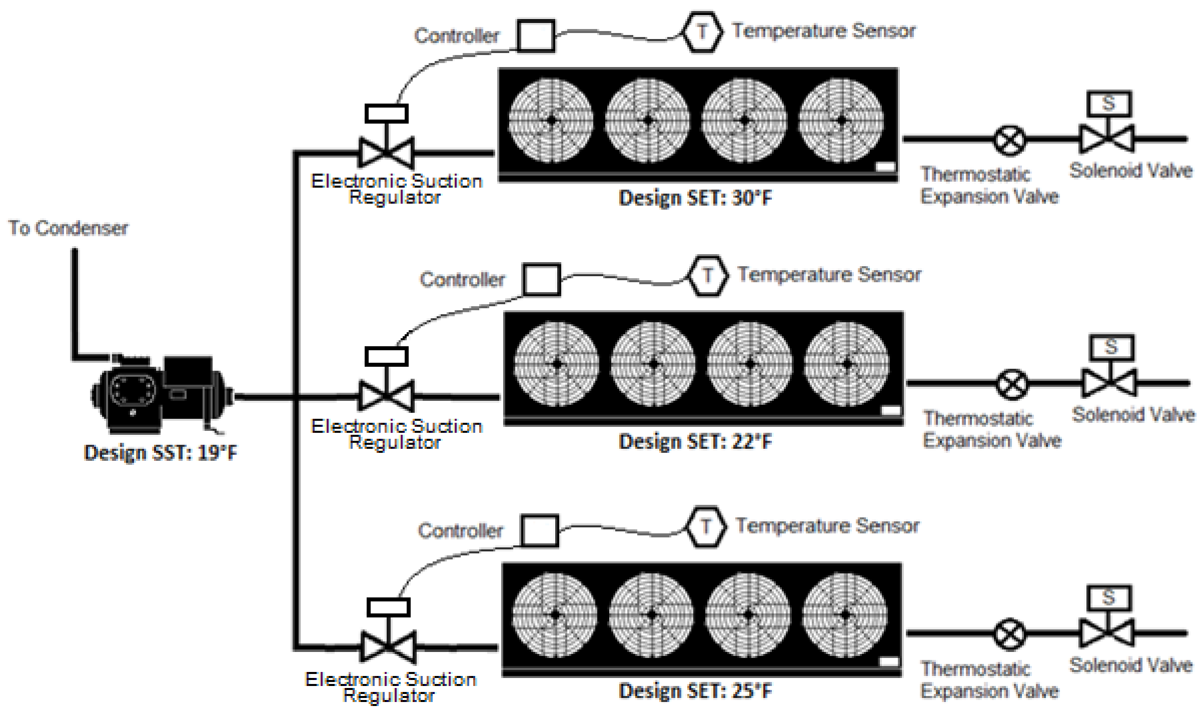
B. Floating Suction Pressure Control With Electronic Suction Regulators

An electronic suction regulator (ESR) valve is an electronically controlled valve used in place of a mechanical evaporator pressure regulator valve. ESRs are also known in the industry as electronic evaporator pressure regulators (EEPRs). 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 modulation provides more accurate temperature compared to an EPR that 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

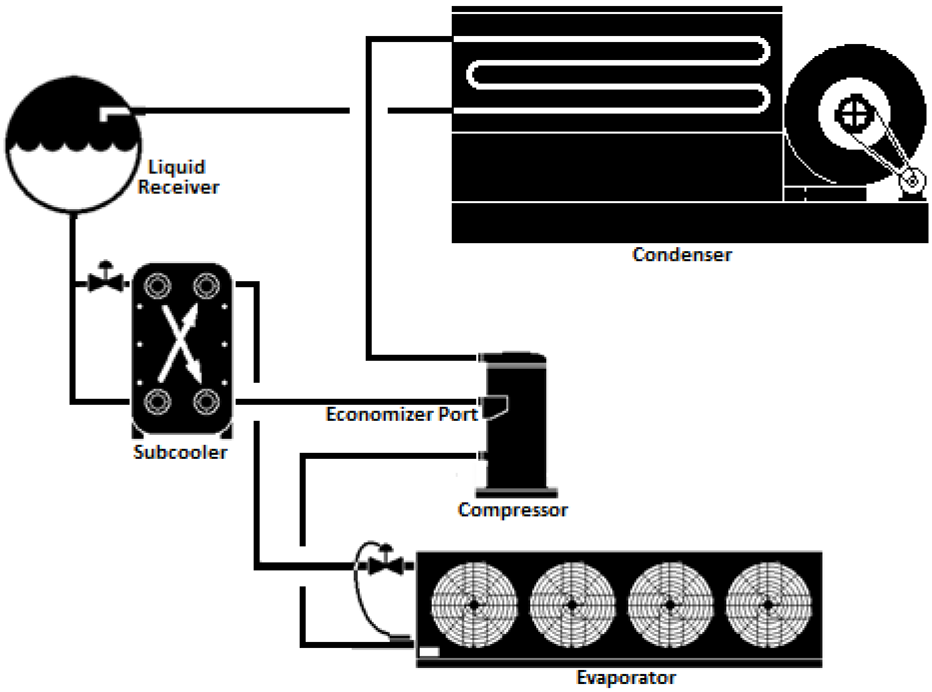
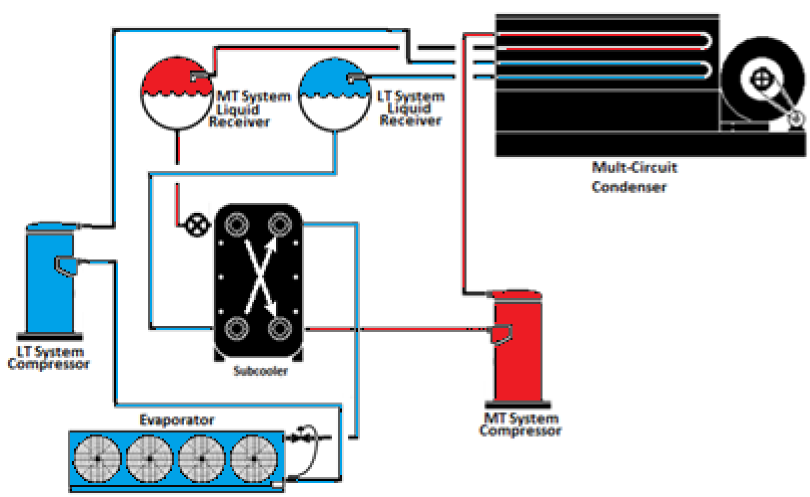


Figure 10-14: Liquid Subcooling Provided By a Separate Medium-Temperature System



10.5.4 Refrigerated Display Case Lighting Control Requirements

§120.6(b)3

All lighting for refrigerated display cases, and glass doors of walk-in coolers and freezers shall be controlled by either automatic time switch controls or motion sensor controls or both.

A. Automatic Time Switch Control

Automatic time switch controls shall turn off the lights during nonbusiness hours.

Timed overrides for a display case lineup or walk-in case may be used to turn on the lights for stocking or nonstandard 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 makeup for the cases and walk-ins and 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. Several 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 THR of 150,000 Btu/h or greater must be used 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 10-19

Question

A store has three new distributed refrigeration systems, A, B and C, with design 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 design THR of greater than 150,000 Btu/h, whereas refrigeration system A has a 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 10-20

Question

How should the THR 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 10-21

Question

A 35,000 ft^2 food store is expanding 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 to replace 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 multicircuit 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

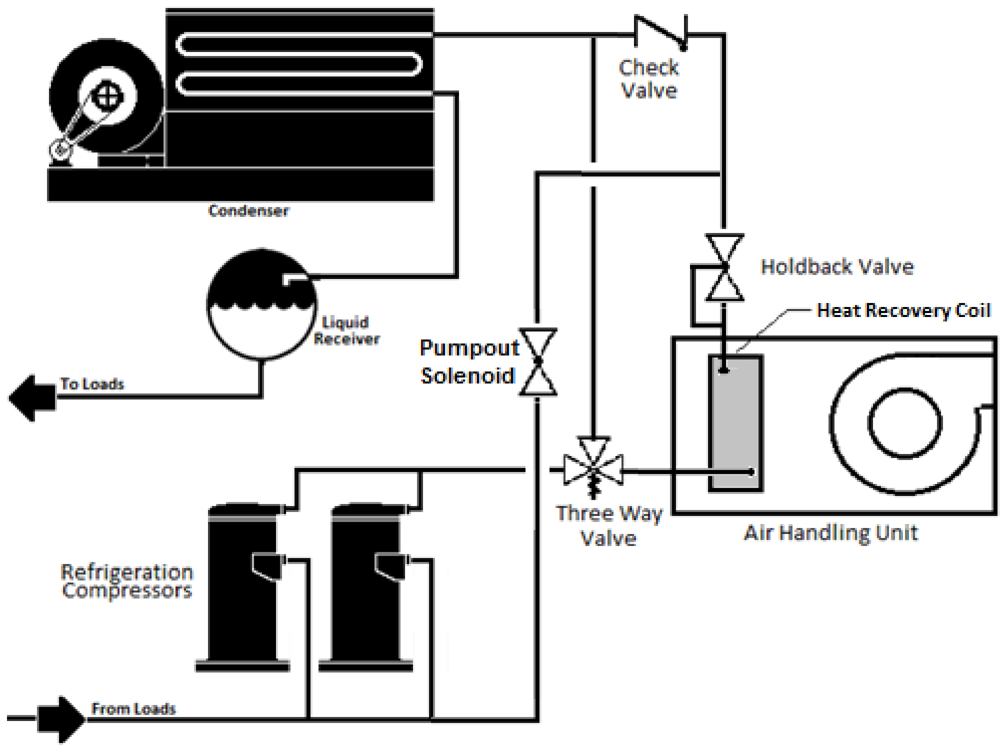
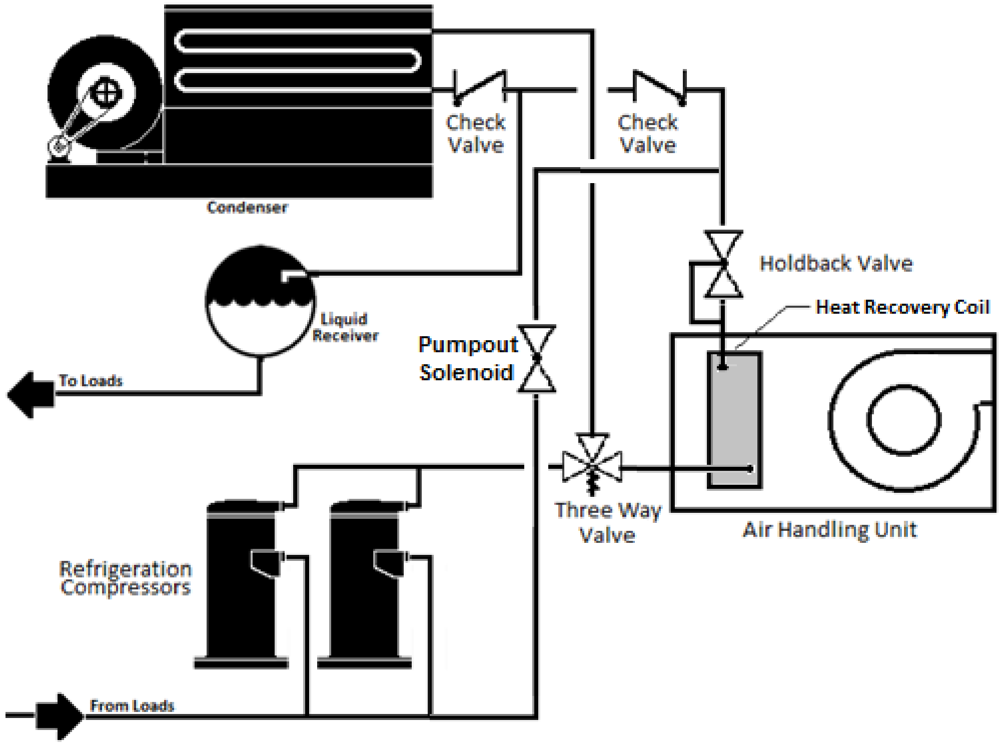


Figure 10-16 shows a parallel-connected direct-condensing configuration. In this configuration, the heat recovery coil handles the entire condensing load for the connected refrigeration system(s) when the air-handling unit is in heating mode. Reduced refrigerant charge is the primary advantage of this 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, 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

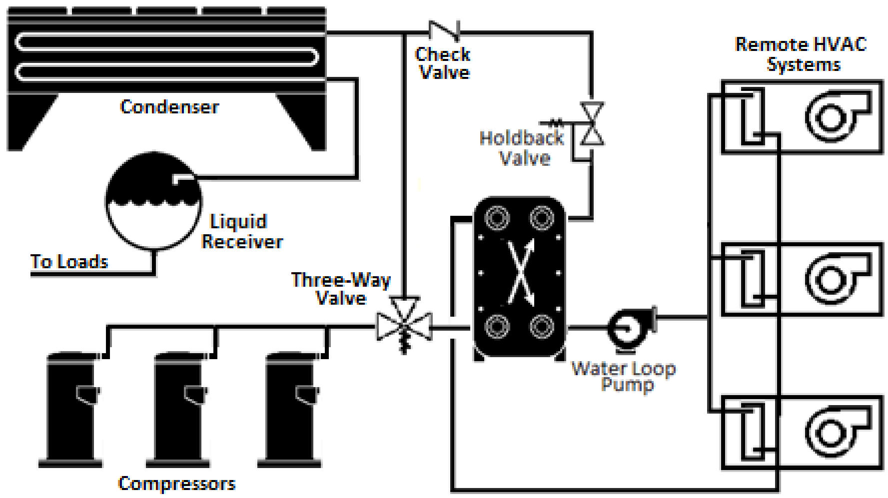


B. Indirect Heat Recovery

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.

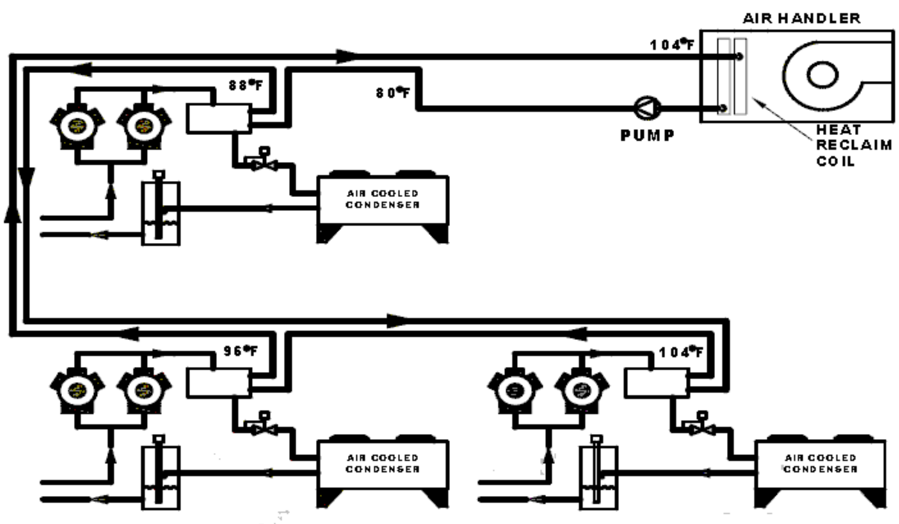
The refrigerant-to-fluid heat exchanger can be located close to the refrigeration system compressors, maximizing the available heat for recovery while keeping the overall refrigerant charge increase low. This configuration is also suitable when multiple HVAC units are employed for the refrigeration heat recovery. Indirect systems must use 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



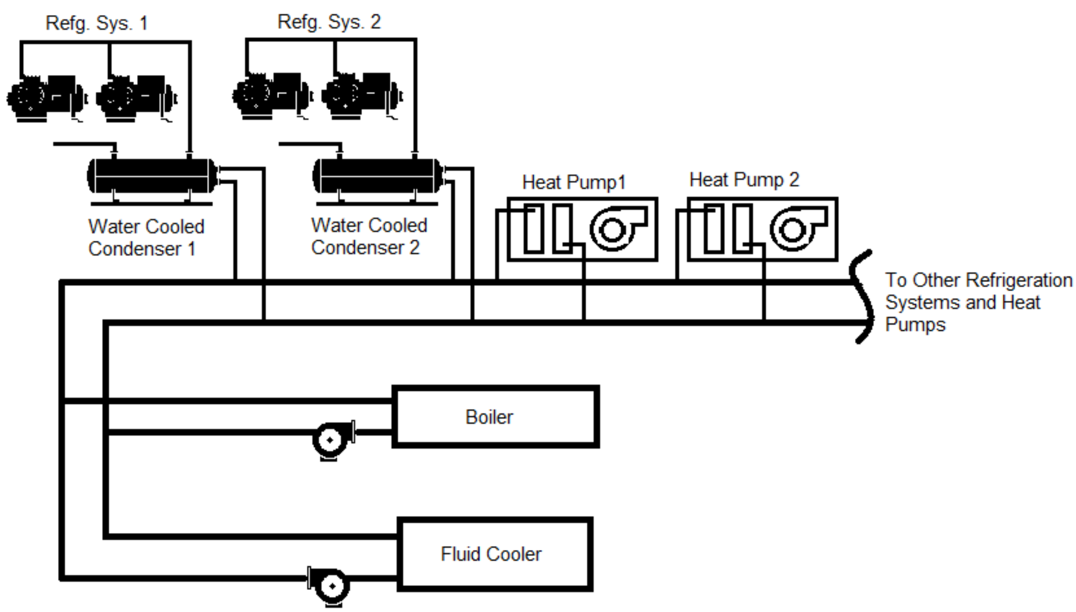
This configuration allows the refrigerant-to-water condenser temperature difference (TD) to be kept low at each refrigeration system (e.g. 8°-10°F is possible) while maintaining a sufficiently high water-side TD at the air-handling unit (e.g. 20°-25°F depending on specifics) to allow an effective selection 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

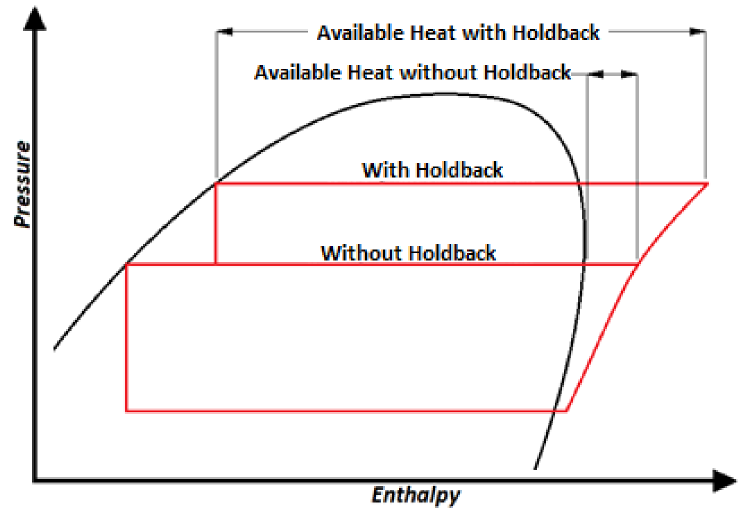


10.5.5.2 **Control Considerations**

A. Holdback Considerations

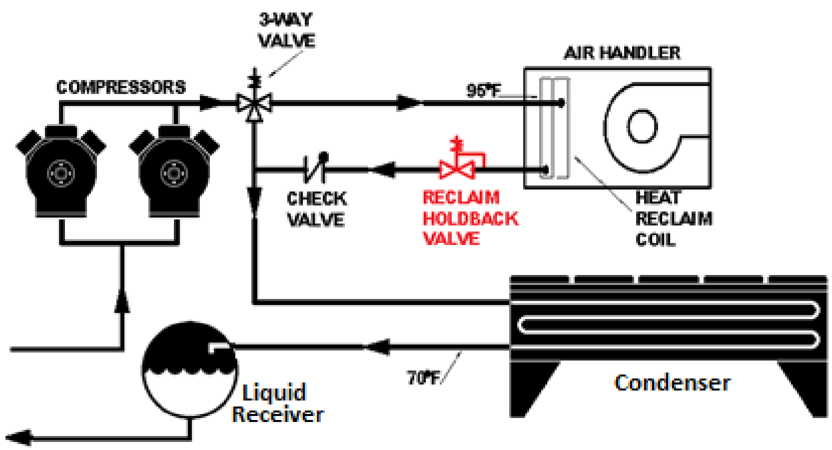
For direct and indirect systems, a holdback valve is required to control the refrigerant condensing temperature in the heat recovery coil (for direct systems) or the refrigerant-to-water condenser (for indirect systems) during heat recovery. Regulating the refrigerant pressure to achieve condensing recovers 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 the inlet and is at the exit of the recovery heat exchanger. Figure 10-21 shows a direct-condensing configuration with the proper location of the holdback valve.

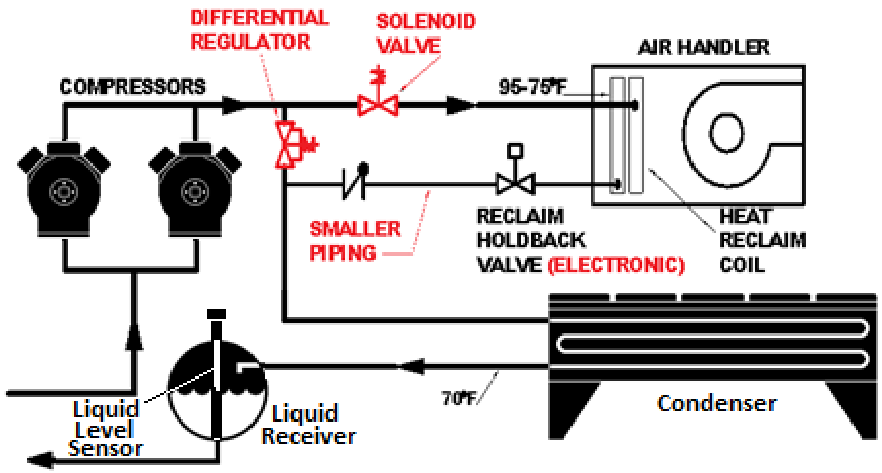
Figure 10-21: Direct-Condensing Configuration Showing Location of Holdback Valve



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

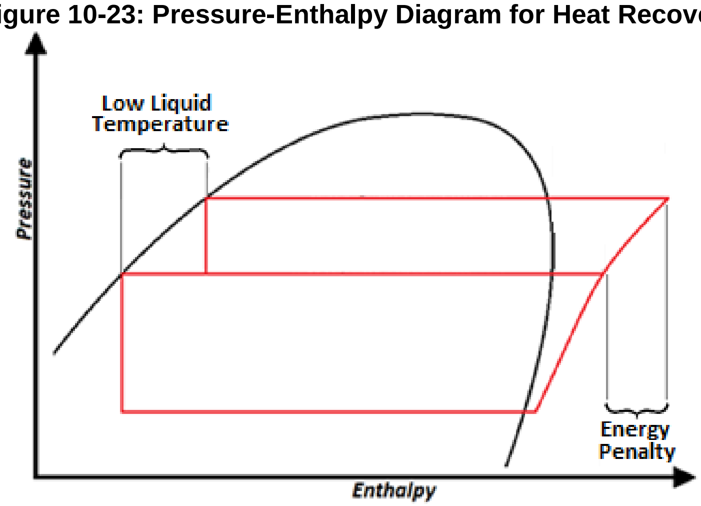


B. Heat Recovery and Floating Head Pressure

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 10-22

Question

A supermarket is being constructed that will use 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 ft^2

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 recover 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

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 in 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

$$TD = 95^{o}F - 65^{o}F$$

$$TD = 30^{o}F$$

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:

$$\text{MBH per SQ FT} = \frac{\text{Design Coil Capacity}}{\text{Coil Face Area}} / \text{Correction Factor}$$

$$\text{MBH per SQ FT} = \frac{4184\ \text{MBH}}{41.7\ ft^2} / 0.6$$

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 three-row, 10-fin-per-inch coil for this application.

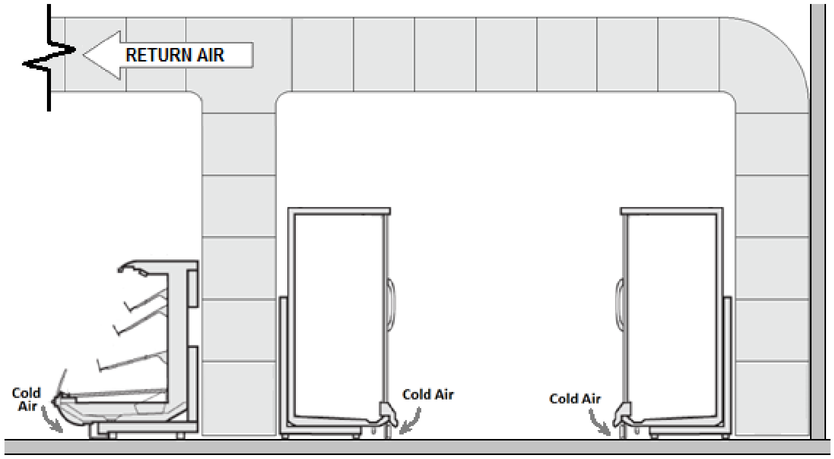
More commonly, computerized selection tools are used to select heat recovery coils, allowing vendors to provide multiple selections for comparison.

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.

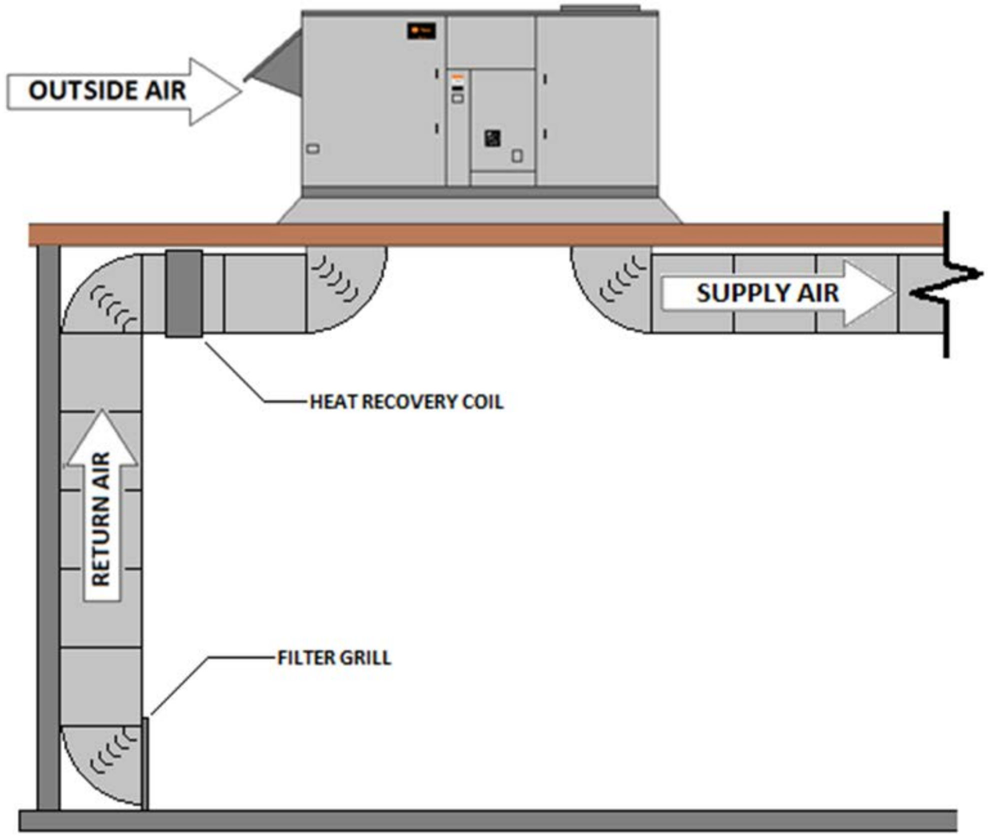
Figure 10-24: Low Return Air Example



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 in the refrigerated space, which predominantly provide heating. The fan design must allow for the additional ductwork and coil pressure drop.

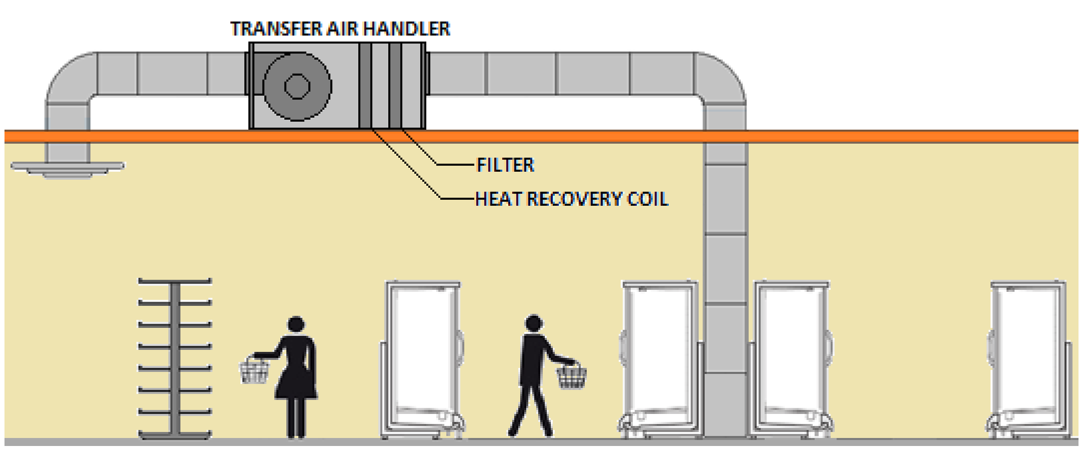
Figure 10-25: Heat Recovery Coil in Return Air Duct



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 use 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

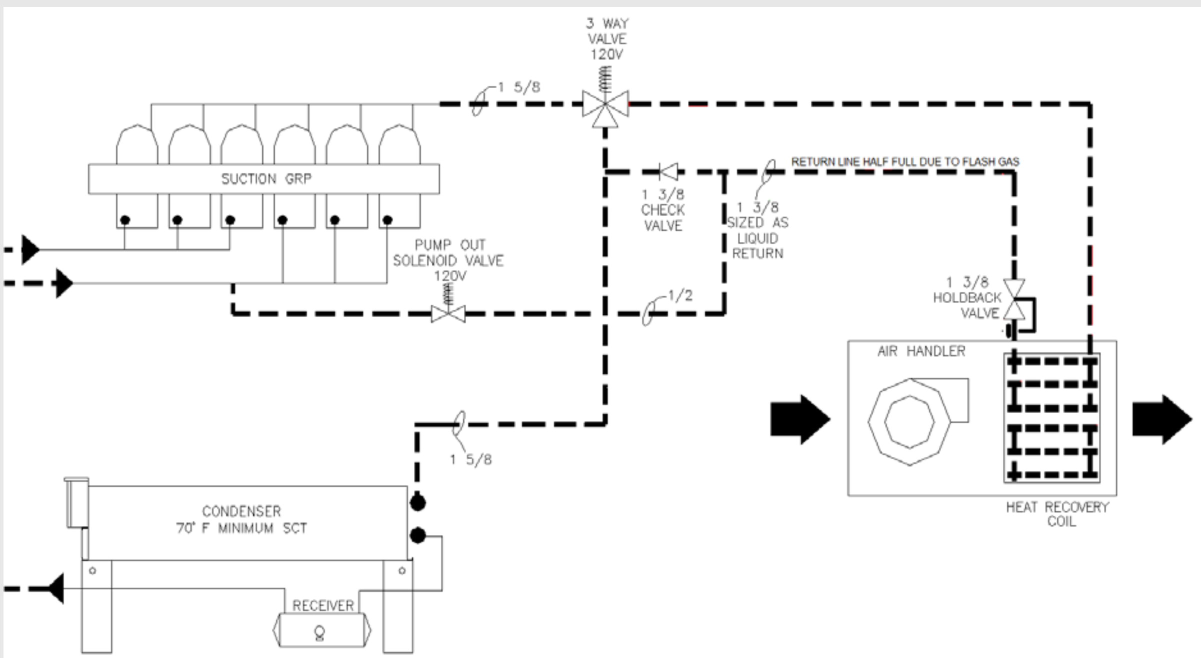
The Energy Standards require that the increase in HFC refrigerant charge from all equipment related to heat recovery for space heating shall be less than 0.35 lbs. for every 1,000 Btuh of heat recovery capacity at design conditions. Refrigerant charge may increase due to the addition of the recovery 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 10-23

Question

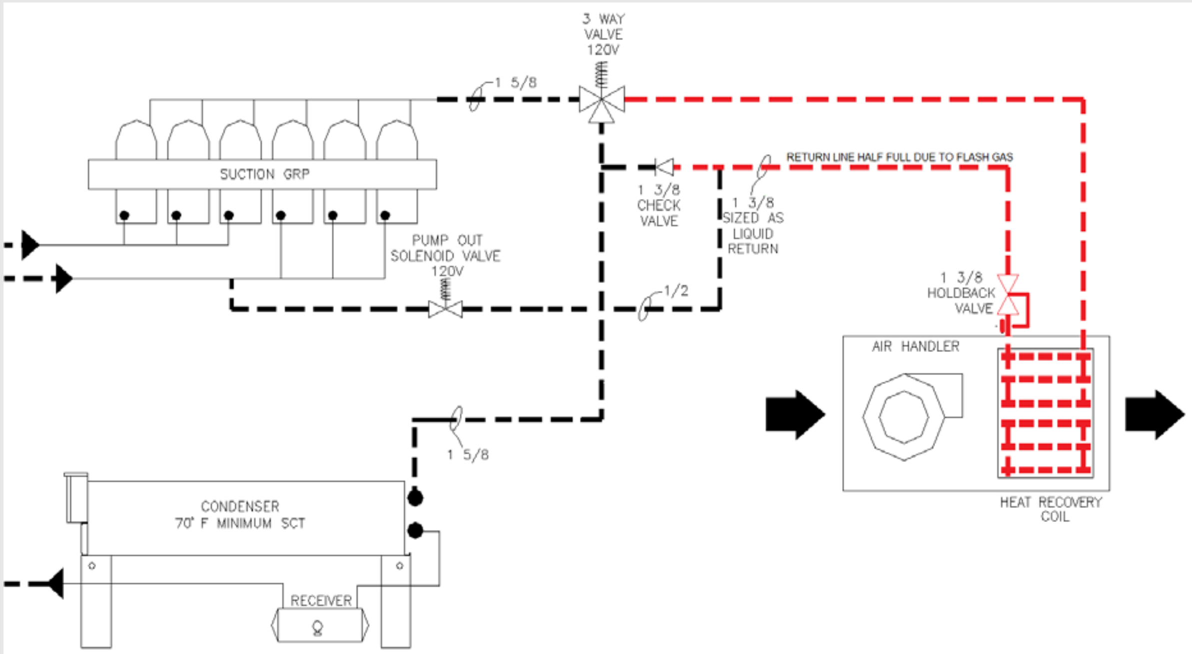
A heat recovery system is being designed for a new supermarket. The refrigerant is R-404A. The proposed design is shown below:



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 10-24

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 the manufacturer's 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 10-25

Question

In the example above, does the recovery design comply with the requirement in the Energy Standards that the recovery design shall use 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 complies with the Energy Standards.

Example 10-26

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 complies with the Energy Standards.

10.5.6 Additions and Alterations

§141.1(b)

The specific requirements for additions and alterations for commercial refrigeration are included in §120.6(b).

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 between 28°F (-2°C) and 55°F (13°C). Freezers are defined as refrigerated spaces designed to operate below 28°F (-2°C). The Energy Standards does not address walk-in coolers and freezers, defined as refrigerated spaces less than 3,000 ft^2, as these are covered by the Appliance Efficiency Regulations (Title 20). However, refrigerated warehouses and spaces with a total of 3,000 ft^2 or more and served by a common refrigeration system are covered by the Energy Standards and required to comply with §120.6(a).

Furthermore, areas within refrigerated warehouses designed solely for quick chilling or quick freezing of products have some exceptions for evaporators and compressors. Quick chilling and freezing spaces are defined as spaces with a design refrigeration evaporator load of greater than 240 Btu/hr-ft^2 of floor space, which is equivalent to 2 tons per 100 ft^2 of floor space. A space used for quick chilling or freezing and 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 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 compliance, the compressor plant requirements in §120.6(a)5B 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 compliance, the provisions addressing condensers, subsection §120.6(a)4A and 4B, 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 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**

Section 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 that 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 10-27

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-ft^2 at the applied conditions. Does the space have to comply with the space requirements in §120.1(a) of the Energy Standards?

Answer

Yes. If the warehouse is 3,000 ft^2 or larger or served by a refrigeration system serving 3,000 ft^2 or more, it must meet all the requirements in subsections 1,2, 6, and 7. It also must meet the requirements of subsections 3A, 4C, 4D, 4E, 4F, 4G, 5A, and 5C. There are exceptions for 3B, 3C, 4A, 4B, and 5B.

Example 10-28

Question

A refrigerated warehouse space is used to cool and store melons received from the field. After the product temperature is lowered, 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 all the space requirements of §120.1(a) of the Energy Standards?

Answer

Yes. While the design evaporator capacity is greater than 240 Btu/hr-ft^2 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 of §120.1(a) of the Energy Standards.

Comment: This measure 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 Chapter 10.

Example 10-29

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 all the requirements of §120.1(a) of the Energy Standards?

Answer

Yes. Since more than 80 percent of the design capacity of the system serves storage space, the refrigeration system requirements apply.

Example 10-30

Question

A new refrigerated warehouse is being constructed, which will include a 1,500 ft^2 cooler space and a 2,500 ft^2 freezer space. Both the cooler and freezer are served by a common refrigeration system. Is the refrigeration system required to comply with this standard?

Answer

Since the suction group serves a total 4,000 ft^2 of refrigerated floor area, the spaces must meet all the requirements of §120.6(a).

10.6.2 Building Envelope Mandatory Requirements

Section 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 that 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 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 10-31

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 10-32

Question

A refrigerated warehouse is constructed of a wall section consisting of 4 inches of concrete, 6 inches of medium density (2 lb/ft^3) 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?

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.

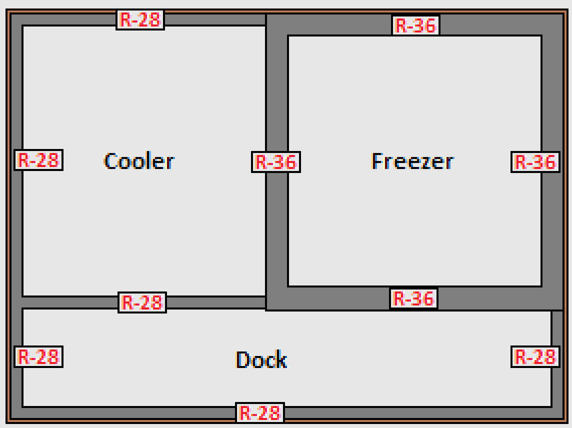
Example 10-33

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.



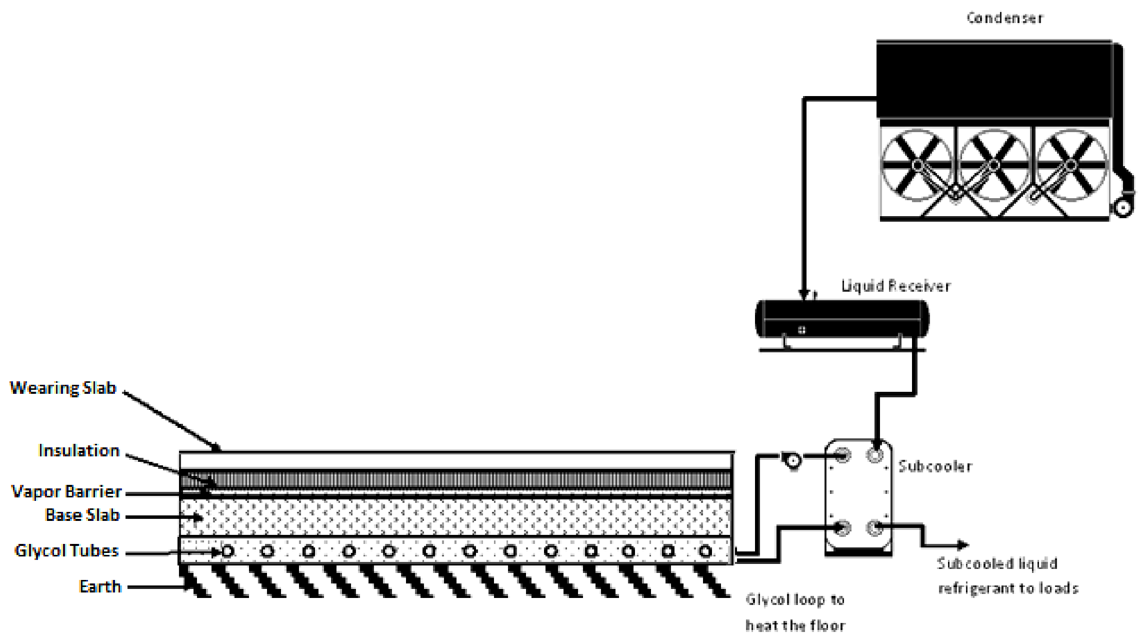
B. Freezer Floor Insulation

Freezer spaces with 3,000 ft^2 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 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 the underslab heat is provided by an underslab heating system that increases productive refrigeration capacity. An example of an underslab heating system using heat from a refrigerant liquid subcooler is shown in Figure 10-27.

Figure 10-27: Underslab Heating System That Uses 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 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 using 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 12 p.m. to 6 p.m. weekdays from 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 nonrefrigerated 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

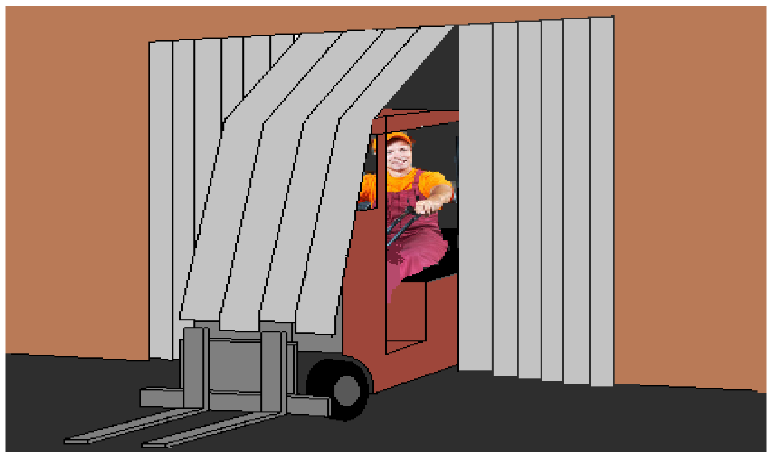


Figure 10-29: Biparting Automatic Door

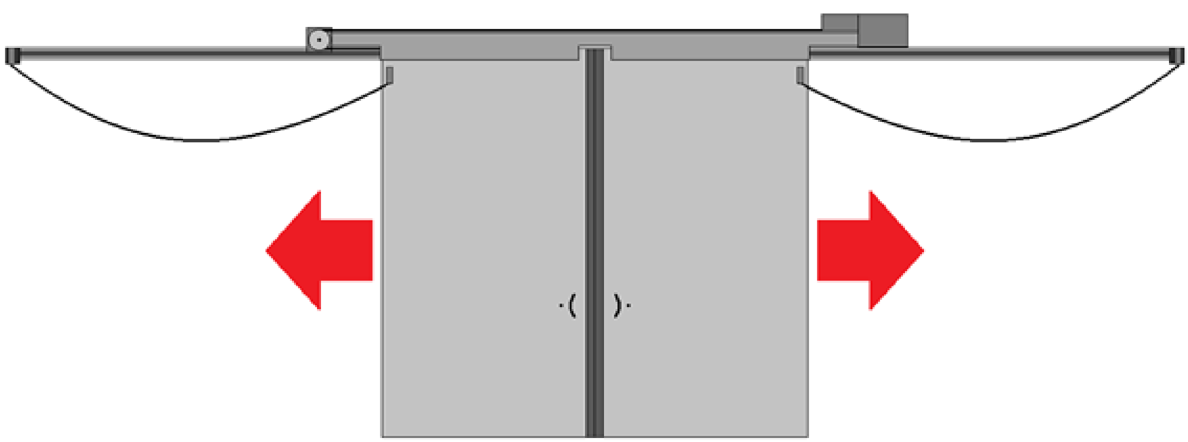


Figure 10-30: Hinged Door With Spring-Action Door Closer and Door "Tight" Closer

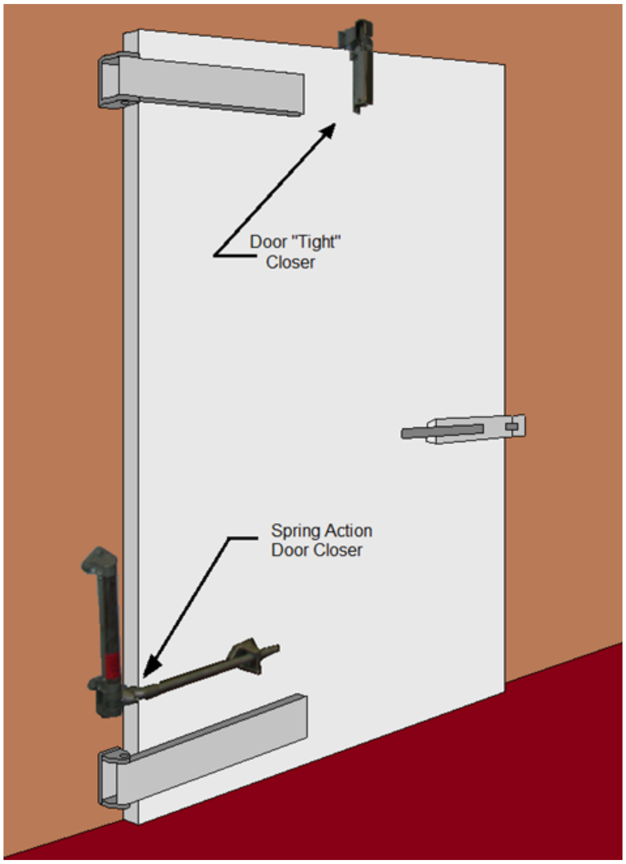
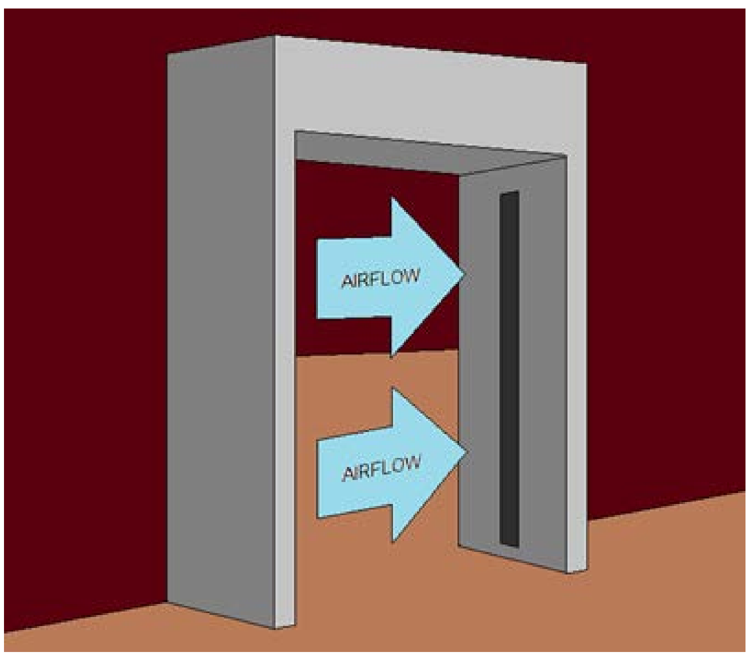


Figure 10-31: Air Curtain



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 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:

a. Single-acting or double-acting hinge-mounted doors with a spring assembly or cam-type gravity hinges.

b. Powered single-sliding, biparting, or rollup doors that open based on a pull cord, proximity or similar sensors, or by operator signal and close automatically through similar actions or after a period sufficient to allow passageway transit.

An air curtain is a commercial fan-powered assembly intended to reduce air infiltration and designed by the manufacturer for use on refrigerated warehouse passageways and on the opening size and the temperatures for which it is applied.

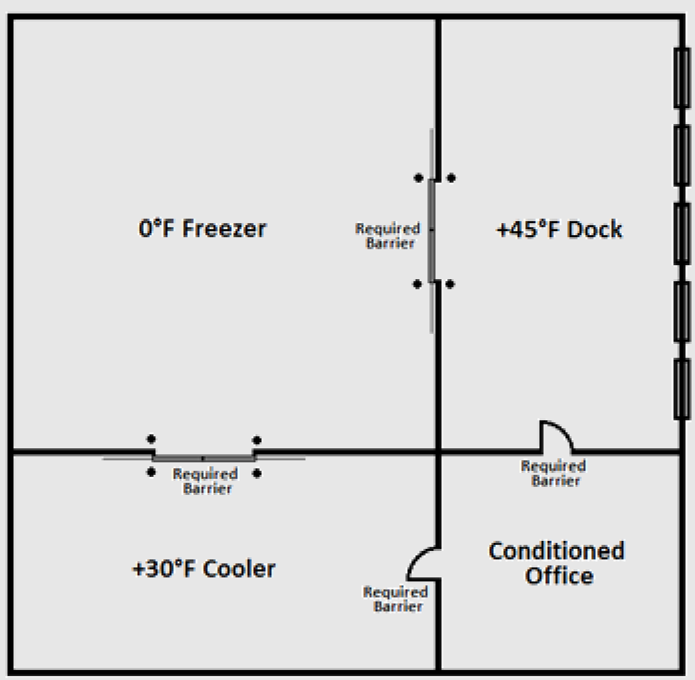
There are two exceptions to the requirements for infiltration barriers:

1. Openings with less than 16 ft^2 of opening area, such as small passageways for conveyor belts
2. Loading dock doorways for trailers.

Example 10-34

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 10-35

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 doors, 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

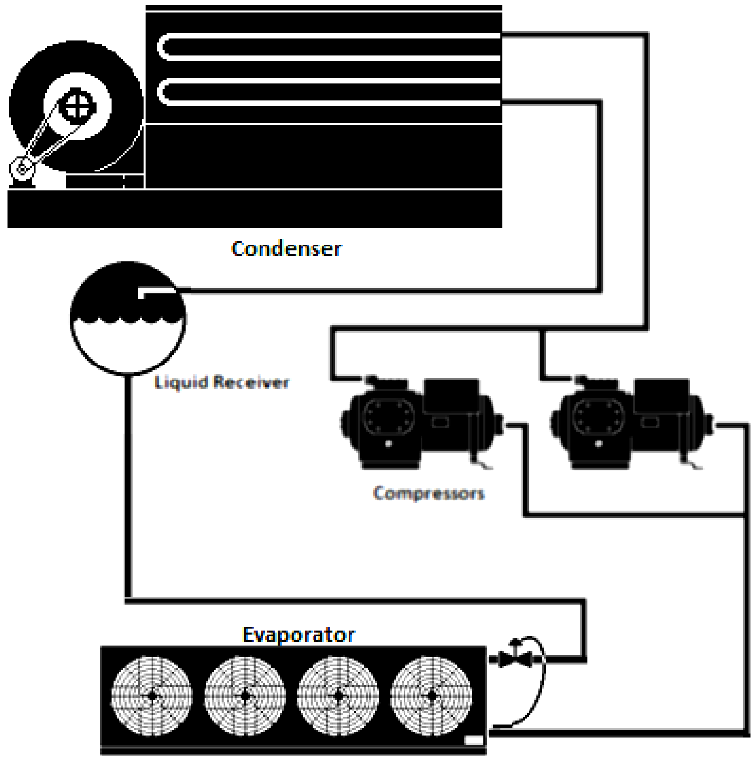


Figure 10-33: Single-Stage System With Flooded Evaporator Coil

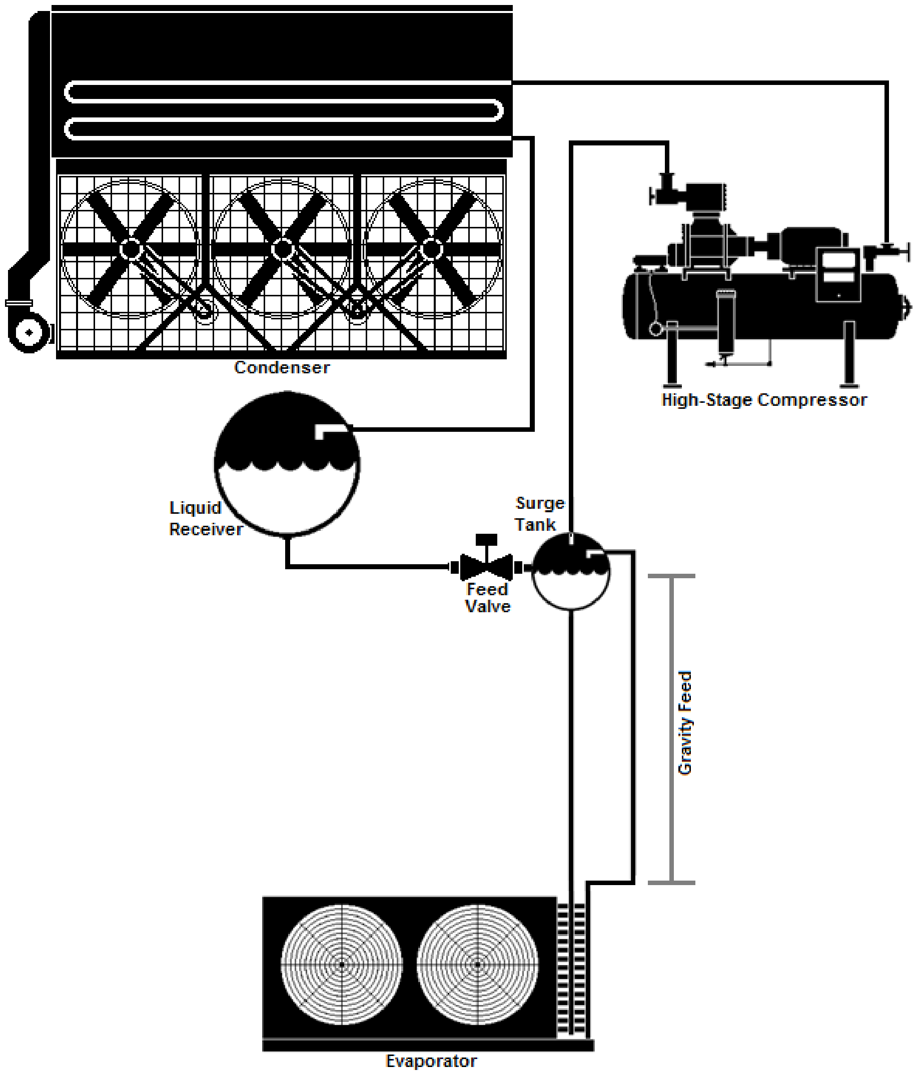


Figure 10-34: Single-Stage System With Pump Recirculated Evaporator Coils

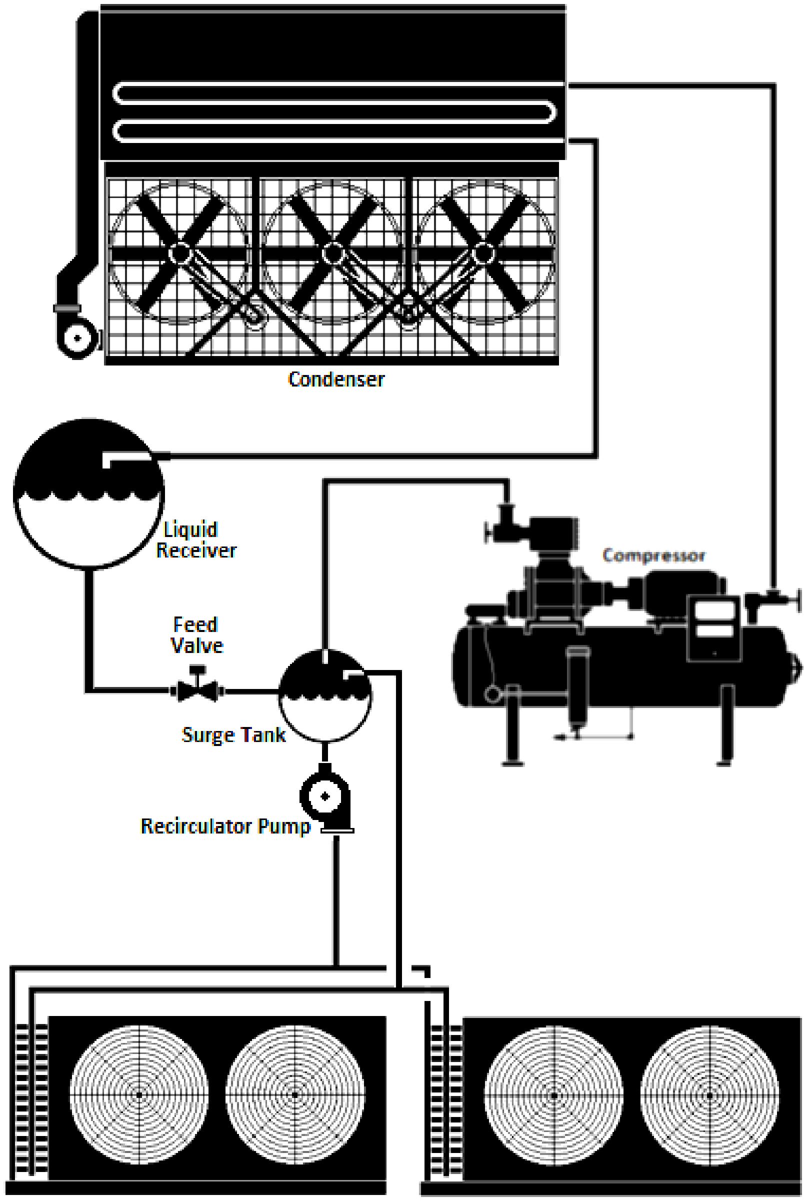


Figure 10-35: Two-Stage System With Flooded Evaporator Coil

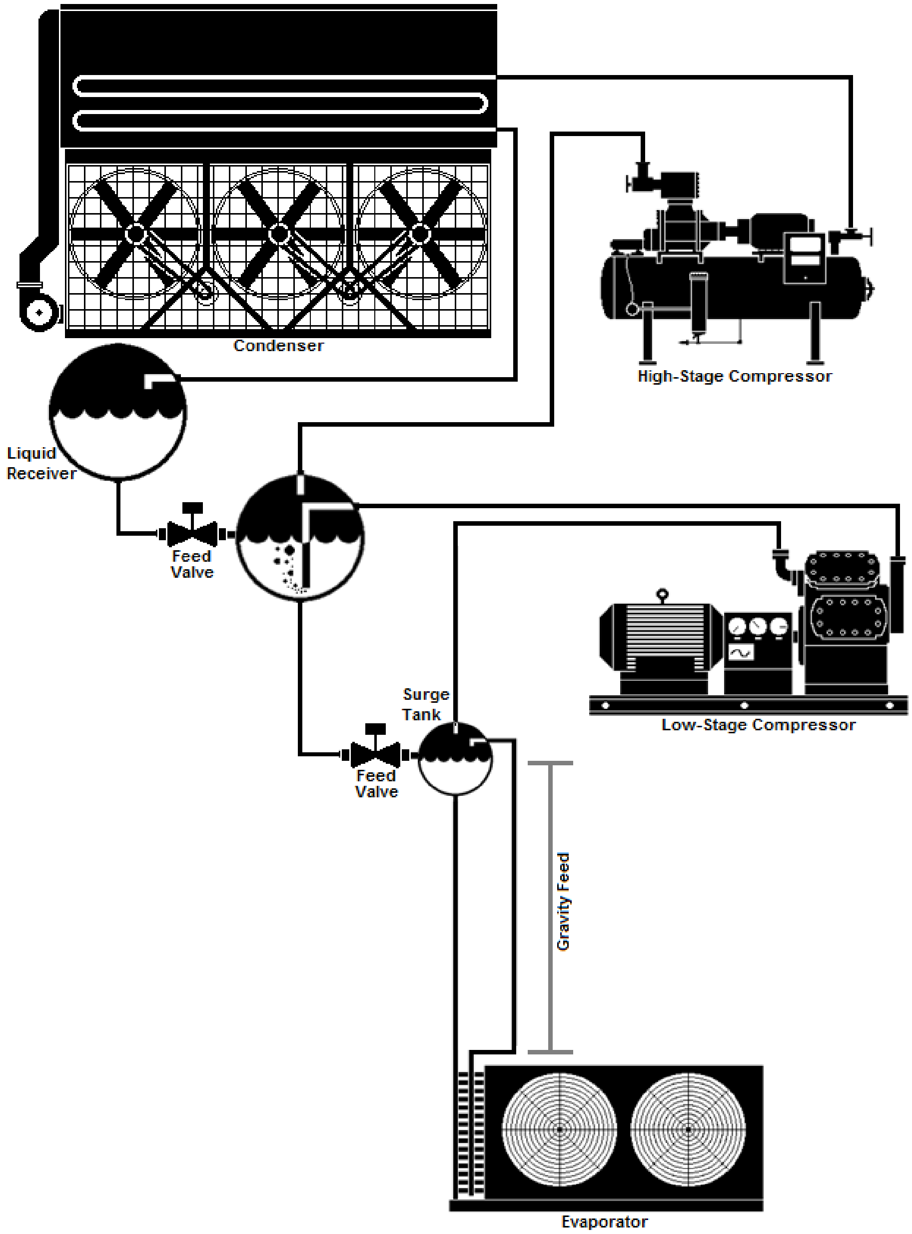
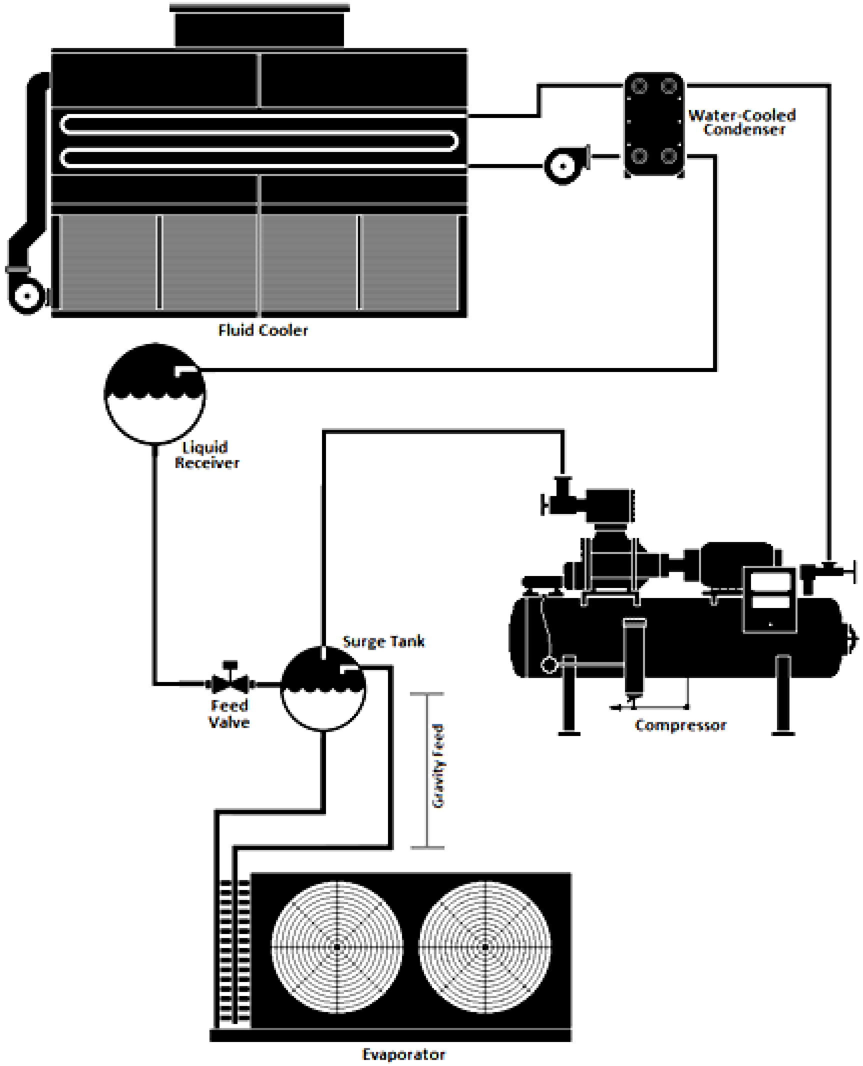


Figure 10-36: Single-Stage System With Water-Cooled Condenser Served by Fluid Cooler



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 Direct Current (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.

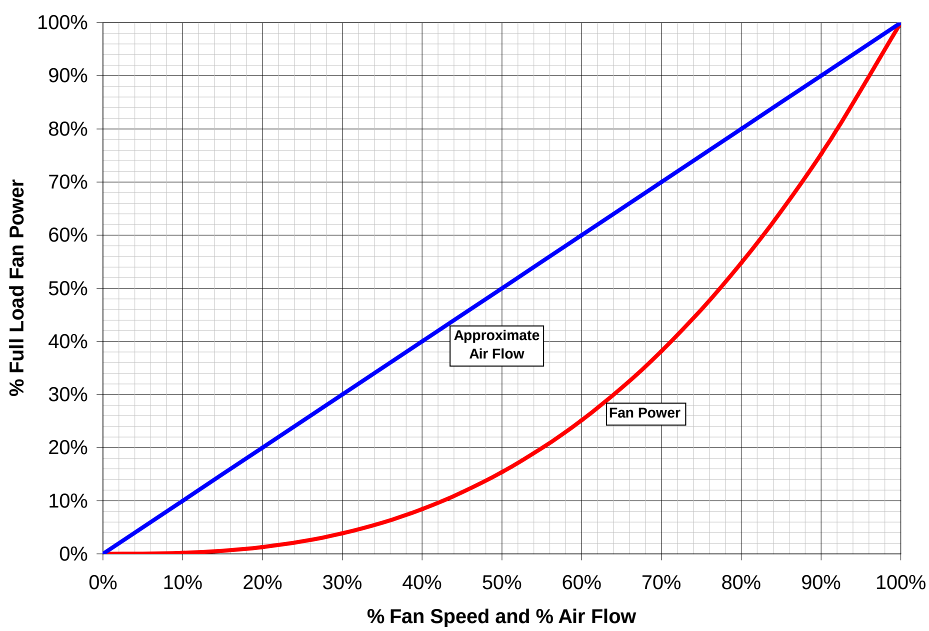
The fan speed is controlled in response to space temperature or humidity. Fan speed should increase proportionally when the space temperature is above the setpoint and decrease when the space temperature is at or below the setpoint, with refrigerant supply and pressure being maintained in the evaporator 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 in these applications will often 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 roughly 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 about 51 percent ($80\%^3 = 51\%$) power while providing nearly 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 have 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 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 be allowed only to float up after fan speeds are at minimum and should be controlled to float back down prior to increasing fan speeds.

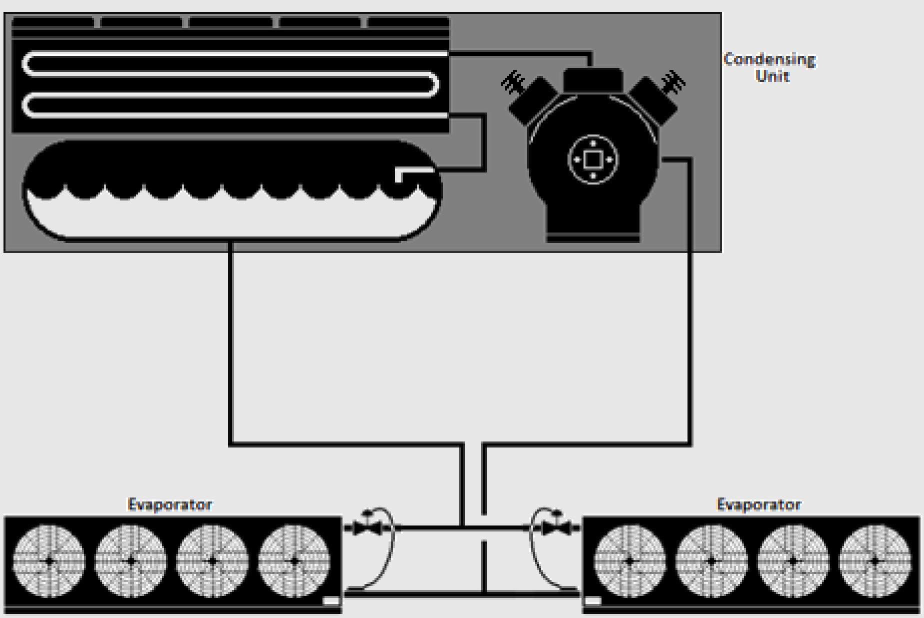
The Energy Standards have three exceptions to the evaporator variable speed requirement:

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 10-36

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?



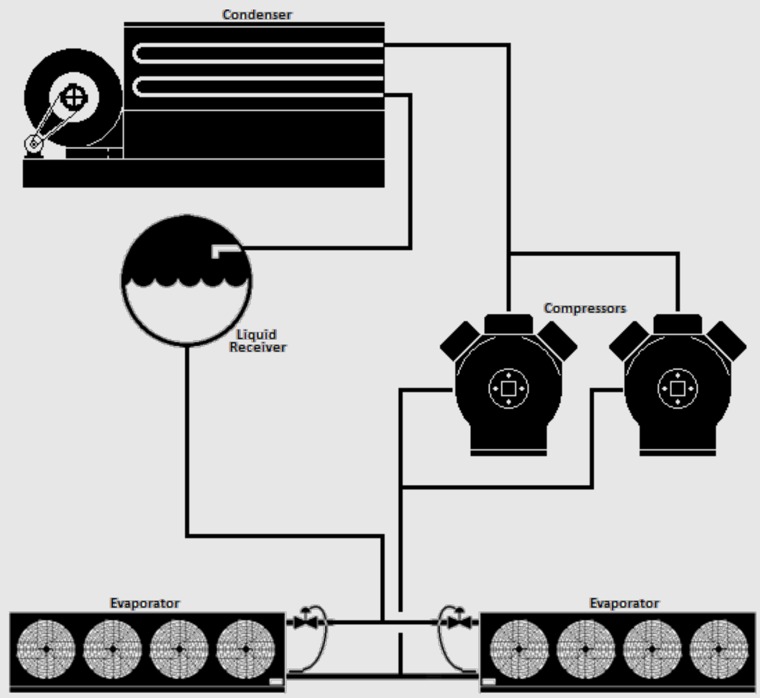
Answer

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 10-37

Question

A refrigeration system uses 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 proportional controls for 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 10-38

Question

A -20°F (-29°C) freezer has several 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 use variable-speed drives and the control system varies the fan speed in response to space temperature. What should the freezer saturated suction temperature be 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).

This example sought to show how evaporator temperature and coil capacity can be considered and maintained to achieve proper variable-speed fan operation and savings. Settings could be 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 10-39

Question

An existing refrigerated warehouse space has eight 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 use a consistent control scheme that 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.

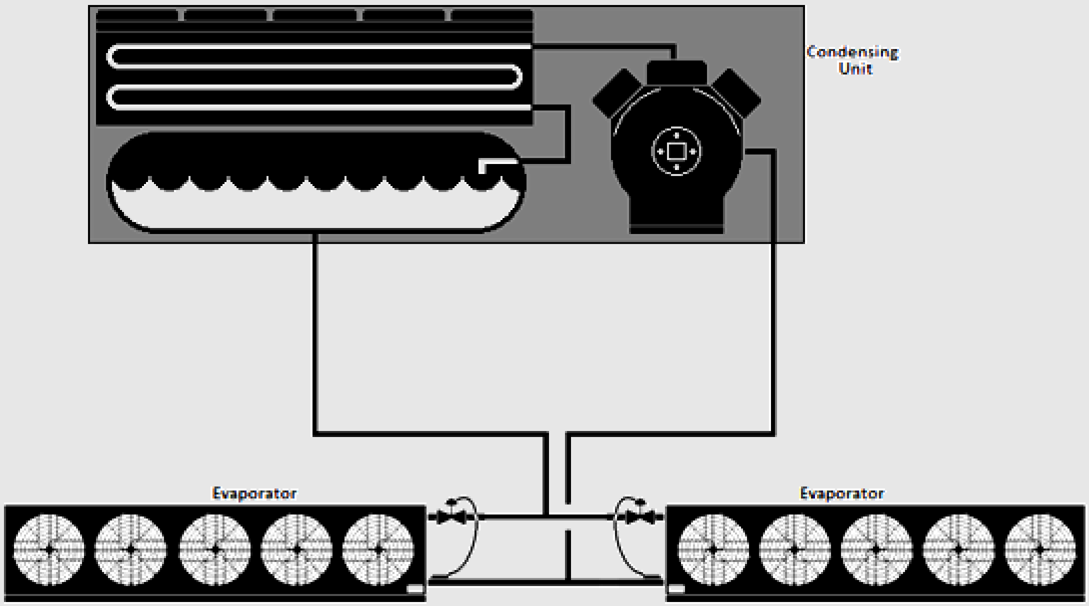
Continuously variable-speed control is not mandatory for evaporators that are served by a single compressor that does not have variable-capacity capability (i.e. the compressor cycles on and off in response to space temperature). For these systems, evaporator airflow must be reduced by at least 40 percent when the compressor is off. This can be accomplished in several ways, for example:

1. Two-speed evaporator fan control, with speed reduced by at least 40 percent when cooling is satisfied and the compressor is off.
2. Turning off a portion of the fans in each evaporator to accomplish at least 40 percent reduction in fan power. Typically, baffles are required to prevent reverse flow through fans that are turned off.
3. 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 percent of the duty cycle while the compressor is off.

Example 10-40

Question

A split system with a packaged air-cooled condensing unit using 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 use controls that cycle at least 4 of the 10 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. Fan-powered adiabatic condensers are covered by §120.6(a)4C.

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 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, 4B, and 4C for condensers serving refrigeration systems for which more than 20 percent of the design cooling load comes from quick chilling or freezing space, or process (nonspace) 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 100 ft² of floor area, at system design conditions.

Another exception to §120.6(a)4B, for air-cooled condenser sizing, applies if a condensing unit has a total compressor power less than 100 hp. A condensing unit includes compressor(s), condenser, liquid receiver, and control electronics that are packaged in a single product.

Example 10-40

Question

A new food processing plant is being constructed that will include an 800 ft² blast freezer, a holding freezer, and a loading dock. The design evaporator capacity of the blast freezer is 40 tons of refrigeration (TR). 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?

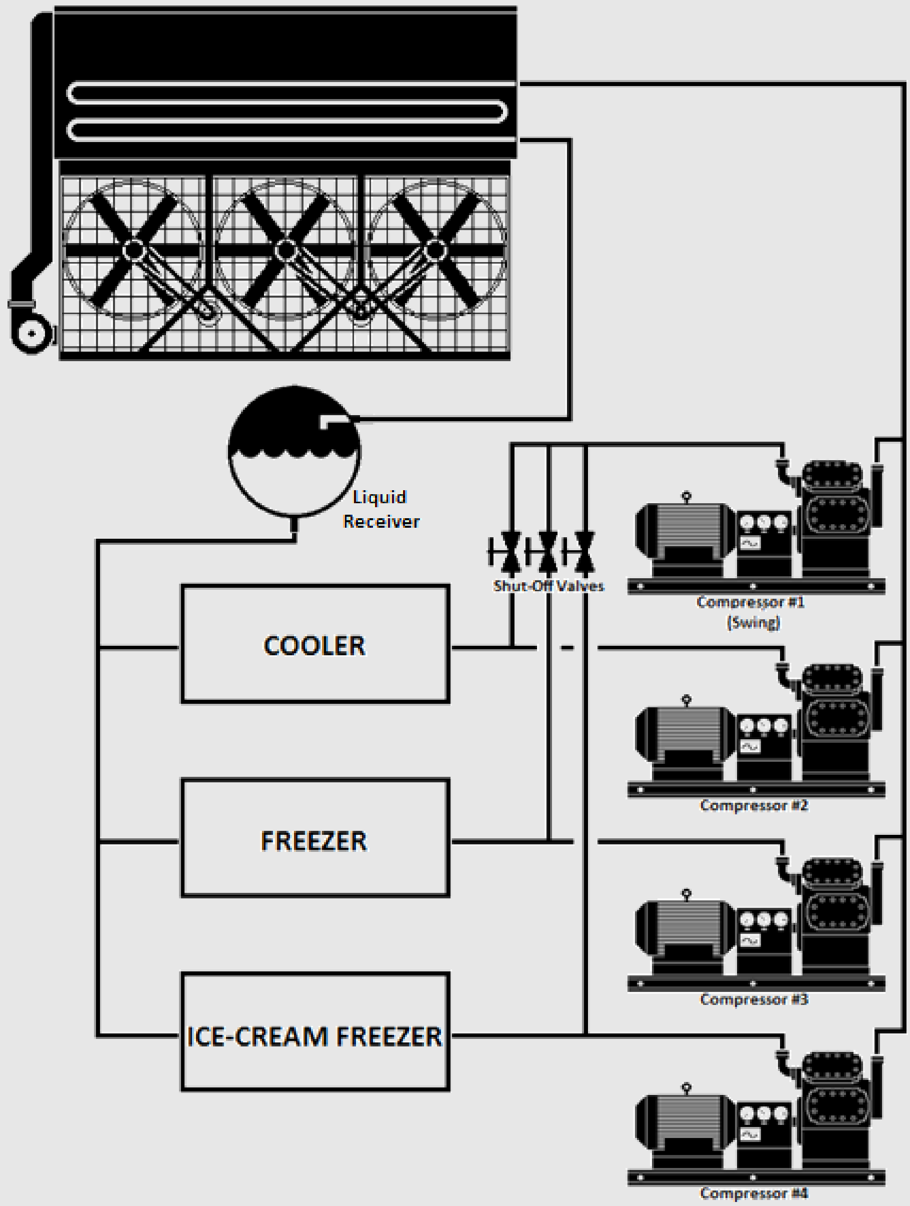
Answer

The blast freezer evaporator capacity divided by the floor area is 40 TR/800 ft², which is equal to 5 TR/100 ft². 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, because 40% (i.e. greater than 20%) of the design refrigeration capacity is from quick freezing.

Example 10-42

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 backup 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 backup for other compressors. If the compressor is solely for use as backup, 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 this section, designers should use the 0.5 percent design wetbulb 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 WETBULB 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 10-43

Question

A refrigerated warehouse is being constructed in Fresno. 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 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 10-44

Question

What is the minimum size for a condenser for a refrigeration system with the following parameters?

Located in Fresno
Design SST: 10°F
Suction group: Three equal-sized dedicated 100 hp screw compressors (none are backup units)
Evaporative condenser
240 TR cooling load

Answer

From the previous example, it was determined that the design wetbulb temperature (WBT) to demonstrate compliance for Fresno 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 THR for the suction group at the design conditions of 10°F SST and 95°F SCT. Each selected compressor has a rated capacity of 240 TR 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 = 9,403,500 Btuh

To comply with the Energy Standards, a condenser (or group of condensers) must be selected that is capable of rejecting at least 9,403,500 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 this section, designers should use the 0.5 percent design drybulb 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 the 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 10-45

Question

An air-cooled condenser is being sized for a system that has half of the associated installed capacity serving cooler space and the other half serving freezer space. What is the design TD to be added to the design drybulb temperature?

Answer

This measure specifies a design approach of 15°F (8.3°C) for coolers and 10°F (5.6°C) for freezers. 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 percentage of the total installed capacity dedicated to coolers by 15°F (8.3°C). Next, multiply the percentage 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% x 15°F*) + (50% x 10*°F*) = 7.5*°F + *5*°F = *12.5*°F

3. Adiabatic Condenser Sizing

§120.6(a)4C

§120.6(a)4C provides maximum design SCT values for adiabatic condensers. These requirements are the same as for §120.6(b)1E. See section 10.5.2.3 for details.

B. Fan Control

Condenser fans for new air-cooled, evaporative or adiabatic condensers, or fans on cooling towers or fluid coolers used to reject heat on new refrigeration systems, must use 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 reduce condenser capacity. As load increases, fans should be turned back on before 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 the control logic that 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 wetbulb temperature, the target SCT for air-cooled condensers must be reset according to ambient drybulb temperature, and the target SCT for adiabatic condensers when operating in dry mode must be reset according to ambient drybulb temperature. There is no requirement for SCT control during wetbulb (adiabatic) operation. This requirement for the adiabatic condenser is applicable to all systems and is independent of the type of refrigerant used

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 use as much condenser capacity as possible without excessive fan power, a common practice for refrigerated warehouse systems is to optimize the control TD over a period such that the fan speed is between approximately 60 and 80% during normal operation (i.e. when not at minimum SCT). While not required, evaporative condensers and systems using 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 using 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 use 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.

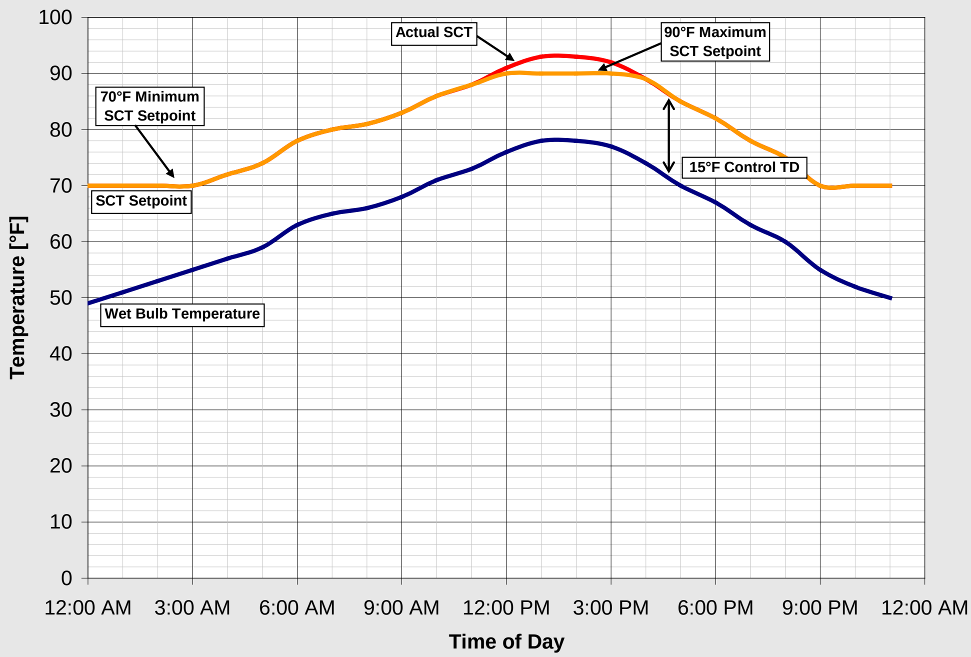
Example 10-46

Question

A refrigerated warehouse with evaporative condensers is being commissioned. The control system designer has used a wetbulb-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 wetbulb 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 wetbulb-following control strategy with a 15°F (8.3°C) TD and 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 wetbulb 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) that may be used to limit the maximum control setpoint, regardless of the ambient temperature value or TD parameter.



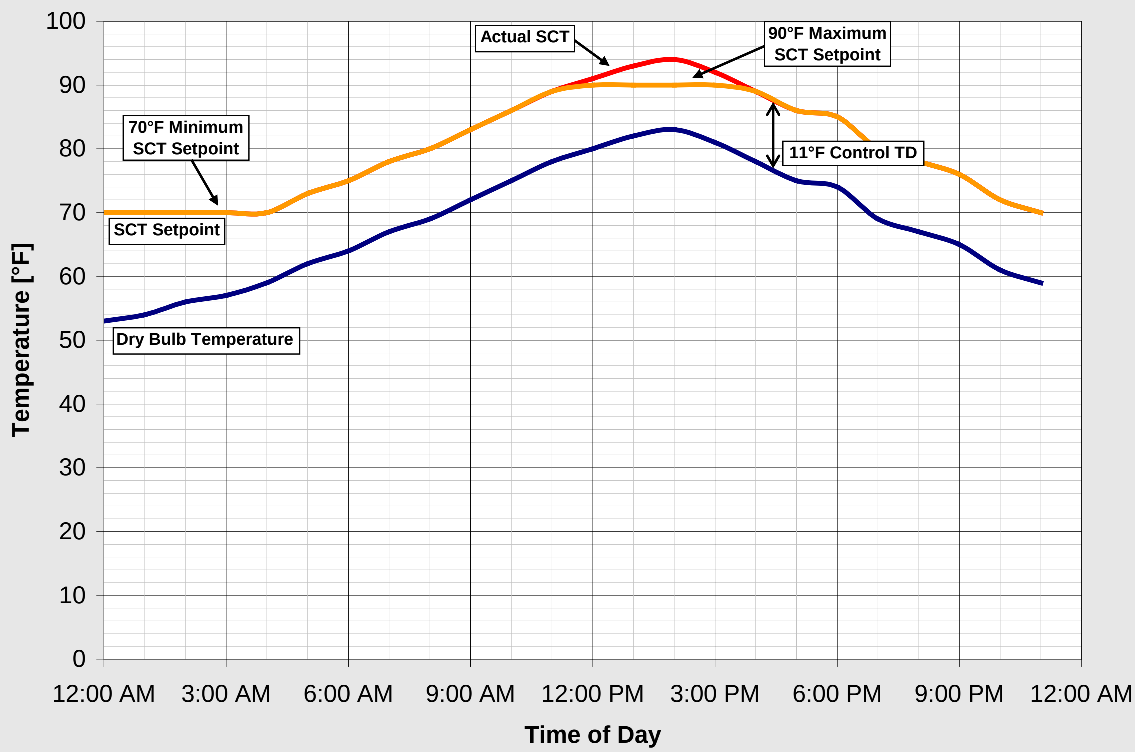
Example 10-47

Question

A cold storage facility with an air-cooled condenser is being commissioned. The control system designer has used 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 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) that may be used 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, and C, 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 and adiabatic 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

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM SPECIFIC EFFICIENCY*	RATING CONDITION
Outdoor Evaporative-Cooled with THR Capacity > 8,000 MBH	All	350 Btuh/W	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/W	
Outdoor Air-Cooled	Ammonia	75 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Drybulb Temperature
	Halocarbon	65 Btuh/W	
Adiabatic Dry Mode	Halocarbon	45 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Drybulb Temperature
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:

a. Outdoor, evaporative, THR greater than 8,000 MBH at specific efficiency rating conditions.

b. Outdoor, evaporative, THR less than 8,000 MBH at specific efficiency rating conditions.

c. Indoor, evaporatively cooled.

d. Outdoor, air-cooled, ammonia refrigerant.

e. Outdoor, air-cooled, halocarbon refrigerant.

f. Adiabatic (dry-mode operation), halocarbon refrigerant.

g. 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, 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 determining compliance with this section.

For air-cooled and adiabatic condensers, manufacturers typically provide the capacity at a given temperature difference (TD) between SCT and drybulb temperature. Manufacturers typically assume that 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. For adiabatic condensers, the dry mode capacity 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 (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 10-48

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 four-pole open fan motor, the minimum efficiency is 91.0%. For a 5 HP six-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

This condenser meets the minimum efficiency requirements because 381 Btu/hr per watt is higher than the 160 Btu/hr per watt requirement.

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 use a microchannel 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 affects 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. 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 percent 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.

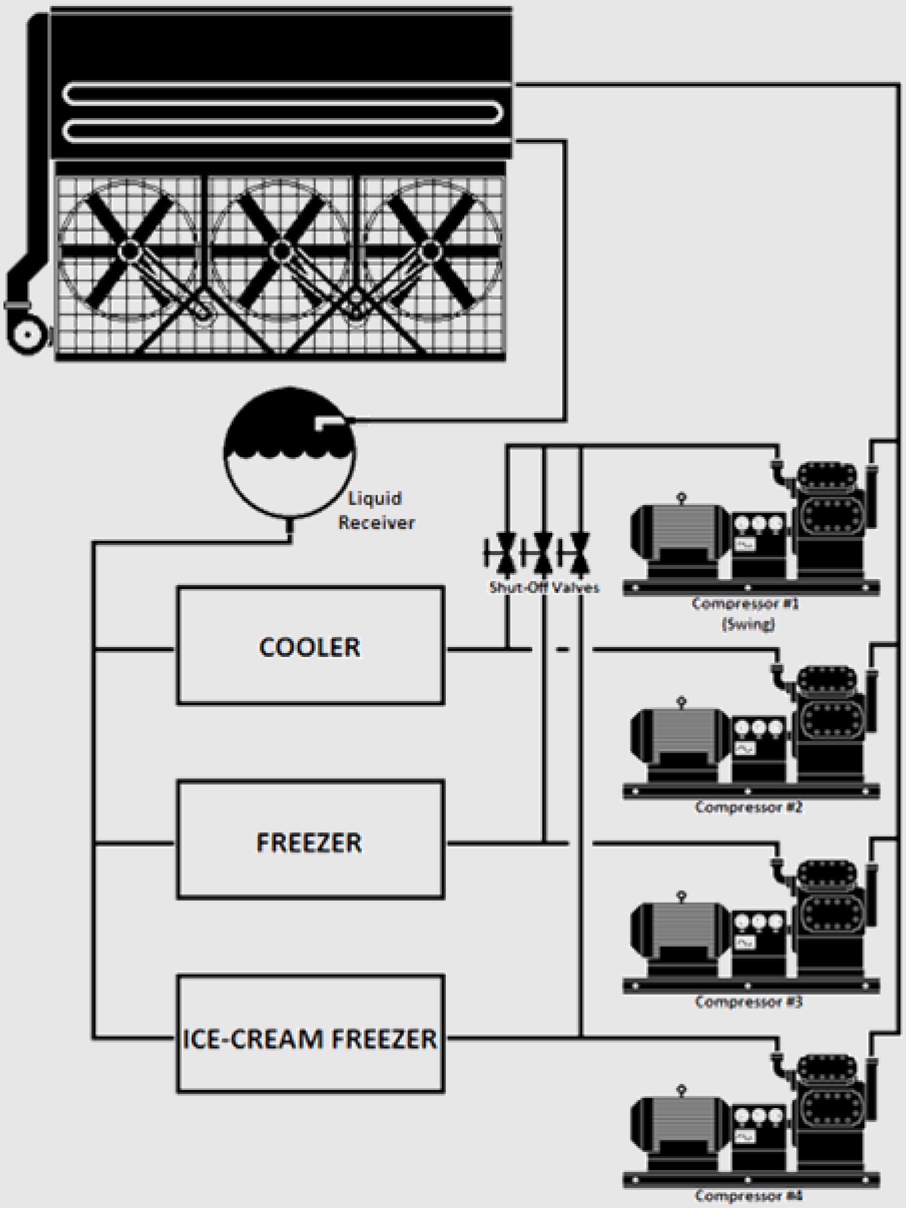
An exception to §120.6(a)5B (controlling compressor speed in response to refrigeration load) is provided for compressors on a refrigeration system with more than 20 percent of the design cooling load from quick chilling or freezing space, or nonspace process refrigeration cooling. The “refrigeration 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 150 HP shall incorporate the capability to automatically vary the volume ratio (i.e. variable Vi) to optimize efficiency at off-design operating conditions.

Example 10-49

Question

The system shown below has three 200 HP open-drive screw compressors serving three 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. Exception 1 to §120.6(a)5B applies only 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 backup 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.
- Adiabatic 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 wetbulb temperature. Trends of wetbulb 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 load 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 drybulb temperature. Trends of drybulb 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 energy savings. This control setting should be adjusted during average load so that condenser capacity is effectively used but fan speed is not excessive.

E. Adiabatic Condensers

NA7.10.3.3

Adiabatic 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 drybulb temperature when operating in dry mode. Trends of drybulb 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 used but fan speed is not excessive.

F. Variable-Speed Compressors

NA7.10.4

The controls and equipment for the variable-speed control of screw compressors are 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

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 the following:

- 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 an 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 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 an alteration.

Example 10-50

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 10-51

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?

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 10-52

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 an alteration. The alteration requirements apply when all the evaporators in the space are changed.

Example 10-53

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 10-54

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

§140.9(c) sets the minimum requirements for laboratory and factory exhaust systems. Laboratories have an average annual energy intensity 10-20 times larger than offices when normalized by building area. The primary drivers of laboratory building energy are long operation hours, exhaust fan energy, and makeup air conditioning in addition to typically high internal loads.

To help reduce laboratory and factory energy use, there are four categories of exhaust energy saving measures:

- Exhaust and makeup air reduction
- Reduction of conditioned makeup air
- Exhaust fan power reduction
- Fume hood automated sash closures

Laboratories in healthcare facilities are not required to meet the requirements of §140.9(c).

10.7.2 Mandatory Measures

There are no mandatory measures specific to laboratory exhaust, but the equipment efficiencies in §110.1 and §110.2 apply.

10.7.3 Prescriptive Measures

Summary of measures contained in this section:

- Airflow Reduction Requirements - §140.9(c)1
- Exhaust System Transfer Air - §140.9(c)2
- Fan System Power Consumption - §140.9(c)3
- Fume Hood Automatic Sash Closure - §140.9(c)4

10.7.3.1 **Airflow Reduction Requirements**

§140.9(c)1 requires that all laboratory exhaust with minimum circulation rates of 10 air changes per hour (ACH) or lower shall be designed for variable-volume control on the supply, fume exhaust, and general exhaust. This requirement will enable the system to reduce zone exhaust and makeup airflow rates to the minimum allowed for ventilation or to maintain the required differential pressure for the zone.

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)1]. Examples include hoods using perchloric acid, hoods with radio isotopes, and exhaust systems conveying dust or vapors that need a minimum velocity for containment.

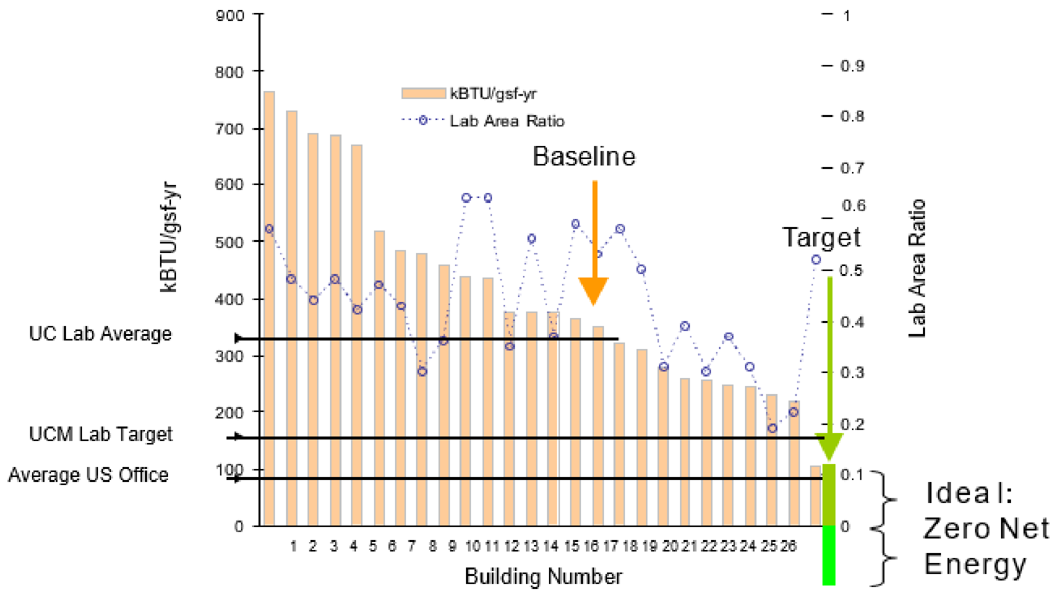
A second exception is provided for new zones added to an existing constant volume exhaust system [Exception 2 to §140.9(c)1].

The energy and demand savings depend strongly characteristics of the facility, including:

1. Ratio of lab to non-lab space.
2. Minimum airflow required by code or the facility EH&S department. These range from 4 to 18 ACH or higher.
3. Climate zone.

Figure 10-38 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 axis. The 26 labs are arranged from highest to lowest normalized energy use. The right axis 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 its laboratories; and the average national energy end use for office buildings.

Figure 10-38: Laboratory Benchmarking From Labs 21 for San Francisco Bay Area



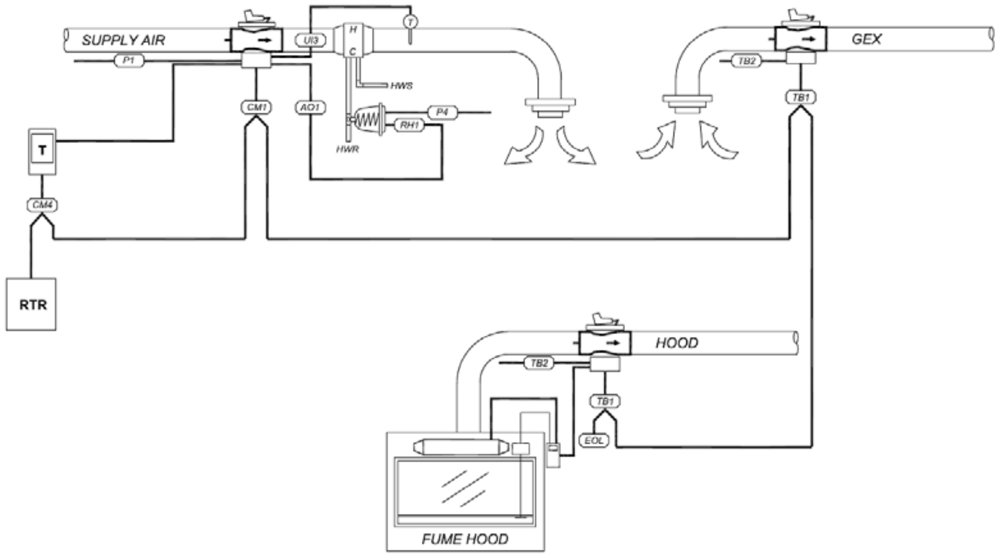
Using the criteria for cost-effectiveness in the Energy Standards and very conservative estimates of the first costs (using costs from VAV retrofits not new construction), this measure was shown to be cost-effective in all California climate zones up to 14 ACH of minimum ventilation

Using off-the-shelf variable air volume (VAV) controls can greatly reduce the energy use in laboratory buildings. The Energy Standards require VAV controls on all zones not required to be constant volume by the AHJ, facility EH&S department, or other applicable health and safety codes. Furthermore, ANSI/AIHA Z9.5 and NFPA 45 allow lower minimum airflows for many hoods, which increases the savings from VAV design.

Figure 10-39 below shows the zone components for a 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. When used, the hood valve 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 reheat coils to maintain space comfort for heating. The GEX is typically used to control the cooling, on a 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 either variable volume or constant volume depending on the application. A hood might for instance be required to maintain 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 attached exhaust also serves variable-volume zones. The same rule applies 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 are 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.

10.7.3.2 **Exhaust System Transfer Air**

This section limits the amount of conditioned air supplied to a space with mechanical exhaust. The benefit of this requirement is to take advantage of available transfer air. By doing so, the amount of air that needs to be conditioned is limited, thus saving energy. Conditioned supply air is limited to the greater of:

1. The supply flow required to meet the space heating or cooling load.
2. The ventilation rate required by the AHJ, facility EH&S department, or by §120.1(c)3.
3. The mechanical exhaust flow minus the available transfer air.

The supply flow required to meet the space heating or cooling loads can be documented by providing load calculations.

Available transfer air can be from adjacent conditioned spaces or return air plenums that are on the same floor, same smoke or fire compartment, and within 15 feet. To calculate the available transfer air:

1. Calculate the minimum outside air required by adjacent spaces.
2. From 1, subtract the amount of air required by adjacent space exhaust.
3. From 2, subtract the amount of air required to maintain pressurization of adjacent spaces. This is your available transfer air.

Exceptions are provided for:

1. Laboratories classified as biosafety level 3 or higher.
2. Vivarium spaces.
3. Spaces required to maintain positive pressure differential relative to adjacent spaces.
4. Spaces that require a negative pressure relationship and the demand for transfer air may exceed the available transfer airflow rate.
5. Healthcare facilities.

10.7.3.3 **Fan System Power Consumption**

Newly installed laboratory and factory exhaust systems greater than 10,000 CFM have three prescriptive pathways to show compliance with this section. Regardless of the path chosen, all exhaust systems must meet the discharge requirements of ANSI Z9.5.

ANSI Z9.5-2012 Discharge Requirements:

Section 5.4 and Appendix 3 of ANSI Z9.5, Laboratory Ventilation, describe standards for laboratory exhaust system design including the discharge requirements cited by this section of the Energy Standards.

Exhaust Fan System Power Consumption:

As described in greater detail for the previous VAV section, one of the major drivers of laboratory and factory energy is fan power. To reduce this demand, three prescriptive pathways have been added for the 2019 code cycle. The first and simplest pathway is an exhaust system power limit of 0.65 or 0.85 W/cfm depending on system design. The other two options do not limit exhaust system power, but instead require exhaust volume flow rate control based on either local wind conditions or exhaust chemical concentration.

Option 1: Exhaust System Efficacy:

- Systems without air treatment devices are limited to 0.65 W/cfm of exhaust air.
- Systems with air filtration, scrubbers, or other air treatment devices are limited to 0.85 W/cfm of exhaust air.
- An exception is provided for systems with **code required** air treatment devices that cause static pressure drop greater than 1 inch of water. For example, a local jurisdiction which has an ordinance for high exhaust filtration, which causes high filter static pressure, due to smell or other exhaust considerations.

Option 2: Wind-Based Exhaust Volume Flow Rate Control:

This compliance path saves fan energy by reducing exhaust stack airflow when local wind conditions permit. The Energy Standards, ANSI Z9.5, and other best engineering practices dictate several necessary components to this type of system:

1. Anemometer Sensors:

   a. Two anemometer sensors must be used to enable sensor fault detection.

   b. Installation location must exhibit similar wind speed and direction to the free stream air above the exhaust stacks.

   c. Sensors must be located high enough to be above the wake region created by nearby structures.

   d. Sensors must be factory calibrated.

   e. Sensors must be certified by the manufacturer to an accuracy of ± 40 feet per minute (fpm), ± 5.0 degrees, and to require calibration no more than every five years.

2. Dispersion Modeling:

   a. Wind dispersion analysis must be used to create a look-up table for exhaust volume flow rate versus wind speed/direction.

   b. Look-up table must contain at least eight wind speeds and eight wind directions to define the safe exhaust volume flow rate.

c. Exhaust volume flow rate must be based on maintaining downwind chemical concentrations below health and odor limits as defined by the 2018 American Conference of Governmental Industrial Hygienists, Threshold Limit Values and Biological Indices, or more stringent, local, state, and federal limits if applicable.

3. Sensor Fault Management:

a. Minimum sensor failure thresholds:

- If any sensor has not been calibrated within the associated calibration period.
- Any sensor that is greater than ±30% of the four-hour average reading for all sensors.

b. Upon sensor failure, the system must revert to a safe exhaust volume flow rate based on worst-case wind conditions. Furthermore, the system must report the fault to an Energy Management Control System or other application which notifies a remote system provider.

4. Certification of requirements listed in NA7.16 for wind speed/direction control

Option 3: Contaminant Concentration-Based Exhaust Volume Flow Rate Control:

This compliance path saves fan energy by reducing exhaust airflow when the exhaust contaminant concentration is low enough to maintain safe downwind concentrations. The Energy Standards and best engineering practices dictate several necessary components to this type of system:

1. Chemical Concentration Sensors:

- Two contaminant concentration sensors must be used in each exhaust plenum to enable sensor fault detection.
- Sensors must be photo ionization detectors.
- Sensors must be factory calibrated.
- Sensors must be certified by the manufacture to an accuracy of ± 5% and require calibration no more than every six months.

2. Dispersion Modeling:

- Wind dispersion analysis must be used to determine contaminant-event thresholds (contaminant concentration levels), which control when the exhaust volume flow rate can be turned down during normally occupied hours.

- Exhaust volume flow rate must be based on maintaining downwind chemical concentrations below health and odor limits as defined by the 2018 American Conference of Governmental Industrial Hygienists, Threshold Limit Values and Biological Indices, or more stringent, local, state, and federal limits, if applicable.

3. Sensor Fault Management:

- Minimum sensor failure thresholds:
  - If any sensor has not been calibrated within the associated calibration period.
  - Any sensor that is greater than ±30% of the four-hour average reading for all sensors.
- Upon sensor failure, the system must revert to a safe exhaust volume flow rate based on worst-case wind conditions. Moreover, the system must report the fault to an energy management control system or other application that notifies a remote system provider.

- Certification of requirements listed in NA7.16 for contaminant control

Example 10-55

Question

A laboratory space has 2,500 ft^2 of conditioned floor area, a drop ceiling for plenum space, and ceiling height of 10 feet. The lab has a minimum ventilation rate of 2,500 cfm.

Is this laboratory required to have variable-volume exhaust and makeup air flow to comply with Section 140.9(c)1?

Answer

In the absence of any other code or environmental health & safety requirement for constant speed operation, Section 140.9(c)1 requires that laboratories have variable-volume exhaust and makeup airflow if the minimum ACH is less than or equal to 10. For this laboratory space, ACH is equal to the following, noting that ACH is calculated for laboratory conditioned space not including plenum volume:

$$ACH = 2{,}500 \text{ cfm} \times 60 \text{ min / hr} / (2{,}500 \text{ ft}^2 \times 10 \text{ ft}) = 6 \text{ ACH}$$

Thus, if there is no conflicting code or safety requirement for constant volume operation, this space requires a variable-volume HVAC system.

Example 10-56

Question

A variable-volume supply fan and a variable-volume exhaust fan serving a lab system has a fan system design supply airflow and design exhaust airflow of 8,000 cfm. The system consists of one supply fan operating at an input power of 4.0 bhp and one exhaust fan operating at an input power of 8.0 bhp. The exhaust system uses a 0.6 in. pressure drop filtration device, airflow control devices, and serves fume hoods.

Does this fan system comply with the fan power requirements in Title 24?

Answer

For laboratory exhaust systems with total flow rates less than or equal to 10,000 cfm, the total fan energy of the space conditioning system and the laboratory exhaust system must comply with Section 140.4(c). First, the design fan power must be calculated in bhp, as shown below:

Design Fan Power = 5.0 bhp + 8.0 bhp = 13.0 bhp

Then, the fan power limit in section 140.4(c) is determined. From Table 140.4-A, the allowable system input power for the system is:

$$bhp = CFMs \times 0.0013 + A$$

$$= 8{,}000 \times 0.0013 + A = 10.4 + A$$

where A accounts for pressure drop adjustments.

From Table 140.4-B, the pressure drop adjustment for the exhaust flow control device (FC) is 0.5 in. of water, the pressure drop adjustment for fully ducted exhaust systems (DE) is 0.5 in. of water, and the pressure drop adjustment for the fume hoods (FH) is 0.35 in. of water. The pressure drop adjustment for fully ducted exhaust systems is included because laboratory exhaust systems are required under Title 8 to be fully ducted. An additional pressure drop adjustment is allowed to be equal to the design pressure drop of an exhaust filtration device (FD) which for this design is 0.6 in. of water column. The airflow through all these devices is 8,000 cfm, so the additional input power that is allowed is 3.8 bhp, as calculated below.

$$A = [CFM_{FC} \times PD_{FC} + CFM_{DE} \times PD_{DE} + CFM_{FH} \times PD_{FH} + CFM_{FD} \times PD_{FD}] / 4{,}131$$

$$A = [8{,}000 \times 0.5 + 8{,}000 \times 0.5 + 8{,}000 \text{ x } 0.35 + 8{,}000 \text{ x } 0.6] / 4131 = 3.8 \text{ bhp}$$

The total allowed input power is 10.4 bhp plus 3.8 bhp, or 14.2 bhp. Because the design fan power of 13.0 bhp is less than 14.2 bhp, the system does comply using the procedure in section 140.4(c). If the system did not comply, one could evaluate several methods of dropping the design brake horsepower such as: lowering pressure drop though the system by increasing duct size or selecting low pressure drop valves or low pressure drop duct fittings. Alternatively, brake horsepower can be dropped by selecting a fan with higher fan efficiency at the design point.

Example 10-57

Question

A variable-volume supply fan and a variable-volume exhaust fan serving a lab system has a fan system design supply airflow and design exhaust airflow of 12,000 cfm. The system consists of one supply fan operating at an input power of 10.0 bhp served by a nominal 15 hp motor and one exhaust fan operating at an input brake horsepower of 18.0 bhp served by a nominal 25 hp motor, which at design conditions draws 14.4 kW. The exhaust system uses a 0.6 in. pressure drop filtration device and airflow control devices and serves fume hoods.

Does this fan system comply with the fan power requirements in Title 24?

Answer

For laboratory exhaust systems with total flow rates greater than 10,000 cfm, the fan energy of the space conditioning system is regulated by the requirements of Section 140.4(c) and the fan energy of the laboratory exhaust system is regulated by Section 140.9(c)3.

For laboratory exhaust systems with total flow rates greater than 10,000 cfm, the fan energy of the space conditioning system is regulated by the requirements of Section 140.4(c) and does NOT include the design exhaust fan power or the pressure drop adjustment credits for:

– Exhaust systems required by code or accreditation standards to be fully ducted.

– Exhaust airflow control devices.

– Exhaust filters, scrubbers, or other exhaust treatment.

– Exhaust systems serving fume hoods.

– Biosafety cabinets.

The fan power limit in Section 140.4(c) is determined. From Table 140.4-A, the allowable system input power for the system can be calculated for either the design motor horsepower for the fan or the brake horsepower supplied to the fan.

For the motor horsepower approach for a variable-volume system, with maximum design airflow rate, cfm_s, of 12,000 cfm, the nominal horsepower shall be no greater than:

$$hp < cfm_s \times 0.0015 = 12{,}000 \times 0.0015 = 18 \text{ hp}$$

The supply fan had a nominal horsepower of 15 hp. The space conditioning system passes using this approach.

For the fan brake horsepower approach in Section 140.4(c), the allowable system input power for the space conditioning system is:

$$bhp = CFMs \times 0.0013 + A$$

where A accounts for pressure drop adjustments.

In this case, there are no fan pressure adjustments as all the exhaust system and fume hood credits are accounted for in the allowances to Section 140.9(c)3.

Allowable fan brake horsepower = CFMs × 0.0013 = 12,000 x 0.0013 = 15.6 bhp.

The supply fan had a design brake horsepower of 10.0 bhp, and since this design is less than 15.6 bhp, the space conditioning system passes using this approach.

The second half of this calculation is to determine whether the fan power of the laboratory exhaust systems complies with the requirements in Section 140.9(c)3. As given from the design documents, the exhaust fan draws 14.4 kW during design conditions while moving 12,000 cfm of air. The design fan watts per cfm is:

Design Exhaust Fan W/CFM = 14.4 kW x 1,000 W/kW / 12,000 CFM = **1.2 W/CFM**

As described in Section 140.9(c)3B, an exhaust system with an air filtration device will have a maximum allowable exhaust fan power of 0.85 W/CFM. Therefore, the maximum allowable exhaust fan power for this system is **0.85 W/CFM**. This is less than the fan system input power of 1.2 W/CFM. Therefore, the system does not comply with the fan power of Section 140.9(c)3B. The designer could redesign the system for lower design watts per cfm by increasing the height of the stack or alternatively design the system to vary the flow rate from the exhaust stack in response to wind speed in accordance with Section 140.9(c)3C or vary the flow rate from the exhaust stack in response to measured contaminant concentration in the exhaust plenum in accordance with Section 140.9(c)3D.

10.7.3.4 Fume Hood Automatic Sash Closure

Fume hood intense laboratories with VAV HVAC systems and vertical fume hood sashes are prescriptively required to install automatic sash closure systems. This measure saves energy by reducing laboratory exhaust air and makeup air conditioning. For this measure, fume hood intense means the air change rate of the space is driven by the fume hood exhaust, not minimum ventilation requirements. See **Table 10-4** below, which specifies fume hood intensity by linear hood density and minimum ventilation air change rate.

The Energy Standards and best engineering practices dictate several necessary components to this type of system:

1. Zone Presence Sensors:
    - Each sash closure system must have a dedicated zone presence sensor that detects people near the fume hood. Sensor should not be triggered by movement in adjacent zones.
2. Sash should automatically close within 5 minutes of sensing no presence within the fume hood zone.
3. Sash closure system safeguards:
    a. Sash automatic closing should stop when no more than 10 lbs is detected.
    b. Sash should have obstruction sensors that can detect obstructions, including transparent materials such as glassware.
4. Sash closure system must be configurable in a manual open mode.
    1. Manual open mode requires user input (push button, pedal, etc.) to open the sash and will not open automatically from presence detection.
    2. This mode is important for two reasons:
        - Safety: One example is a fume hood that has cross traffic that could cause inadvertent opening in automatic mode. This unnecessarily exposes occupants to dangerous chemicals.
        - Energy Savings: In general, a manual open configuration will save the most energy because the hood is only intentionally opened. Automatic opening mode could cause the sash to open unnecessarily, and fume hoods use more energy when fully open.
    3. Automatic closing is unaffected by manual open mode
    4. The Energy Standards only require the option of manual mode; sashes can still be configured in auto open mode, if preferred.
5. Certification of requirements listed in NA7.17

Fume Hood Intense Laboratories:

The intention of the fume hood intense definition is to only require automatic sash closures for spaces that have ventilation driven by fume hood exhaust, not minimum outdoor air requirements. With regard to this table, *linear feet of fume hoods* refer to the nominal hood width, not the sash opening width. The following table defines all spaces that qualify as fume hood intense:

Table 10-4: Fume Hood Intensive Laboratories

Occupied Minimum Ventilation ACH	≤ 4	> 4 and ≤ 6	> 6 and ≤ 8	> 8 and ≤ 10	> 10 and ≤ 12	> 12 and ≤ 14
Hood Density (linear feet per 10,000 ft^3 of laboratory space)	≥ 6	≥ 8	≥ 10	≥ 12	≥ 14	≥ 16

Example 10-58

Question

A variable-volume laboratory space has two rooms with 10-foot ceilings, both of which have minimum ventilation rates of 6 ACH. One room has two 6-foot fume hoods and a floor area of 1,000 square feet. The second room has three 6-foot fume hoods and a floor area of 2,500 square feet.

Which fume hoods are required to have automatic sash closing controls, according to Section 140.9(c)4?

Answer

For each space, determine the fume hood density (FHD) as calculated below, noting that hoods of any sash type contribute to the nominal hood length.

$$FHD = 10{,}000\ ft^3 \times \text{Total nominal hood length} / (\text{lab space volume})$$

$$FHD_{1000} = 10{,}000\ ft^3 \times 2 \times 6\ \text{feet} / (1{,}000\ ft^2 \times 10\ ft) = 12$$

$$FHD_{2500} = 10{,}000\ ft^3 \times 3 \times 6\ \text{feet} / (2{,}500\ ft^2 \times 10\ ft) = 7.2$$

Using the column for minimum ventilation rate of 6 ACH in reference Table 140.9-B, fume hood densities greater than or equal to 8 are fume hood intensive. Since the 1,000 ft^2 room is fume hood intensive, any hoods with vertical only sashes in that space are covered by the automatic sash closing controls prescriptive requirement. Since the 2,500 ft^2 room is not fume hood intensive, that space is not required to have sash closing controls.

Example 10-59

Question

A building has two laboratory spaces with fume hoods, one with a minimum ventilation rate of 8 ACH and one with a minimum ventilation rate of 12 ACH. Both are designed to have variable-volume HVAC systems even though Section 140.9(c) only requires variable air volume when minimum ACH is 10 or less.

Which fume hoods are required to have automatic sash closing controls, according to Section 140.9(c)4?

Answer

If the spaces are deemed to be fume hood intensive according to Table 140.9-B for the corresponding minimum ACH, they are required to have sash closing controls on any vertical sash hoods. Automatic sash closing controls are required for any vertical-only hoods in fume hood intensive spaces in variable-volume laboratories.

10.7.4 Additions and Alterations

Variable Exhaust and Makeup Airflow

As noted in the previous, section variable volume controls are not required if you are adding zones to an existing constant volume system.

Exhaust System Transfer Air

Additions and alterations must comply with the requirements of this section. For alterations, this means that any additional exhaust and conditioned air resulting from an alteration must comply with this section.

Fan System Power Consumption

All newly installed exhaust systems greater than 10,000 cfm must meet the requirements of this section. Alterations and additions that increase an existing exhaust system's airflow rate over the 10,000 cfm threshold do not need to meet the requirements.

Fume Hood Automatic Sash Closure

Additions and alterations must meet the requirements of this section. The addition of fume hoods to a space resulting in a density above the values of Table 140.9-B requires compliance with this section for those newly installed fume hoods.

10.8 Compressed Air Systems

§120.6(e)

10.8.1 Overview

Section 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 ≥ 25 hp. For alterations, an exception is given for systems containing one or more centrifugal compressors. An exception is also given for systems serving healthcare facilities.

Key terms and definitions:

A. **Online compressors:** all compressors available to serve peak load. Online compressors do not include backup 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 backup compressors.

B. **Backup compressors:** compressors not used to meet peak compressed air flow loads. Backup 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. Backup 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:** 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 the 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 in units of kW/100 acfm. The lower the specific power, the more efficient the compressor is at a given compressed air load.

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 the most efficient operating point. This is displayed in Figure 10-42.

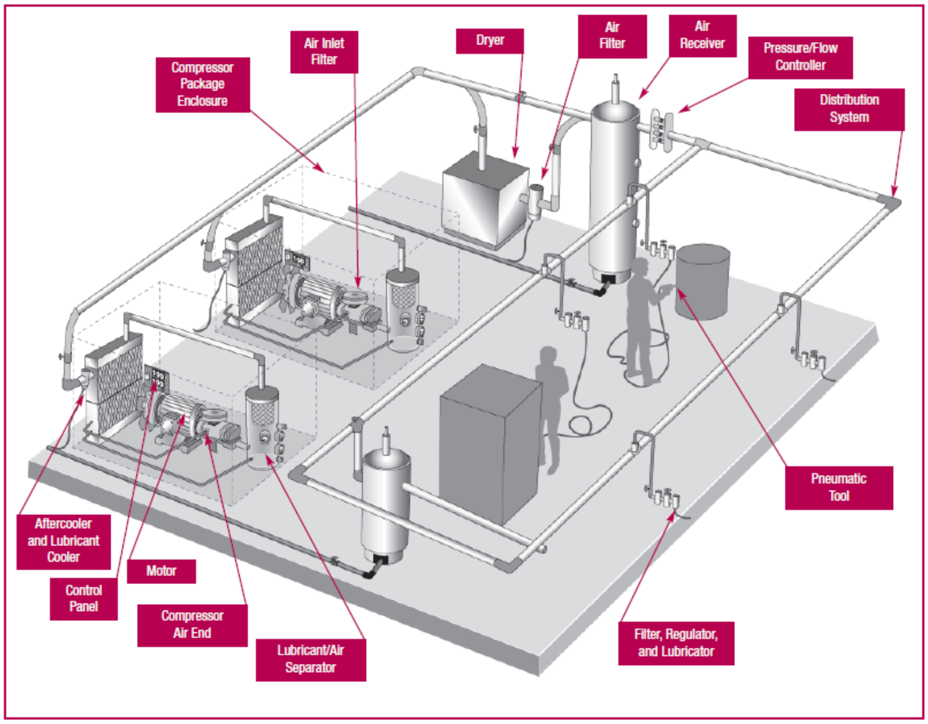
H. **Largest net capacity increment:** the largest increase in capacity when switching between combinations of base compressors that is expected to occur under the compressed air system control scheme. See Example 10-54.

I. **Primary Storage:** tanks or other devices that store compressed air. 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 near an end-use device.

As described in the following paragraphs, there are three 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 the full range of the system.

There are two 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 net capacity increment.
   - Primary storage of at least two gallons per acfm (2 gal/acfm) of the largest trim compressor.

- Effective trim capacity is the range of compressed air flow rates where the specific power (W/acfm) is no greater than 115% of the minimum specific power (Figure 10-42).

Both paths aim to reduce the amount of cycling of fixed-speed compressors by using 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 the 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 the 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 a 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) 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 10-60

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?*

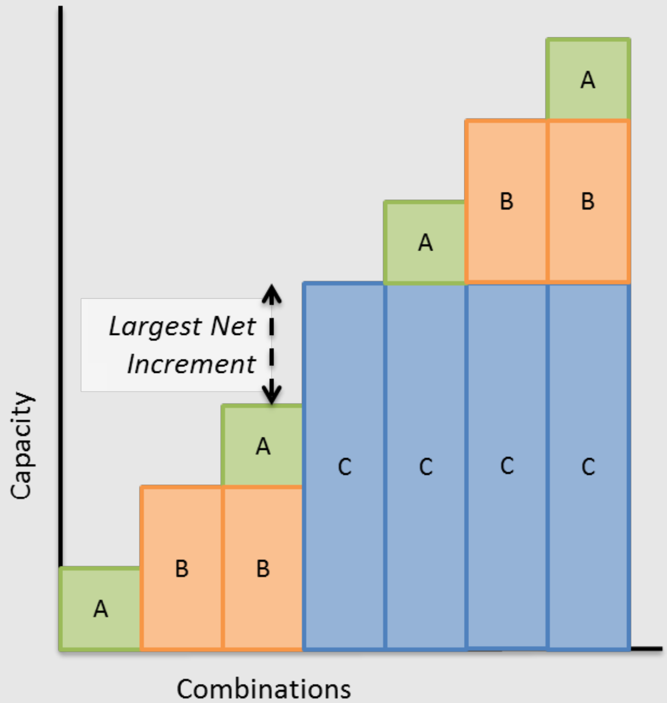
Answer

As shown in the image below, there are eight 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 10-61

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 10-62

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.

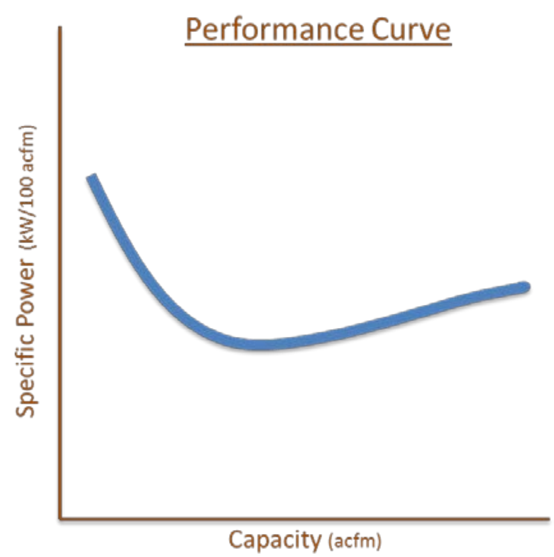
B. Compliance Option 2: Other Compressors as Trim Compressor

§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

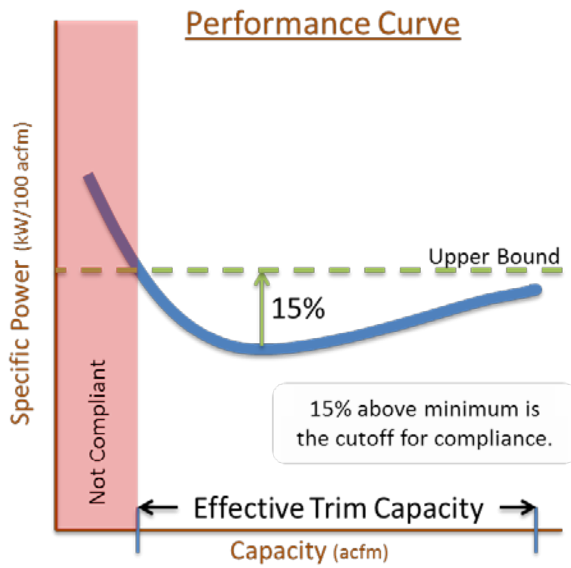


The capacity of the compressor is along the x-axis, while the power is on the y-axis. The curve in Figure 10-41 is a typical shape of a performance curve for a VSD compressor. The lower the specific power, the more energy-efficient the compressor is at that condition.

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, is used to size 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 10-63

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 10-64

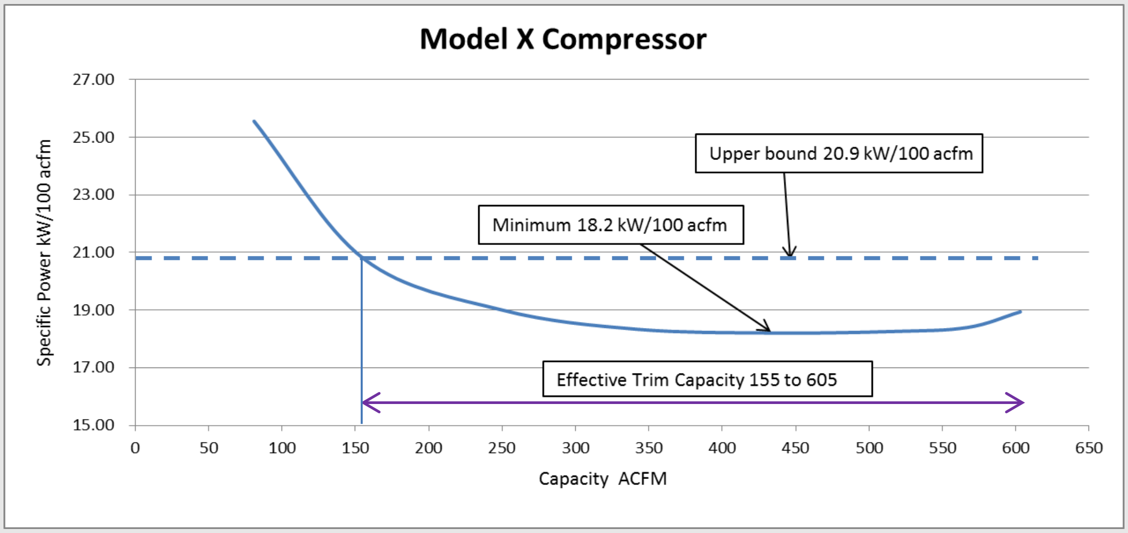
Question

A manufacturer provided the following data for its 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 10-64

Question

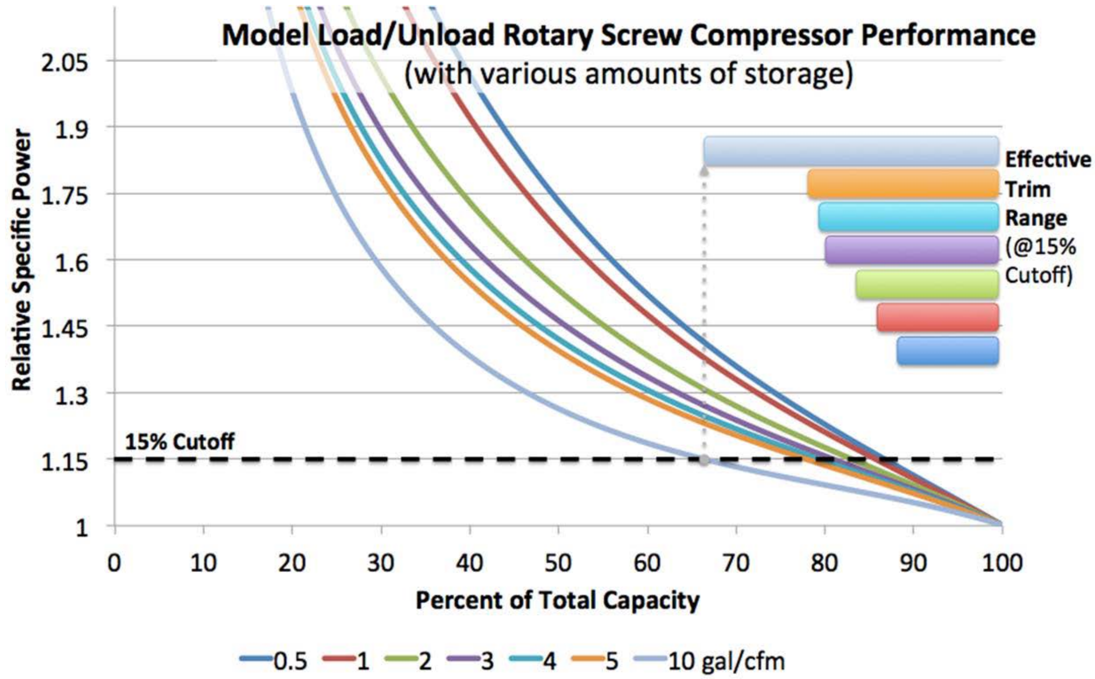
What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

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 airflow rates. Generally, higher levels of storage improve part-load performance. The following data, in Figure 10-43 and for this example, were 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



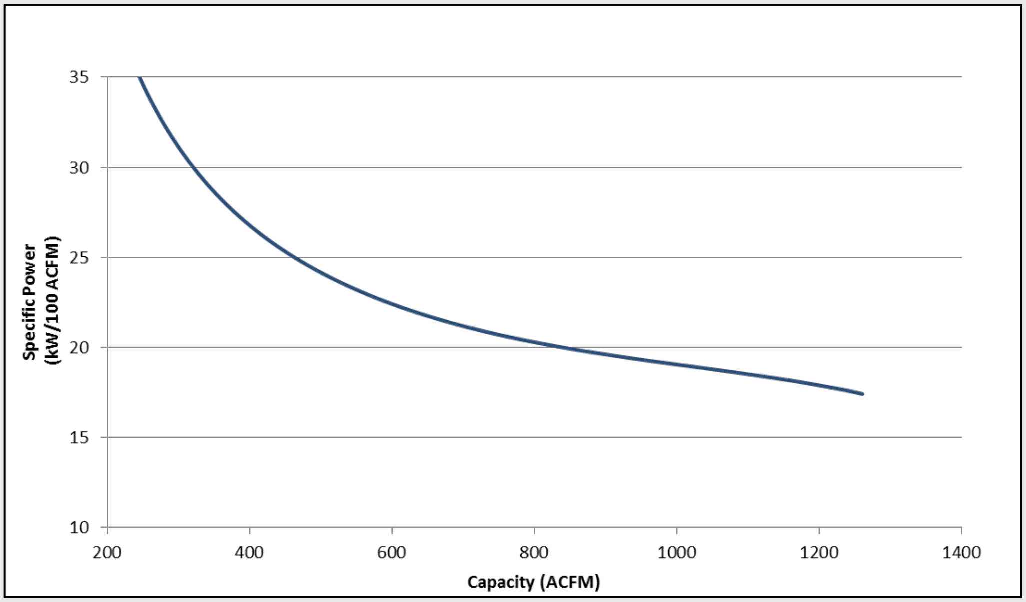
Source: Derived from Fact Sheet 6 – Compressed Air Storage, Improving Compressed Air Storage: a Sourcebook for Industry, U.S. Department of Energy, 2003

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 10-65

Question

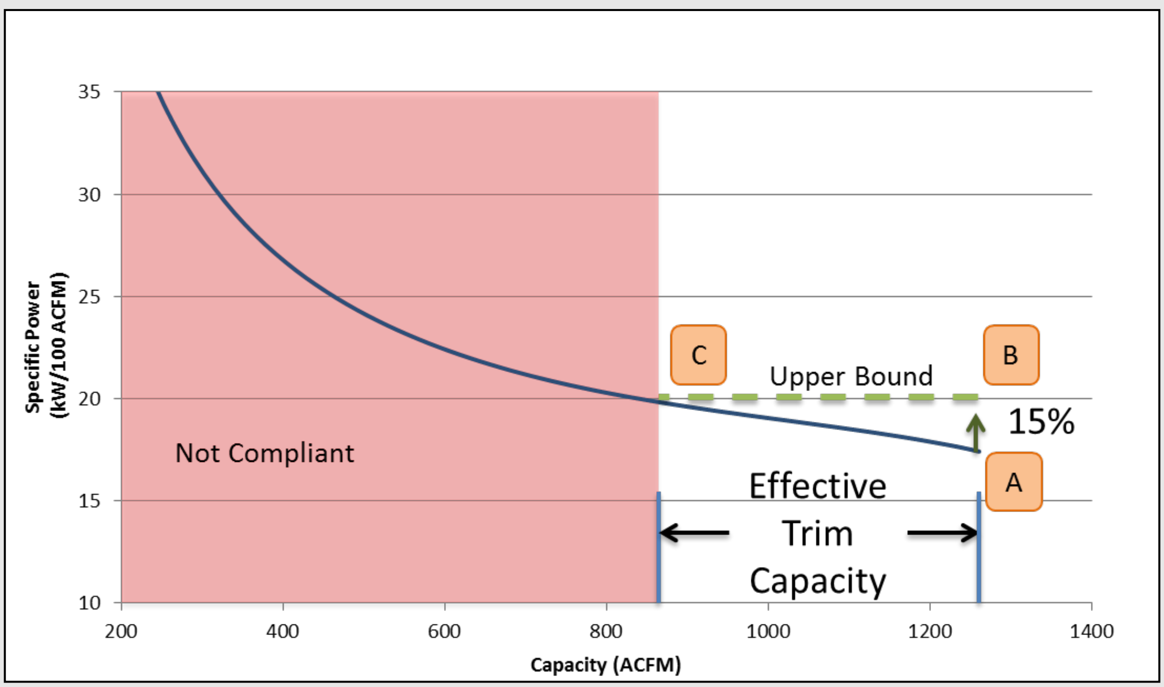
Part-load data were approximated below for a 250-hp load-unload, single-stage, rotary-screw compressor (with a capacity of 1,261 acfm) coupled with 10 gallons/cfm of storage. Would this provide the minimum effective trim capacity for this system to comply with Option 2 using the previous examples?



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 1,261 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 10-66

Question

What is the required minimum primary storage capacity for the trim compressor from the previous example to comply with Option 2?

Answer

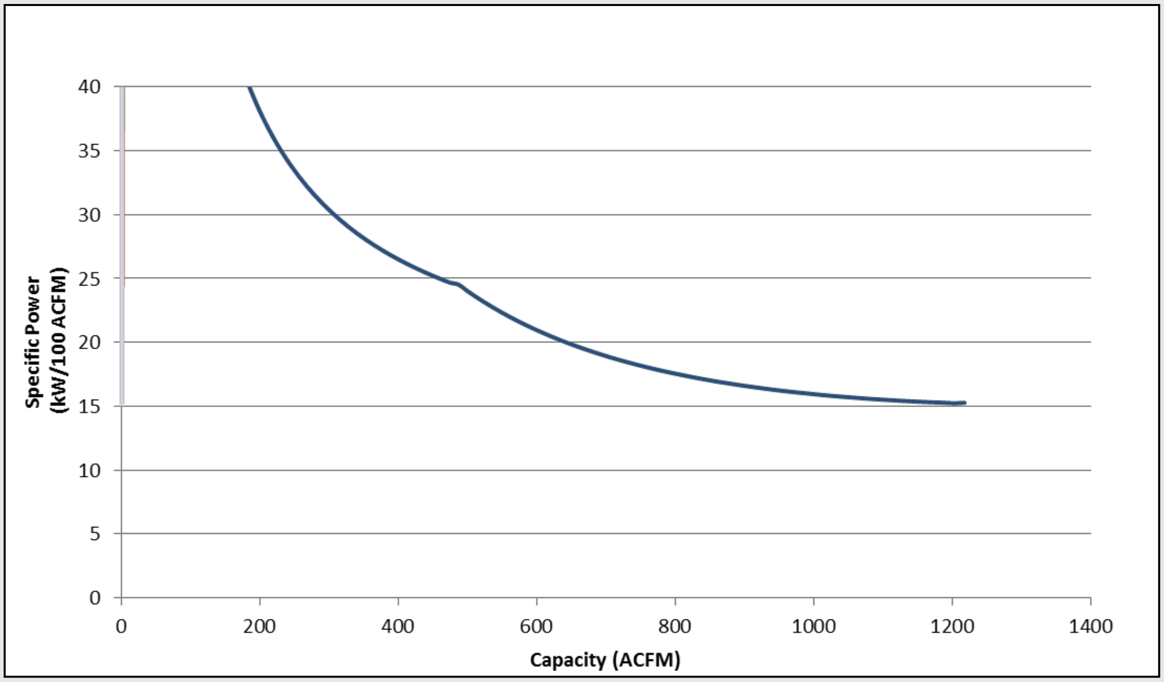
This compressor has a rated capacity of 1,261 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1261 * 2 = 2,522 gallons of storage.

However, a minimum of 10 gallons of storage per acfm was needed for the screw compressor with load/unload controls to have a large enough effective trim capacity. The minimum required primary storage to meet 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 1,261 * 10 = 12,610 gallons.

Example 10-67

Question

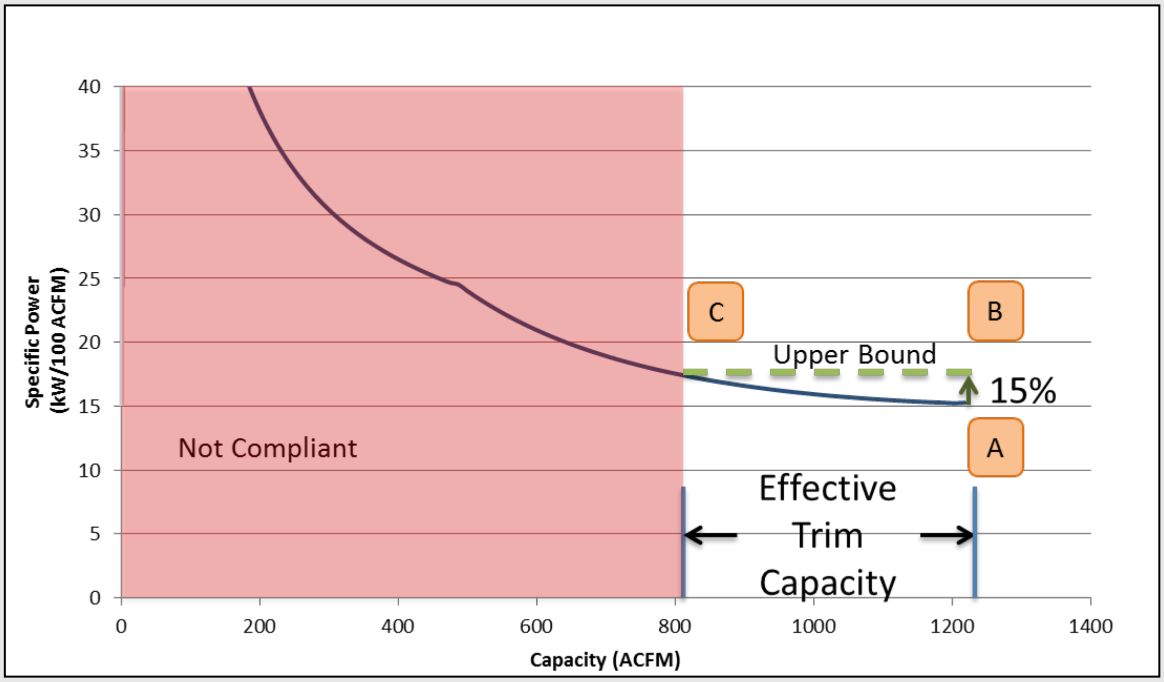
Part-load data were approximated below for a 250-hp variable-capacity compressor. Would this provide the minimum effective trim capacity for this system to comply with Option 2?



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 1,218 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 1,218 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 10-68

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 1,218 acfm, and per §120.6(e)1B it must have 2 gallons of storage per acfm of rated capacity or 1,218 * 2 = 2,236 gallons of storage.

10.8.2.2 **Controls**

§120.6(e)2

This section applies to compressed air systems with more than one on-line compressor and a combined power of ≥100 hp. This section requires an automated control system that 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 that 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 that are being altered and that have a total compressor capacity ≥ 25 hp. These requirements will be triggered by replacing a compressor, adding a compressor, or removing a compressor.

These requirements do 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 apply only when the combined capacity of compressor replacements and/or additions are 50 percent or more of the existing online capacity (not including backup compressor capacity) of the compressed air system. Because the capacity of a compressor is closely correlated to horsepower, for simplicity of compliance and enforcement, the combined horsepower of the alterations or additions or both can be used to determine the total combined capacity.

Example 10-69

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 10-70

In some cases, after a compressed air assessment, it is recognized that the on-line compressor capacity can be downsized. As an example, a plant has a system with a 100 hp on-line compressor and a 100 hp backup compressor. After the assessment, it is identified that the maximum horsepower needed to meet the air demand is only 50 hp. The project scope calls for the installation of one 50 hp compressor and leaving both existing 100 hp compressors as backup compressors.

Question

What requirements of §120.6(e) apply?

Answer

After the retrofit, the on-line compressor horsepower is 50 hp. Because the total on-line compressor horsepower is greater than 25 hp, the requirements of §120.6(e) 1, 2, and 3 must be considered.

The new 50 hp compressor is 50 percent of the existing on-line capacity; therefore, the requirements of §120.6(e)1 apply.

Because 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 staging control apply only if after the alterations/additions, there are more than one online compressor and the total combined horsepower is greater than 100 hp.

The acceptance testing mentioned in §120.6(e)3 tests for system blow-off and short cycling. These issues are affected 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 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 shutoff 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 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 shutoff 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 shutoff devices.

Installed dampers can be interlocked with the gas valve so that the damper closes and inhibits airflow 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 shutoff 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:

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.

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 airflow 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 the firing range of a burner. Maintaining low excess air levels at all firing rates provides significant fuel and cost savings while 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 proportional-integral-derivative (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 are easy because oxygen not consumed during combustion is present in the exhaust gases. Detecting and monitoring carbon monoxide assure 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

Section 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. Elevators in healthcare facilities have an exception to the requirements of this section.

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/ft^2). This power density is determined by taking the total wattage of the elevator lighting and dividing by the floor 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 10-71

Question

An elevator with a length of 6 ft and a width of 8 ft has 9 light-emitting diode (LED) lamps at 3 watts each. Does this comply with §120.6(f).1?

Answer

Yes. (9 lamps) x (3 watts/lamp) = 27 watts. The square footage of the cab is (6 ft) x (8 ft) = 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 more than 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 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 an alteration.

10.11 Escalators and Moving Walkways

10.11.1 Overview

Section 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 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. To comply with the Energy Standards, the escalator or moving walkway must also comply 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/s^2 (1.0 ft/s^2).
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 specific period of time has elapsed since the last passenger detection that is greater than three 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

From 6.1.4.1 of ASME A17.1-2013/CSA B44-13, the maximum speed of escalators cannot be more than 0.5 m/s (100 ft/min), measured along the centerline of the steps in the direction of travel.

From 6.2.4.1 of ASME A17.1-2013/CSA B44-13 the maximum speed of a moving walkway depends on the maximum slope at any point on the treadway as listed below:

1. Max slope of 0-8 degrees: 0.9 m/s (180 ft/min)
2. Max slope above 8 & less than 12 degrees: 0.7 m/s (140 ft/min)

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 operates only 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 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.

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11. Performance Approach

11.1 Overview

This chapter summarizes the building performance approach to be used for compliance. It includes a discussion of the alternative calculation methods, the procedures involved in determining the energy budgets of the Standard Design and Proposed Design Building, and how to plan check performance compliance documentation. 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, lighting and mechanical features are defined by the mandatory and prescriptive requirements of the Building Energy Efficiency Standards (Energy Standards). The standard design features are defined in detail within the Nonresidential Alternative Calculation Method Reference Manual.

The performance method is the most detailed and flexible compliance path. The energy performance of a proposed building 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 Energy Standards rule making process. The Nonresidential ACM Reference Manual is approved by the California Energy Commission (Energy Commission) and includes explanations of the instructions that all compliance software programs must 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 Reference Manual 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 2019 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 square foot 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 known as California Building Energy Code Compliance (CBECC). For compliance purposes, The Act 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, convective, and radiative heat gain and loss through walls, roof/ceilings, doors, floors, windows, and skylights.
- Solar radiant heat gain from windows and skylights.
- 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, etc.).

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 budget 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 are 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 (Annual TDV Energy Use, kBtu/ft ^{2}-yr)				§ 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	10.65	10.67	-0.02	-0.2%
Space Cooling	63.92	63.79	0.13	0.2%
Indoor Fans	17.55	17.47	0.08	0.5%
Heat Rejection	--	--	--	--
Pumps & Misc.	0.64	0.64	--	0.0%
Domestic Hot Water	1.77	1.77	--	0.0%
Indoor Lighting	33.04	33.05	-0.01	0.0%
COMPLIANCE TOTAL	**127.57**	**127.39**	**0.18**	**0.1%**
Receptacle	106.83	106.83	0.0	0.0%
Process	17.40	17.40	0.0	0.0%
Other Ltg	--	--	--	--
Process Motors	--	--	--	--
TOTAL	**251.80**	**251.62**	**0.2**	**0.1%**

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 components 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 Appendix JA2.
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). The shading would be from permanently affixed shading devices, such as overhangs and fins. The shading inputs would consist of depth, distance, and extension relative to the glass.
6. **Horizontal (Skylight) Fenestration**: Each horizontal or skylight glass area, orientation, tilt, U-factor, SHGC, and VT.
7. **Ventilation Air**: Ventilation (introduction of outside air) values in cfm/ft^2.
8. **Fan Power**: Fan power must be included. Fan power should be based on shaft brake horsepower at the equipment’s rated condition (modeled horsepower must be substantiated by information contained in the construction documents).
9. **Cooling and Heating Efficiency**: The efficiency of the equipment included in the proposed design at AHRI conditions.
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 AHRI 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 proposed and standard design TDV energy budgets are separated into a compliance total, which is the basis for building compliance with the performance method, and a total building energy usage, which adds receptacle, process and other non-regulated energy usage.

The compliance total TDV energy can be summarized into three main components:

1. The space conditioning energy use.
2. The indoor lighting energy use.
3. The service water heating energy use.

Non-regulated energy; process, receptacle, other lighting, and process motors; is treated as compliance neutral. The standard design will always match the proposed energy usage for these categories.

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 0.40 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 dwelling units, the proposed lighting power is input into the software. For residential occupancies (hotel guest rooms or high-rise residential spaces), 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, the standard design service water heating system is determined as described in the Nonresidential ACM Reference Manual.
2. For hotels, motels and high-rise residential spaces, the water heating TDV energy budget is calculated using the methods and assumptions documented in the Residential ACM Reference Manual.

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 determined as described 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, 0.40 W/ft^2 is assumed for both the proposed energy use and the energy budget

The default service water heating system is determined as described in the Nonresidential ACM Reference Manual.

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 depend on the building's existing space conditioning system. The user can either input the existing space conditioning system, including actual sizes and types of equipment, or specify that the existing system is unknown. When the existing system is entered, the compliance software applies the proposed building's space conditioning features to create a similar 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. When the system is unknown, the software will automatically create a system in the proposed design to match the standard design.

The default service water heating system is determined as described in the Nonresidential ACM Reference Manual and 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 11-2

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 percent 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-E of the Energy Standards. Note that §141.0(b)2 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)2. A credit is assigned to an alteration (improvement) that exceeds the requirements in §141(b)2 as summarized in Table 141.0-E 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-E 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 or detrimental 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.

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

[1]This method may also be used whenever an alteration is made to existing buildings, whether or not there is an addition to the building at the same time.

based on the alterations meeting the requirements of §141.0(b)2 summarized in Table 141.0-E 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 and §141.0(b)2 for that component. When the performance approach is used, the altered component must meet or exceed the requirements in §141.0(b)1 and §141.0(b)3, or other alteration(s) must be made to the existing building that exceed the requirements of §141.0(b)3 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.

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

Commissioning is included in the design and construction process of newly constructed nonresidential buildings to verify that the building's energy systems and components meet the owner's or owner representative's project requirements.

Commissioning under Part 6 is required for nonresidential buildings of 10,000 square feet and larger, excluding healthcare facilities (which instead follow a procedure specified in Chapter 7 of the California Administrative Code, Title 24, Part 1). Commissioning is also required for nonresidential portions of mixed-use buildings when the total space of these portions is 10,000 square feet or larger.

Newly constructed buildings with less than 10,000 square feet of nonresidential area are only required to perform a design review, though they may elect to perform a more complete commissioning process. Design review is discussed in Section 12.4.

Part 6 does not require retrocommissioning of existing buildings; neither commissioning nor design review are required for building additions or alterations. That said, this guide may still be useful for projects engaging in retrocommissioning.

12.1 Overview

The following key terms and acronyms refer to important concepts in commissioning:

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 outcomes.
- **Commissioning (Cx) -** Building commissioning as required in this code is 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 Team -** The people designated to provide insight and carry out tasks necessary for commissioning. Team members may include the commissioning coordinator, owner, owner's representative, building staff, design professionals, contractors, manufacturer's representatives, and testing specialists.
- **Complex Mechanical Systems** - Mechanical Systems that includes
  1. fan systems each serving multiple thermostatically controlled zones; or
  2. built-up air handler systems (non-unitary or non-packaged HVAC equipment); or
  3. hydronic or steam heating systems; or
  4. hydronic cooling systems. Complex mechanical systems are NOT the following:
     a. unitary or packaged equipment listed in Tables 110.2-A, 110.2-B, 110.2-C, and or 110.2-E that each serves one zone, or
     b. two-pipe, heating only systems serving one or more zones.

  NOTE: Mechanical Systems that are not considered, "Complex" are the following:
     a. unitary or packaged equipment listed in Tales 110.2-A, 110.2-B, 110.2-C or 110.2-E that each serves one zone, or
     b. two-pipe, heating only systems serving one or more zones and is not a Complex Mechanical System
- **Design Reviewer** - The person who reviews the design documents to ensure the design will likely meet the OPR.
- **Independent Third-Party Commissioning Professional (Authority/Agent/Provider/Lead) -** An entity contracted by the owner who is not responsible or affiliated with any other member of the design and construction team. This professional leads, plans, schedules, and coordinates the commissioning team and activities.
- **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 must be included in the scope of the commissioning requirements, excluding covered processes.

12.1.1 Selecting Trained Personnel for Commissioning

It is important to designate one person to lead and manage the commissioning activities. This person is referred to as the commissioning coordinator in this manual. Other terms commonly used for this person are commissioning authority, agent, provider, or lead.

The commissioning coordinator must manage the commissioning process, including the development and implementation of the commissioning tasks and associated documents. Trained personnel must execute the tasks and may include members of the owner’s staff, contractors, design team, and independent commissioning professionals.

The 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. Evaluation of the designated commissioning coordinator and trained personnel includes reviewing:

- Technical knowledge.
- 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 Owner's Project Requirements document (OPR) establishes the owner's goals, requirements and expectations for everything related to energy consumption and operation. The energy-related expectations and requirements of the building must be documented before the design phase of the project. This document includes:

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 OPR documents the functional requirements of the project and expectations of the building use and operation as it relates to systems being commissioned. The OPR 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 detail and complexity of the OPR will vary according to building use, type, and systems.

12.2.2 Compliance

The owner or owner’s representative shows compliance by developing or approving the OPR before the design phase. An OPR template is available in the NRCC-CXR-E document. The OPR should include:

A. ***Energy Efficiency Goals*** **-** Establish energy efficiency goals, which may include:

1. Overall energy efficiency.
2. Lighting system efficiency.
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 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:

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:

1. Assembly type, such as, floors, foundations, walls, ceilings, and roofs.
2. Characteristics that merit special attention.

F. ***Enforcement -*** The building official confirms compliance at *plan review* by either:

1. Receipt of a copy of the OPR (optional).

2. Receipt of a completed NRCC-CXR-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 must be completed at the design phase of the building project, and updated as necessary during the design and construction phases. The BOD covers 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 it is developed early and updated during the design process.

12.3.2 Compliance Method

Compliance requires the completion of the BOD, which should include:

A. HVAC Systems and Controls

1. Provide a description of system –type, location, controls, 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:
   a. Load calculation method/software.
   b. Load calculation assumptions.
   c. Summer outdoor design conditions, °F drybulb and °F wetbulb.
   d. Winter outdoor design conditions, °F drybulb and °F wetbulb.
   e. Indoor design conditions, °F drybulb cooling, %RH cooling; °F drybulb heating, % RH heating.
   f. Applicable codes, guidelines, regulations and other references used.
4. Sequence of Operations – operating schedules and setpoints (may refer to plans or specifications).

B. Describe how the system meets the OPR**Indoor Lighting System and Controls**

1. Provide a 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:
   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 a 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 a 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

The building official confirms compliance at plan review by either:

1. Receipt of a copy of the BOD document (optional).
2. Receipt of a completed NRCC-CXR-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 is 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 must include the Design Review Checklist in the Certificate of Compliance (see §10-103).

3. Construction Documents Design Review. The design review forms list the items that must be checked by the design reviewer during the construction document review. The completed forms must be returned to the owner and design team for review and sign-off. The building owner or owner's representative must include the design review forms in the Certificate of Compliance (see §10-103).

12.4.1 Intent

The intent of design phase review is to improve compliance with the Energy Code, 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:

   a. Project coordination, including design reviewer involvement.

   b. Project scheduling, including design review.

   c. Project scope.

   d. OPR and BOD.

   e. Design Elements and assumptions.

   f. HVAC system selection.

   g. Construction documents design review checklists to be completed.

   h. Energy Efficiency Measures.

   i. Complete and Sign Certificate of Compliance – Cx Design Review Kickoff NRCC-CXR-E.

B. Construction Document Review

1. The design team provides the design reviewer with a set of plans and specifications late in design as agreed upon in design review kickoff, typically around 90 percent construction document completion.
2. The design reviewer provides a review of the commissioning documents - NRCC-CXR-E:
3. Completed form is 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 shown by completion of the NRCC-CXR-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. 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 Code requires specific functional test compliance documents (Certificate of Acceptance) to be included in the construction documents. These functional test compliance documents are a part of the commissioning requirements.

12.5.3 Compliance

Compliance is achieved by including commissioning requirements in the project plans and specifications. The commissioning specifications should include:

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, subcontractors, vendors, and construction manager.
2. Commissioning coordinator.
3. Owner and 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, tests, reviews and approves functional test compliance documents, directs and executes tests, records test results, and approves completed tests. These roles may vary by system or assembly.

D. Meeting requirements.

E. Commissioning schedule management procedures.

F. Issues 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.
6. Example compliance documents (recommended).

I. Submittal review and approval process.

J. Content, authority, and approval process of the commissioning plan.

K. Commissioning documents 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

The building official can confirm 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 must be completed to document how the project will be commissioned and must be started during the design phase of the building project. The commissioning plan must include:

A. General project information.

B. Commissioning goals.

C. Systems to be commissioned.

D. Plans to test systems and components:

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 is performed.
5. Criteria for acceptable performance.
6. Commissioning team information including roles.
7. Commissioning activities, schedules, and responsibilities. Plans for the completion of commissioning requirements listed in §120.8(g) through §120.8(i).

12.6.1 Intent

The commissioning (Cx) plan establishes the 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

Compliance is shown by completing the Cx Plan. The following gives guidance for developing the Cx plan:

A. ***General project information* -** Provide project identifying information, including:

1. Project name, owner, and location.
2. Building type and area.
3. Project schedule.
4. Contact information of individual or company providing the commissioning services.

B. ***Commissioning Goals* –** Record the commissioning goals, including:

1. Code requirements.
2. OPR and BOD requirements.
3. Requirements for commissioning activities 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 to be commissioned
   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* must *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 criteria for acceptable performance of each system to be tested.

D. ***Commissioning Team Information* -** Provide a contact list for all Commissioning team members, including:

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 commissioning 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 work.
3. List the required Cx deliverables, reports, compliance documents, and verifications expected at each stage of commissioning.
4. Include the confirmation process for the O&M manual, systems manual, and the facility operator and maintenance staff training.

12.6.4 Enforcement

The building official can confirm compliance at plan review by receipt of a copy of the Cx plan.

12.7 Functional Performance Testing

§120.8(g)

Functional performance tests must show 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 must include information addressing each of the building components tested, the testing methods used, and any readings and adjustments made.

12.7.1 Intent

Functional performance tests ensure 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 systems to be functionally tested and 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 on systems described in the BOD. Not all of the systems described in the BOD will have acceptance testing requirements per the Energy Code. Some acceptance tests must be performed by a certified acceptance test technician, see Chapter 13 for more details.

12.7.3 Compliance

Compliance is shown by developing and implementing test procedures for each piece of commissioned equipment and interface between equipment and systems according to the building-specific Cx plan. The tests should verify the 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 contribute toward compliance with §120.8(g), but do not cover all necessary testing.

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. Instruments - List of the instruments and tools needed to complete the test.
6. Reference - In each procedure, 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

The building official confirms 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 Documents and Training

§120.8(h), Documentation and Training.

A systems manual and systems operations training are required.

§120.8(h)1, Systems Manual.

The operation of the building and its systems must be included in the systems manual and delivered to the building owner or representative and facilities operator. The systems manual must include:

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 site events log.
4. Description of major systems.
5. Site equipment inventory and maintenance notes.

A copy of all special inspection required by the enforcing agency or the Energy Code.

12.8.1 Intent

The systems manual provides information needed to understand, operate, and maintain the equipment and systems. It informs those not involved in the design and construction of the building systems. This manual 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 shown by providing the systems manual. The systems manual includes:

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. OPR
        ii. BOD
    b. Project undocumented events
    c. Record drawings and 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* and ***maintenance, including general site operating procedures, basic trouble shooting, recommended maintenance requirements site events log***

1. Basic operation
   a. Equipment operation instructions
   b. Interfaces and interlocks
   c. Initial maintenance provided by contactor
2. General site operating procedures
   a. Instructions for changes in major system operating schedules
   b. Instructions for changes in major system holiday and 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 is 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 with specific pieces of equipment or systems over time. An issues log is a formal and record of problems or concerns discovered within a facility and the recommended solution to those problems. 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:

1. Issue 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

The building official can confirm 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 maintenance staff for each equipment type or system must be documented in the commissioning report. Training materials must include:

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 demonstrate 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

The written training program includes:

- 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 of 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 works 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 service procedures and techniques (electrical current, pressure, 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

The building official can confirm compliance during field inspection by:

1. Receipt of a copy of the written training program and completed attendance forms.
2. 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 must be completed and provided to the owner or representative.

12.10.1 Intent

The commissioning report documents commissioning and test results. The report includes confirmation from the commissioning coordinator that commissioned systems meet the conditions of the OPR, BOD, and contracts.

12.10.2 Compliance Method

The commissioning report includes:

A. Executive summary of process and results of commissioning – 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 completed and scheduled

E. Attach commissioning process documents

1. Commissioning Plan
2. OPR
3. BOD
4. Executed installation checklists
5. Executed functional performance test compliance documents
6. Recommendations for end-of-warranty review activities

12.10.3 Enforcement

The building official can confirm compliance during *field inspection* by receipt of a copy of the commissioning report.

Example 12-1

Question

I am constructing a 100,000 ft2 mixed occupancy building. 10 percent of the conditioned floor area is for commercial/retail use, and the remaining spaces are residential. Since the building is primarily residential, does it need to be commissioned?

Answer

Yes. Because the nonresidential portion of the building is 10,000 square feet or greater, it will need to be commissioned. However, the commissioning requirements of Section 120.8 only apply to the nonresidential portions of the building.

Example 12-2

Question

I am constructing a mixed occupancy building which has both residential and nonresidential spaces. The water heating system serves both the residential and nonresidential spaces of the building. Do I need to include the water heating system in the building commissioning?

Answer

Yes. Since the water heating system is serving both residential and nonresidential spaces, the water heating system must be included in commissioning.

Example 12-3

Question

Is commissioning required for nonresidential buildings which have less than 10,000 ft2 of conditioned space?

Answer

No, although the design review portion of commissioning is required.

Example 12-4

Question

Do the commissioning requirements apply to tenant improvements (first time buildouts) for multi-tenant buildings such as a strip mall?

Answer

Possibly, it depends on the local enforcement agency's policy. Commissioning may be completed for the entire building prior to tenant improvements, or for each individual tenant improvement. Check with your local enforcement agency for their commissioning policies for multi-tenant buildings.

Example 12-5

Question

Do the commissioning requirements apply to unconditioned nonresidential buildings?

Answer

No, the scope of the Energy Standards does not include commissioning (Section 120.8) for unconditioned nonresidential buildings in Section 100.0(e)2C.

Example 12-6

Question

Is third party design review required for buildings with complex systems that serve less than 10,000 square feet?

Answer

No, the licensed professional engineer who completes and signs the Design Review Kickoff Certificate(s) of Compliance, and the Construction Document Design Review Checklist Certificate(s) of Compliance does not need to be a third party (see Section 10-103(a)1).

Example 12-7

Question

Are covered processes required to be included in commissioning?

Answer

No, covered processes are excluded from the commissioning requirements (see Section 120.8). Covered processes can be included in the Basis of Design document (see Section 120.8(c)), however it is not required.

Example 12-8

Question

Can the person responsible for commissioning also perform acceptance testing?

Answer

It depends. A commissioning professional can perform acceptance testing provided that they have also gained certification as an Acceptance Test Technician (or ATT). A commissioning professional that is not an ATT cannot perform acceptance tests that are reserved to ATTs.

Table of Contents

13. Acceptance Test Requirements

13.1 Overview

13.1.1 What Is Acceptance Testing

From simple thermostats and manual light switches to complex building automation systems, controls are integral to building health, safety, comfort, and energy efficiency.

Acceptance test requirements specify targeted inspections and functional performance tests that demonstrate that the building components, equipment, systems, and interfaces conform to the *2019 Building Energy Efficiency Standards* (or *Energy Standards*, inclusive of Reference Nonresidential Appendix NA7), as specified on applicable construction documents (plans).

This helps ensure that the building achieves the energy savings potential specified in its design and protects installing technicians by providing demonstrable proof that the system functioned as required by code when it was installed.

13.1.2 Roles and Responsibilities

13.1.2.1 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 (ATT).

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When is a Certified Acceptance Test Technician Required?

- Given that the industry certification threshold for certified lighting ATTs has been satisfied, a certified ATT is required to perform the lighting acceptance tests 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 mechanical acceptance tests referenced by §120.5 and sign the Certificate(s) of Acceptance.
- Other acceptance tests, such as those covering process systems and equipment found in §120.6, do not require that the field technician be a certified ATT.
- Acceptance tests covering the scope of Nonresidential Appendix NA2 are commonly performed by HERS Raters but can be performed by ATT's at the discretion of the local jurisdiction. NA2 covers single-zone systems less than 5,000 square feet (sf.), infiltration (blower door) testing of high rise residential dwelling units and verifying flow rates of high-rise dwelling ventilation systems.

More information on becoming certified and other information on acceptance test technicians can be found at http://www.energy.ca.gov/title24/attcp/.

13.1.2.2 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 documented by the certificate of acceptance. In assuming responsibility for the work as a whole, the responsible person assumes responsibility for the acceptance testing work performed by his or her field technician, agent or employee.

The responsible person may perform the acceptance testing if qualified to do so 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. (Aside from being licensed, a responsible person that conducts his or her own testing will also need to be a certified ATT if he or she is performing an acceptance test that requires a certified ATT.)

13.1.2.3 Acceptance Test Technician

An acceptance test technician (ATT) is a certification standard for technicians that install lighting controls and mechanical system in newly constructed or existing nonresidential buildings. The certification is restricted to applicants with a minimum of three years of professional experience and expertise in either lighting or mechanical controls. Qualifying experience for certification is provided by verifiable employment as an electrical contractor, certified general electrician, licensed architect, professional engineer, controls installation and startup contractor, HVAC installer, mechanical contractor, Testing and Balancing certified technician, or certified commissioning professional with verifiable experience in lighting controls or HVAC installations. ATTs are provided classroom and laboratory training to perform acceptance testing. ATTs must pass classroom and laboratory testing to gain their certification. The ATT is required to work with the Energy Commission approved acceptance test technician certification provider to track and verify quality assurance of his or her acceptance test performance.

13.1.2.4 Third-Party Hers Rater or Third-Party Quality Control Program Installer

Most acceptance tests are specifically required to be conducted by an ATT. However, the acceptance tests in NA2 (for single-zone systems less than 5,000 sq. ft., including those serving high-rise multifamily dwellings) are commonly conducted a certified, third-party HERS Rater, given the system designs (and therefore associated duct leakage and flow rate tests) are highly similar to low-rise residential systems. The local enforcement agency can, at its discretion, allow an ATT to conduct these tests.

13.1.2.5 Commissioning Provider

A commissioning provider (formerly called a commissioning agent) is not defined by the Energy Standards but is an industry term for a person who may be contracted by the owner to verify functional performance testing is conducted to ensure proper performance at building turnover. Commissioning during construction may or may not be required by §120.8; in general, commissioning is required for newly constructed nonresidential buildings with more than 10,000 square feet in floor area, while smaller buildings are required to complete just the design review phase of commissioning. Section120.8 does not apply to healthcare facilities, which have parallel requirements in Chapter 7 of the California Administrative Code (Title 24, Part 1), and it does not apply to additions or alterations of existing buildings.

Although system commissioning and acceptance testing are related, not all projects that require acceptance testing will also require commissioning. If a commissioning agent is part of the project team, he or she will often be present for functional performance testing of major building systems to verify they were completed and passed on behalf of the building owner. (Commissioning providers may instead perform acceptance testing themselves, and if this is the case, they will also need to be a certified ATT if they are performing an acceptance test that requires a certified ATT.)

13.1.2.6 Enforcement Agency

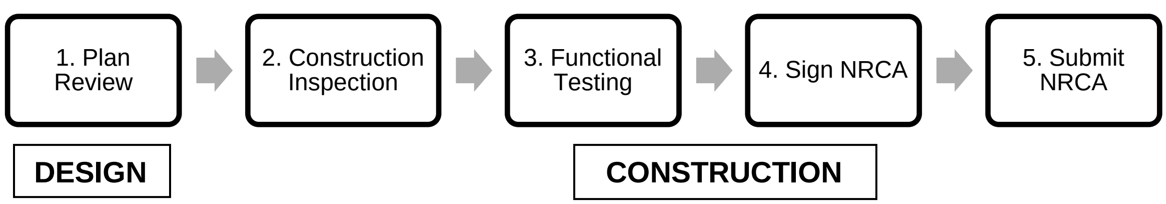
The certificate of acceptance must be submitted to the enforcement agency, typically at time of inspection, to receive the final certificate of occupancy. Enforcement agencies shall not release a *final* certificate of occupancy unless the submitted certificate of acceptance demonstrates that the specified systems and equipment have been shown to be perform 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. For details on how to do this most efficiently, see the “Submit NRCA” step below.

13.1.3 Acceptance Testing Process

The acceptance requirements require five major checkpoints to be conducted. They are: shown in Figure 13-1 below.

Figure 13-1: Steps in the Acceptance Testing Process



13.1.3.1 Plan Review

The responsible person must review the plans and specifications to ensure that they conform to the acceptance requirements, typically done before signing a nonresidential certificate of compliance (NRCC). Usually the responsible person for design phase review is the designer, commissioning agent, or test technician.

In reviewing the plans, the responsible person notes the appropriate certificate of compliance then lists all the respective acceptance tests that will be performed and the parties responsible for performing the tests. An exhaustive list is required so that when the acceptance tests are discussed during bid or scope negotiations, all parties are aware of the scope of acceptance testing on the project.

13.1.3.2 Construction Inspection

A visual inspection during construction assures that installed products or equipment are present and capable of complying with the Energy Standards. The construction inspection also assures proper installation of equipment and current calibration.

The responsible person (or, in some cases, the field technician) must perform a construction inspection before testing. Sections 13.4-13.7 of this chapter include construction inspection checklists for each acceptance test.

Reviewing the acceptance requirements in the checklist with the contractor before installation may help the process run smoothly. 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 Energy Standards before equipment installation.

13.1.3.3 Functional Testing

A field technician assumes responsibility for performing the required acceptance requirement 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.

Sections 13.4-13.7 of this chapter include functional testing checklists for each acceptance test.

13.1.3.4 Sign Nonresidential Certificate of Acceptance (NRCA)

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.

As noted previously, the responsible person may also perform the field technician's responsibilities and, if so, must sign the field technician declaration on the certificate of acceptance. If the acceptance test requires a certified ATT, the responsible person must be a certified ATT to perform the acceptance test.

If the project includes the need for duct leakage testing, then the HERS Rater verification must be performed and submitted, or “registered,” with the HERS Provider using the compliance documentation (NRCV). This verification is performed in addition to the acceptance test performed by the technician. However, it is also allowed for a certified Mechanical-ATT to perform the acceptance test and avoid the need for HERS Rater verification.

13.1.3.5 Submit NRCA

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 the ATTCP will require that certified ATTs electronically submit all completed certificates of acceptance as a condition of maintaining their certification status.

Building inspectors will review the NRCA documents during inspection, and can verify certified ATT status by noting whether the NRCA document was completed electronically through an ATTCP. Lighting controls NRCA documents should not be accepted if completed by hand or electronically outside the ATTCP online interface. Moreover, there is a place for ATTs to enter their certification numbers on the signature block for every NRCA document they sign. ATTCPs list their ATTs (names and certification numbers) on their websites. Depending on which ATTCP logo is shown on the submitted lighting controls NRCA document, the inspector could look up an ATT certification number, if necessary.

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Considerations When Coordinating Acceptance Tests

- When planning construction, consider costs of testing within subcontractor bids, scheduling time within the overall construction schedule and coordination with commissioning if required on the project.
- Purchasing sensors and equipment with calibration certificates often reduces the amount of time required for site calibration, which can lower overall costs.
- In some cases, performing tests immediately after installation or during set-up and commissioning is most economical, though this requires the complete installation of any associated systems and equipment necessary for proper system operation.

13.2 Certificate of Acceptance

Certificate of acceptance (NRCA) forms consist of worksheets to document the results of construction inspections and functional testing, as well as a signatory page. Table 13-1 shows the NRCA documents and related references.

Naming Convention. The name of the compliance document can give you clues about the documents use. The NRCA prefix indicates a nonresidential certificate of acceptance. The next set of letters specifies the building component; for example, “LTI” indicates indoor lighting. The suffix will tell you whether a certified acceptance test technician “-A” or field technician “-F” is appropriate to perform the functional performance test. Remember that an ATT can act as a field technician, but a current ATT certification is required for someone to sign as an ATT.

Table 13-1: Acceptance Documents

Component	Certificate of Acceptance Test Form Name	Energy Standards Reference	Reference Nonresidential Appendix NA7	Required Certification
Envelope	NRCA-ENV-02-F Fenestration Acceptance	§10-111 & §110.6(a)5	NA7.4.1	NONE
	NRCA-ENV-02-F Window Films	§10-111 & §110.6(a)5	NA7.4.2	Made available to ATT
	NRCA-ENV-02-F Dynamic Glazing	§10-111 & §110.6(a)5	NA7.4.3	Made available to ATT
	NRCA-ENV-03-F Clerestories for PAF	§140.3(d)1	NA7.4.4	Made available to ATT
	NRCA-ENV-03-F Interior and exterior horizontal slats for PAF	§140.3(d)2	NA7.4.5	Made available to ATT
	NRCA-ENV-03-F Interior and exterior lighting shelves for PAF	§140.3(d)3	NA7.4.6	Made available to ATT
Mechanical	NRCA-MCH-02-A Outdoor Air Acceptance	§120.1(b)2 & §120.5(a)1	NA7.5.1.1 NA7.5.1.2	ATT not yet required
	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	ATT not yet required
	NRCA-MCH-04-A Air Distribution Systems Acceptance	§120.5(a)3, §140.4(l)	NA7.5.3	ATT not yet required
	NRCA-MCH-05-A Air Economizer Controls Acceptance	§120.5(a)4 & §140.4(e)	NA7.5.4	ATT not yet required
	NRCA-MCH-06-A Demand Control Ventilation Systems Acceptance	§120.1(c)4 & §120.5(a)5	NA7.5.5	ATT not yet required
	NRCA-MCH-07-A Supply Fan VFD Acceptance	§120.5(a)6 & §140.4(c)2B & §140.4(c)2C	NA7.5.6	ATT not yet required
	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	ATT not yet required
	NRCA-MCH-09-A Supply Water Temperature Reset Controls Acceptance	§120.5(a)9 & §140.4(k)4	NA7.5.8	ATT not yet required
	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	ATT not yet required

Table 13-1: Acceptance Documents

Component	Certificate of Acceptance Test Form Name	Energy Standards Reference	Reference Nonresidential Appendix NA7	Required Certification
	NRCA-MCH-11-A Automatic Demand Shed Control Acceptance	§110.12(b), §120.5(a)10	NA7.5.10	ATT not yet required
	NRCA-MCH-12-A Fault Detection & Diagnostics (FDD) for Packaged Direct Expansion Units	§120.2(i), §120.5(a)11	NA7.5.11	ATT not yet required
	NRCA-MCH-13-A Automatic Fault Detection & Diagnostics (FDD) for Air Handling Units & Zone Terminal Units Acceptance	§120.5(a)12	NA7.5.12	ATT not yet required
	NRCA-MCH-14-A Distributed Energy Storage DX AC Systems Acceptance	§120.5(a)13	NA7.5.13	ATT not yet required
	NRCA-MCH-15-A Thermal Energy Storage (TES) System Acceptance	§120.5(a)14	NA7.5.14	ATT not yet required
	NRCA-MCH-16-A Supply Air Temperature Reset Controls Acceptance	§140.4(f), §120.5(a)15	NA7.5.15	ATT not yet required
	NRCA-MCH-17-A Condenser Water Supply Temperature Reset Controls Acceptance	This test is required if this control strategy is implemented. §120.5(a)16	NA7.5.16	ATT not yet required
	NRCA-MCH-18-A Energy Management Control Systems	§110.2(e), §120.2(h), §120.5(a)17, §130.4(b), §130.5(f), §150.0(k)	NA7.7.2	ATT not yet required
	NRCA-MCH-19-A Occupancy Standby	§120.2(e)3 §120.5(a)18	NA7.5.17	ATT not yet required
Indoor Lighting	NRCA-LTI-02-A Lighting Controls	§110.9(b), §130.1(c)	NA7.6.2	ATT
	NRCA-LTI-03-A Automatic Daylighting Controls	§130.1(d)	NA7.6.1	ATT
	NRCA-LTI-04-A Demand Responsive Lighting Controls	§110.12(c)	NA7.6.3	ATT
	NRCA-LTI-05-A Institutional Tuning Power Adjustment Factor	§140.6(a)2J	NA7.7.4.2	ATT
Outdoor Lighting	NRCA-LTO-02-A Outdoor Lighting Acceptance Tests	§110.9(b), §130.2(a & c)	NA7.8	ATT
	NRCA-PRC-01-F Compressed Air System Acceptance	§120.6(e)	NA7.13	NONE

Table 13-1: Acceptance Documents

Component	Certificate of Acceptance Test Form Name	Energy Standards Reference	Reference Nonresidential Appendix NA7	Required Certification
Covered Process, Systems, and Equipment	NRCA-PRC-02-F Commercial Kitchen Exhaust	§140.9(b)	NA7.11	NONE
	NRCA-PRC-03-F Parking Garage Exhaust	§120.6(c)	NA7.12	NONE
	NRCA-PRC-04-F Refrigerated Warehouse – Evaporator Fan Motor Controls Acceptance	§120.6(a)3 §120.6(a)7	NA7.10.2	NONE
	NRCA-PRC-05-F Refrigerated Warehouse – Evaporative Condenser Controls Acceptance	§120.6(a)4 §120.6(a)7	NA7.10.3.1	NONE
	NRCA-PRC-06-F Refrigerated Warehouse – Air-Cooled Condenser Controls Acceptance	§120.6(a)4 §120.6(a)7	NA7.10.3.2	NONE
	NRCA-PRC-07-F Refrigerated Warehouse – Compressor Variable Speed Acceptance	§120.6(a)5 §120.6(a)7	NA7.10.4	NONE
	NRCA-PRC-08-F Refrigerated Warehouse – Electric Resistance Underslab Heating System Acceptance	§120.6(a)2 §120.6(a)7	NA7.10.1	NONE
	NRCA-PRC-12-F Elevator Lighting and Ventilation Controls	§120.6(f)5	NA7.14	NONE
	NRCA-PRC-13-F Escalator and Moving Walkways Speed Control	§120.6(g)2	NA7.15	NONE
	NRCA-PRC-14-F Laboratory exhaust ventilation system acceptance test	§140.9(c)	NA7.16	NONE
	NRCA-PRC-15-F Fume hood automatic sash closure system acceptance test	§140.4(c)4	NA7.17	NONE
	NRCA-PRC-16-F Adiabatic Condenser fan motor variable speed control	§120.6(a)4C §120.6(a)7	NA7.10.3.3	NONE

13.3 Detailed Instructions for Conducting Acceptance Tests

Separate files providing detailed instructions on how to conduct acceptance tests are located at the Energy Commission website: https://www.energy.ca.gov/title24/2019standards/

13.4 Changes to Acceptance Test Requirements for the 2019 Energy Standards

13.4.1 Building Envelope §110.6:

- No changes

13.4.2 Mechanical Systems and Equipment §120.5:

- New Acceptance Test:
  - Occupied Standby (NRCA-MCH-19 -A)
- Major Modifications:
  - Demand-responsive controls now require documentation confirming they either are a certified OpenADR VEN or are certified to the Energy Commission as capable of communicating with an OpenADR VEN.
  - Automatic Fault Detection and Diagnostics (FDD) for air handling units and zone terminal units (NRCA-MCH-13-A)
    - Separation of Air Handling Unit functional test into functional tests for economizers and valves.
    - Significant modifications to functional test for air handling unit economizers.
    - New functional test added for air handling unit valves.
- Minor Clarifications
  - Air distribution systems (NRCA-MCH-04-E), allowed alternative to HERS Rater verification with certified ATT.

13.4.3 Lighting Controls

- New Acceptance Tests: None.
- Major Modifications:
  - Demand-responsive controls now require documentation confirming they either are a certified OpenADR VEN or are certified to the Energy Commission as capable of communicating with an OpenADR VEN.
  - The functional testing for outdoor lighting controls (NRCA-LTO-02-A) has been simplified.
- Minor clarifications:
  - The role of the lighting controls ATT is clarified for the power adjustment factor allowances as a document reviewer only.
  - There are minor revisions to the lighting controls (NRCA-LTI-02-A) automatic time switch lighting controls functional testing procedures.

13.4.4 Covered Process Systems and Equipment

- New Acceptance Tests:
  - Laboratory Exhaust Ventilation System Acceptance Test (NRCA-PRC-14-F)
  - Fume Hood Automatic Sash Closure System Acceptance Test (NRCA-PRC-15-F)
  - Adiabatic Condensers and Condenser Fan Motor Variable Speed Control (NRCA-PRC-16-F).
- Major Modifications: None.
- Minor Clarifications: None.

13.5 Acceptance Test Technician Certification Provider (ATTCP)

13.5.1 Provider Qualifications

The requirements to become either a nonresidential lighting controls or mechanical Acceptance Test Technician Certification Provider (ATTCP) are very similar. Therefore, this section will address both the lighting controls and mechanical ATTCP application requirements together, calling out specific differences when warranted. The prospective ATTCP must submit a written application to the Energy Commission that documents the following major elements:

13.5.1.1 Organizational Structure

ATTCPs shall provide written explanations of the organization type, bylaws, 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).

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 ATTs.

The Energy Commission has approved several ATTCP applicants and all applications included articles of incorporation, bylaws, and trust agreements. One approved application included the Section 501(c) status (with the corresponding employer identification number) of the organization. A copy of the ethics policy for the ATTCP 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.

13.5.1.2 Certification of ATEs

The ATTCPs shall provide written explanations of their certification and oversight of acceptance test employers (ATEs) that employ ATTs. This explanation shall document how the ATTCP ensures that the ATEs are providing quality control and appropriate supervision and support for their ATTs (§ 10-103.1(c)2 and §10-103.2(c)2).

The ATTCP shall recertify all ATEs before implementing each adopted update to the Energy Standards as these updates affect the acceptance test requirements. Recertification requirements and procedures shall only apply to those specific elements that are new or modified in future updates to Energy Standards.

ATEs must have an understanding of what tasks the ATT is responsible to complete. Moreover, the ATE must manage and provide support to the ATTs 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. The requirement for the ATEs to be retrained for each new code cycle is intended to maintain the current educational level of the ATEs. The quality control that the ATEs provide to the ATTs is different from the quality control that the ATTCPs provide.

The Energy Commission recognizes that there are many roads to compliance regarding 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 it 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. Furthermore, 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.

13.5.1.3 Training and Certification Procedures

These requirements are the most significant of the ATTCP regulations. They encapsulate all the required training, testing, certification, and oversight for the ATTs and ATEs 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.

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):

A. Training Scope

The ATT training must include both classroom and laboratory training. In essence, the ATT 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.

B. ATT Training

i. **Curricula**.

ATTCP training curricula for lighting controls and mechanical ATTs shall include, but not be limited to, the analysis, theory, and practical application of the items listed in §10-103.1(c)3Bi and §10-103.2(c)3Bi, respectively. These include training on the acceptance tests themselves.

Several approved ATTCPs require extensive classroom training to accomplish this educational requirement. One approved ATTCP requires that each applicant hold a third party certificate of training that the Energy Commission found to be equivalent to the curricula required.

ii. **Hands-on training**.

The ATTCP shall describe in its 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.

iii. **Prequalification**.

Participation in the 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.

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 controls or mechanical acceptance testing. The ATTCP must clarify the process that it will use 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, though not specifically required by regulation:

- How is the experience documented (for example, letters from employers or other written evidence), and how is it related to lighting controls 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.

For the 2019 Energy Standards, a note was added to specifically allow ATTCPs to adopt additional prequalification requirements for ATTs, such as “shall not be decertified by another ATTCP.” Any such additional requirements are at the ATTCP's discretion and not required by the Energy Commission.

iv. **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.

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 important, each ATTCP application included a discussion of the basis for each ratio.

v. **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.

When developing and implementing both written and practical tests, the ATTCP may consider the following issues:

- Subject matter experts should validate exams by 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.
- Exam questions should be evaluated annually to confirm reliability, rigor, and lack of bias.
- Lack of bias should be Validated consistent with the Uniform Guidelines on Employee Selection Procedures (1978) Federal Register, 43(166), 38290-38315.

Measures should be adopted 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.

vi. **Recertification.**

The ATTCP shall recertify all ATTs before implementing each adopted update to the Energy Standards when these updates affect the acceptance test requirements. Recertification requirements and procedures shall apply only to those specific elements that are new or modified in future updates to the Energy Standards.

The ATTCP shall develop recertification training curricula for ATTs consistent with training requirements in §10-103.1(c)3A and §10-103.1(c)3B (or §10-103.2(c)3A and §10-103.2(c)3B) and shall submit the proposed recertification training curricula to the Energy Commission for review and approval in the update report required under §10-103.1(d)2 (or §10-103.2(d)2). Once approved, the ATTCP will implement the recertification process.

C. 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 lighting controls or mechanical systems acceptance tests in the Energy Standards.

D. 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.

E. Decertification 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. The ATTCP shall also describe its general procedures for decertified ATTs or ATEs seeking to regain their certification status, including eligibility requirements for recertification (if any).

F. Quality Assurance and Accountability

The quality assurance and accountability requirements for lighting controls and mechanical ATTCPs vary significantly for the 2019 Energy Standards, so they will be discussed separately.

- Lighting Controls

  The ATTCP shall describe in its application to the Energy Commission its procedures for conducting quality assurance and accountability activities, including, but not limited to, the following:

  - The ATTCP shall include quality assurance and accountability measures, including, but not limited to, independent oversight of the certification materials, 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 Energy Standards §130.4.
  - The ATTCP shall review a random sample of no fewer than 1 percent of each ATT's completed compliance forms and shall perform randomly selected on-site audits of no fewer than 1 percent of each ATT's completed acceptance tests. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

  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 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 five 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.

- Mechanical Systems

  The ATTCP shall describe in its applications to the Energy Commission procedures for conducting quality assurance and accountability activities, including, but not limited to, the following:

  - The ATTCPs shall include quality assurance and accountability measures, including, but not limited to, independent oversight of the certification materials, processes, and procedures; visits to building sites where ATTs are completing acceptance tests; certification process evaluations; building department surveys to determine acceptance testing effectiveness; and expert review of the training curricula developed for Energy Standards§120.5.
  - The ATTCP shall review a random sample of no fewer than 1 percent of each ATT's completed compliance forms. The ATTCP shall also randomly select and shadow audit no fewer than 1 percent of each ATE's overseen projects, following the assigned ATT and observing his or her performance

on the job site. Independent oversight may be demonstrated by accreditation under the ISO/IEC 17024 standard.

The mechanical regulation generally follows the same requirements as lighting controls, except the focus for on-site audits is on the ATEs rather than the ATTs.

G. Certification Identification Number and Verification of ATT and ATE Certification Status

The ATTCP shall describe in its applications to the Energy Commission procedures for recording, tracking, and communicating certification status, including but not limited to the following:

- Upon certification of an ATT or ATE, the ATTCP shall issue a unique certification identification number to the ATT or ATE.
- The ATTCP shall maintain an accurate public record of the certification status for all ATTs and ATEs that the ATTCP has certified, including any ATTs or ATEs who have been decertified as specified in §10-103.1(c)3E or §10-103.2(c)3E.
- 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.

Energy Standards compliance will also be simplified by requiring the ATT to include its 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 compliance with these regulations. However, the applications that the Energy Commission has approved all include the implementation of an online presence to contend with the ATT/ATE application processing, complaints process, certification status, and ATT/ATE contact information.

13.5.2 Requirements for ATTCPs to Provide Regular Reports

Section 10-103.1(d) and §10-103.2(d) require ATTCPs to submit two periodic reports to the Energy Commission. All required reports shall contain a signed certification that the ATTCP has met all requirements for this program.

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.

13.5.2.1 Annual Report

The ATTCP shall provide an annual report to the Energy Commission that includes:

1. A summary of the certification services provided over the reporting period, including the total number of ATTs and ATEs certified by the ATTCP during the reporting period and to date.
2. A summary of all actions taken against any ATT or ATE 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 (or §10-103.2(c)3D and §10-103.2(c)3F).

3. A summary of the quality assurance and accountability activities conducted over the reporting period, including the compliance forms reviewed and the on-site audits performed as required under §10-103.1(c)3F(ii) (or §10-103.2(c)3F(ii)) during the reporting period and to date.
4. A summary of the number and type of acceptance tests performed in each local jurisdiction over the reporting period and to date.
5. A signed certification to the Energy Commission that the ATTCP continues to meet the requirements of §10-103.1 (or §10-103.2).

The annual report can include adjustments that are proposed, however, these proposals must be approved according to the application amendment process in §10-103.1(f) or §10-103.2(f).

13.5.2.2 Update Report

The ATTCP shall have no 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 before the effective date of any newly adopted update to the Energy Standards. The ATTCP shall report to the Energy Commission what application amendments are proposed to address changes to the Energy Standards or to ensure training reflects the variety of lighting controls (or mechanical systems) that are encountered in the field.

All required update reports shall contain a signed certification that the ATTCP continues to meet the requirements §10-103.1 (or §10-103.2). Update reports shall be approved through the amendment process provided under §10-103.1(f) (or §10-103.2(f)).

13.5.3 Amendment of ATTCP Applications

The ATTCP may amend a submitted or approved application as described in §10-103.1(f) and §10-103.2(f). The amendment process is intended to give the ATTCP an opportunity both during its initial application approval process and postapproval to modify its application or operations. This is so that ATTCPs can operate as openly as possible with the Energy Commission and address issues as they arise.

The amendment process depends on whether changes being made to an ATTCP application are substantive or nonsubstantive. Substantive amendments will require an approval from the Energy Commission at a regular business meeting. Nonsubstantive amendments can be approved by the Executive Director. The requirements and approval process for both types of amendments are discussed in detail below.

13.5.3.1 Amendment Scope

A. Nonsubstantive Changes

A nonsubstantive change is a change that does not substantively alter the requirements of the application materials for the ATTCP, ATT, or ATE. 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.

- A replacement copy of the affected sections of the ATTCP application with the changes incorporated.
- A copy of the affected sections of the ATTCP application showing the changes in underline and strikeout format.

B. Substantive Changes

A substantive change is a change that substantively alters the requirements of the application materials for the ATTCP, ATT, or ATE. 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 ATE 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.

13.5.3.2 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 §10-103.1 or §10-103.2, then the ATTCP shall either abide by the terms of their previously approved application or have its approval suspended.

13.5.4 Nonresidential Mechanical Acceptance Test Training and Certification

The mechanical ATTCP still has one additional consideration compared to the lighting controls ATTCP. The lighting controls ATTCPs have satisfied the industry certification threshold requirements in §10-103.1(b), which means that only certified ATTs can perform lighting controls acceptance testing. The Mechanical ATTCPs, as of this writing, have not satisfied the following threshold requirements (§10-103.2(b)):

1. A minimum of 300 mechanical ATTs have been trained and certified to complete the acceptance tests of §120.5 by ATTCP(s) approved by the Energy Commission.
2. ATTCPs must provide reasonable access to the training and certification for the following industry groups: 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 determine "reasonable access" by considering factors such as certification costs commensurate with the complexity of the training being provided, certification marketing materials, prequalification criteria, curriculum, and class availability throughout the state.

Until these requirements are met, field technicians can complete mechanical acceptance tests in §120.5 without being a certified mechanical ATT. 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://www.energy.ca.gov/title24/2019standards

CERTIFICATE OF COMPLIANCE			
NRCC-CXR-E	Commissioning Review	Enforcement Agency	Building Commissioning
NRCC-ELC-E	Electrical	Enforcement Agency	Electrical Power Distribution
NRCC-ENV-E	Envelope	Enforcement Agency	Building Envelope
NRCC-LTI-E	Lighting - Indoor	Enforcement Agency	Indoor Lighting
NRCC-LTO-E	Lighting - Outdoor	Enforcement Agency	Outdoor Lighting
NRCC-LTS-E	Lighting - Sign	Enforcement Agency	Sign Lighting
NRCC-MCH-E	Mechanical	Enforcement Agency	Mechanical Systems
NRCC-PLB-E	Plumbing	Enforcement Agency	Water Heating Systems
NRCC-PRC-E	Process	Enforcement Agency	Covered Processes
NRCC-SRA-E	Solar Ready	Enforcement Agency	Solar Ready Areas

CERTIFICATE OF INSTALLATION			
NRCI-ELC-01-E	Electrical	Enforcement Agency	Electrical Power Distribution
NRCI-ENV-01-E	Envelope	Enforcement Agency	Envelope
NRCI-LTI-01-E	Lighting - Indoor	Enforcement Agency	Indoor Lighting
NRCI-LTI-02-E	Lighting - Indoor	Enforcement Agency	Energy Management Control System (EMCS) or Lighting Control System
NRCI-LTI-04-E	Lighting - Indoor	Enforcement Agency	Two Interlocked Lighting Systems
NRCI-LTI-05-E	Lighting - Indoor	Enforcement Agency	Power Adjustment Factors

NRCI-LTI-06-E	Lighting - Indoor	Enforcement Agency	Videoconference Studio Lighting
NRCI-LTO-01-E	Lighting - Outdoor	Enforcement Agency	Outdoor Lighting
NRCI-LTO-02-E	Lighting - Outdoor	Enforcement Agency	Energy Management Control System (EMCS) or Lighting Control System
NRCI-LTS-01-E	Lighting - Sign	Enforcement Agency	Sign Lighting
NRCI-MCH-01-E	Mechanical	Enforcement Agency	Mechanical
NRCI-PLB-01-E	Plumbing	Enforcement Agency	Plumbing
NRCI-PLB-02-E	Plumbing	Enforcement Agency	High Rise Residential/Hotel/Motel Central Hot Water System Distribution
NRCI-PLB-03-E	Plumbing	Enforcement 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	Enforcement Agency	Covered Processes
NRCI-SPV-01-E	Solar Photovoltaic	Enforcement Agency	Solar Photovoltaic System
NRCI-STH-01-E	Solar Thermal Heating	Enforcement Agency	Solar Water Heating Systems

CERTIFICATE OF ACCEPTANCE			
NRCA-ENV-02-F	Envelope	Field Technician	Fenestration Acceptance
NRCA-ENV-03-F	Envelope	Field Technician	Clerestories, horizontal slats and light shelves PAF
NRCA-LTI-02-A	Lighting - Indoor	Acceptance Technician	Lighting Control Acceptance Document
NRCA-LTI-03-A	Lighting - Indoor	Acceptance Technician	Automatic Daylighting Control Acceptance Document
NRCA-LTI-04-A	Lighting - Indoor	Acceptance Technician	Demand Responsive Lighting Control Acceptance Document

NRCA-LTI-05-A	Lighting – Indoor	Acceptance Technician	Institutional Tuning PAF Acceptance Document
NRCA-LTO-02-A	Lighting - Outdoor	Acceptance Technician	Outdoor Lighting Acceptance Tests
NRCA-MCH-02-A	Mechanical	Acceptance Technician	Outdoor Air Acceptance
NRCA-MCH-03-A	Mechanical	Acceptance Technician	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	Acceptance Technician	Air Economizer Controls Acceptance
NRCA-MCH-06-A	Mechanical	Acceptance Technician	Demand Control Ventilation (DVC) Systems Acceptance
NRCA-MCH-07-A	Mechanical	Acceptance Technician	Supply Fan Variable Flow Controls (VFC) Acceptance
NRCA-MCH-08-A	Mechanical	Acceptance Technician	Valve Leakage Test
NRCA-MCH-09-A	Mechanical	Acceptance Technician	Supply Water Temperature Reset Controls Acceptance
NRCA-MCH-10-A	Mechanical	Acceptance Technician	Hydronic System Variable Flow Controls Acceptance
NRCA-MCH-11-A	Mechanical	Acceptance Technician	Automatic Demand Shed Control Acceptance
NRCA-MCH-12-A	Mechanical	Acceptance Technician	Fault Detection & Diagnostics for Packaged DX Units
NRCA-MCH-13-A	Mechanical	Acceptance Technician	Automatic Fault Detection & Diagnostics for Air Handling & Zone Terminal Units Acceptance
NRCA-MCH-14-A	Mechanical	Acceptance Technician	Distributed Energy Storage DX AC Systems Acceptance
NRCA-MCH-15-A	Mechanical	Acceptance Technician	Thermal Energy Storage (TES) System Acceptance
NRCA-MCH-16-A	Mechanical	Acceptance Technician	Supply Air Temperature Reset Controls Acceptance
NRCA-MCH-17-A	Mechanical	Acceptance Technician	Condenser Water Temperature Reset Controls Acceptance
NRCA-MCH-18-A	Mechanical	Acceptance Technician	Energy Management Control System (EMCS) Acceptance

NRCA-MCH-19-A	Mechanical	Acceptance Technician	Occupancy Sensor Acceptance
NRCA-PRC-01-F	Process	Field Technician	Compressed Air System Acceptance
NRCA-PRC-02-F	Process	Field Technician	Commercial Kitchen Exhaust System Acceptance
NRCA-PRC-03-F	Process	Field Technician	Enclosed Parking Garage Exhaust System Acceptance
NRCA-PRC-04-F	Process	Field Technician	Refrigerated Warehouse - Evaporator Fan Motor Controls
NRCA-PRC-05-F	Process	Field Technician	Refrigerated Warehouse - Evaporative Condenser Controls Acceptance
NRCA-PRC-06-F	Process	Field Technician	Refrigerated Warehouse - Air-Cooled Condenser Controls Acceptance
NRCA-PRC-07-F	Process	Field Technician	Refrigerated Warehouse - Variable Speed Compressor Acceptance
NRCA-PRC-08-F	Process	Field Technician	Refrigerated Warehouse - Electric Resistance Underslab Heating System
NRCA-PRC-12-F	Process	Field Technician	Elevator Lighting & Ventilation Controls
NRCA-PRC-13-F	Process	Field Technician	Escalators & Moving Walkways Speed Controls
NRCA-PRC-14-F	Process	Field Technician	Lab Exhaust Ventilation
NRCA-PRC-15-F	Process	Field Technician	Fume Hood Automatic Sash Closure System
NRCA-PRC-16-F	Process	Field Technician	Adiabatic Condensers

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-MCH-24a-H	Mechanical	HERS Rater	Building Envelope Air Leakage Worksheet for IAQ – Manual Meter
NRCV-MCH-24b-H	Mechanical	HERS Rater	Building Envelope Air Leakage Worksheet for IAQ – Automatic Meter
NRCV-MCH-27b-H	Mechanical	HERS Rater	IAQ - Multifamily
NRCV-MCH-27c-H	Mechanical	HERS Rater	IAQ - Multifamily intermittent Scheduled and Real-time control
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 < 225,000 Btu/hr, three phase ≥ 225,000 Btu/hr	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) 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) 10 C.F.R. sections 431.75 and 431.76
Gas infrared heaters patio heaters gas-fired high-intensity infrared heaters gas-fired low-intensity infrared heaters	ASTM F2644-07 ANSI Z83.19- 001 ANSI Z83.20-
Unit heaters gas- fired oil-fired	ANSI Z83.8-2002* UL 731-1995*
Gas duct furnaces	ANSI Z83.8-
Boilers < 300,000 Btu/hr ≥ 300,000 Btu/hr	10 C.F.R. section 430.23(n) (Appendix N to Subpart B of part 430) 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 ft³.	

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 ft³, which is 1.73 x freezer volume (ft³).	

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 (ft³) AV = Adjusted Volume = [1.63 x freezer volume (ft³)] + refrigerator volume (ft³) 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

Appendix C - California Climate Zones

All energy calculations used for compliance with the Standards must use the climate zone applicable to a building project is determined based on its physical location as it relates to the determinations of climate regions found in the Commission publication California Climate Zone Descriptions, which contains detailed survey definitions of the 16 climate zones.

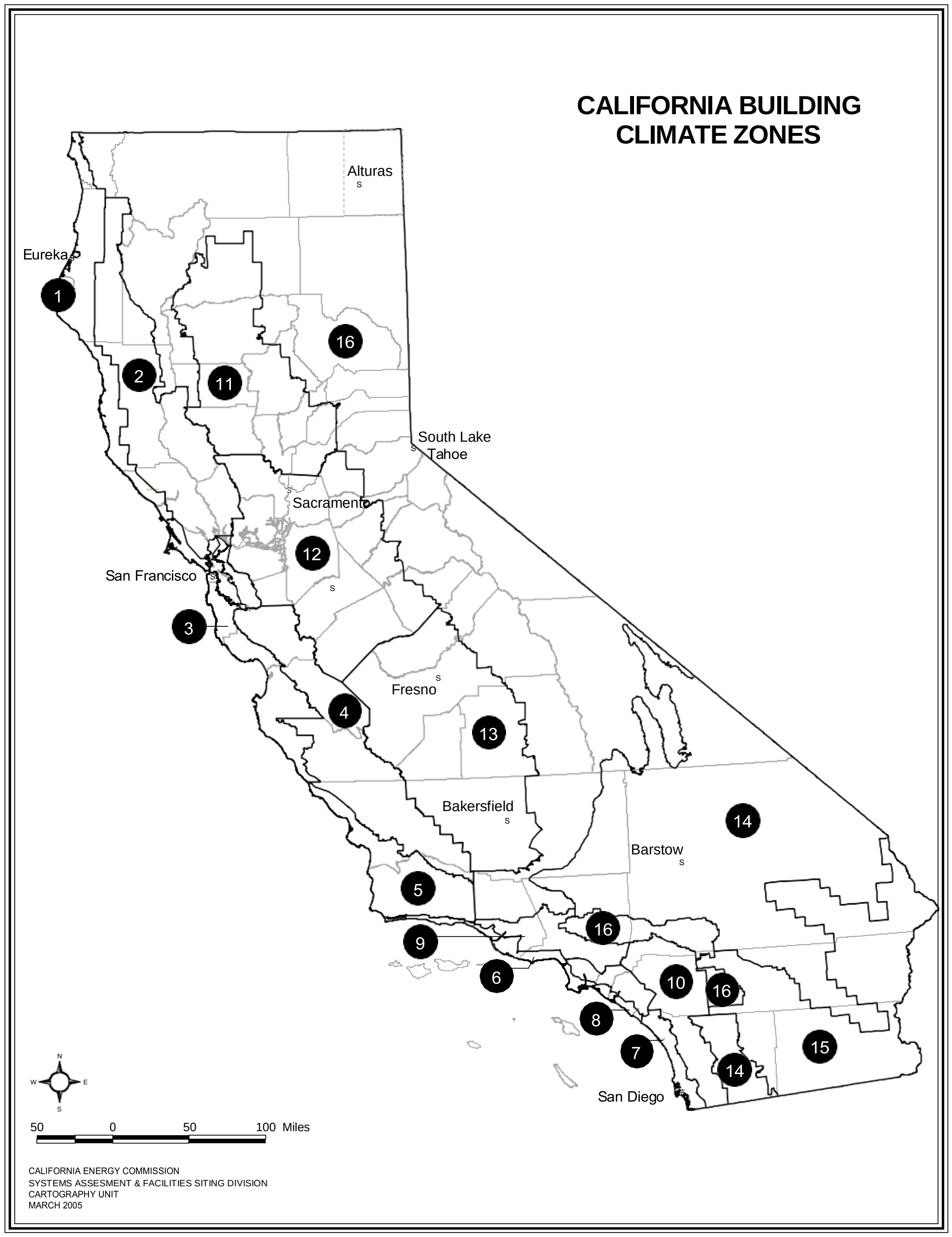
The list of climate zone areas by ZIP code is located on the CEC website here:

http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

CEC has also developed an interactive climate zone lookup tool that allow user to locate climate zone by address or ZIP code. The lookup tool is located here:

http://caenergy.maps.arcgis.com/apps/webappviewer/index.html?id=48317724c00eb4f72992416724 4bbca22

FIGURE 100.1-A—CALIFORNIA CLIMATE ZONES



T:\Projects\CEC\Mexico\MX Border.apr VIEW: CZ Building B&W 8.5X11 LAYOUT:CZ Building B&W 8.5X11

Appendix D - Demand Responsive Controls

This appendix to the nonresidential compliance manual addresses the demand responsive (DR) control requirements in the 2019 Building Energy Efficiency Standards (Energy Standards).

Demand response is an increasingly important function of buildings as distributed energy resources become more common and customers have access to time of use electricity rates and incentive programs designed to encourage demand side optimization. Demand response occurs on a range of timescales, from seconds to seasons, and represents any demand change in response to grid or economic needs. In addition to current time of use electricity rates, utilities in the future will likely connect electricity costs to high frequency fluctuations in both the supply and demand for electricity. Appropriate demand responsive controls allow building operators to maintain the quality of services a building provides and reduce the total cost of energy by automating a building's response to changes in electricity rates.

The following definitions from §100.1 are relevant to the DR control requirements:

> **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:
>
> a. Changes in the price of electricity; or
> b. Participation in programs or services designed to modify electricity use.
>   i. In response to wholesale market prices.
>   ii. When system reliability is jeopardized.
>
> **Demand Response Period** is a period of time during which electricity loads are modified in response to a demand response signal.
>
> **Demand Response Signal** is a signal that indicates a price or a request to modify electricity consumption for a limited time period.
>
> **Demand Responsive Control** is an automatic control that is capable of receiving and automatically responding to a demand response signal.

The DR control requirements ensure that the building is DR capable (i.e., capable of responding to a DR signal). The decision to employ demand response is up to the building owner or manager, in coordination with their utility company and/or a governing authority. A building that is capable of receiving and responding to a demand response signal is sufficient to meet the requirements of the Energy Standards. DR-capable is described as follows:

> **DR-capable:** A building is *capable* of DR when the building has loads that can be automatically managed, DR controls are installed, and the DR controls have been programed/configured so the test control strategy that is defined in the building code can be deployed (note: the DR controls may be programmed with additional control strategies).

Table D-1 summarizes when DR controls are required in nonresidential buildings.

The requirements for DR controls only apply if the controls are used to comply with the building standards (i.e., DR thermostats or a heat pump water heater). If DR controls are installed voluntarily without any code requirements, then they do not need to adhere to the demand responsive controls requirements in Title 24, Part 6.

Table D-1: Summary of DR Control Requirements for Newly Constructed Nonresidential Buildings

Application		Required DR Controls	Response Tested for Title 24 Compliance	Acceptance Test
HVAC	Direct Digital Control (DDC) to the Zone level[1]	Must have DR Controls that are compliant with Sections 110.12(a) and (b)	• During DR Period, in non-critical zones: o In cooling mode, increase the operating cooling temperature 4ºF or more o In heating mode, decrease the operating heating temperature 4ºF or more • Upon conclusion of the DR Period, reset the temperature set points to their original settings. • Provide an adjustable rate of change for the temperature.	NA7.5.10: Automatic Demand Shed Control Acceptance
HVAC	Single-zone air conditioner and heat pump system (without DDC to the Zone Level)[1,2]	Must have thermostatic controls that are compliant with Joint Appendix 5.	Defined in Joint Appendix 5.	Not applicable
Lighting	Lighting in buildings larger than 10,000 square feet[3]	Must have DR controls that are compliant with Sections 110.12(a) and (c)	Reduce lighting power by a minimum of 15 percent below the design full output level for the duration of the Demand Response Period. [3,4]	NA7.6.3 Demand Responsive Controls Acceptance
Sign Lighting	Electronic Message Centers (EMCs) having a new connected lighting power load greater than 15 kW[4]	Must have DR controls that are compliant with Sections 110.12(a) and (d)	Reduce lighting power by a minimum of 30 percent for the duration of the Demand Response Period.	Not applicable
Electrical Power System	Circuit-level controls installed as part of the electrical power distribution system[5]	Must have DR controls that are compliant with Sections 110.12(a)	Not applicable	Not applicable

1. Systems serving exempt process loads that must have constant temperatures to prevent degradation of materials, a process, plants, or animals are exempt.
2. Package terminal air conditioners, package terminal heat pumps, room air conditioners, and room air-conditioner heat pumps are exempt.
3. Spaces with a lighting power density of 0.5 watts per square foot or less and spaces in which lighting power or illuminance is not permitted to be reduced in accordance with health or life safety statues, ordinances, or regulations: 1) are not required to be capable of automatically reducing lighting power when a DR Signal is received; and 2) shall not be included in calculations of the design full output level or the reduced lighting power level.
4. Lighting for EMCs where lighting power or illuminance is not permitted to be reduced by 30 percent in accordance with a health or life safety statute, ordinance, or regulation is exempt.
5. Circuit-level controls installed to control HVAC, lighting, or sign lighting equipment must comply with the requirements for that application.

1. Communications Requirements for DR Controls

§110.12(a)1-3

There are two main communication requirements that apply to all DR controls:

1. The control must, at minimum, be installed with an OpenADR 2.0a or 2.0b certified virtual end node (VEN), or be on the Energy Commission's list of certified demand responsive controls; and
2. The control must, at a minimum, include the hardware necessary to receive signals over one of the following communication paths: WiFi, ZigBee, BACnet, Ethernet or hard wire.

These are minimum requirements, meaning that the control may have (and use) additional communication features, as long as the required minimum features are included.

1.1 Communication with Entity that Initiates DR Signal

§110.12(a)1

The DR control system must have the capability of communicating with the entity that initiates a DR signal by way of an OpenADR certified virtual end node (VEN).

The OpenADR 2.0 protocol is the primary open-standard protocol used in the California market. It implements a profile within the Organization of Structured Information Standards (OASIS) Energy Interoperation information and communication model that defines two types of communications entities – virtual top nodes (VTNs) and virtual end nodes (VENs). VTNs are either physical or cloud based information exchange servers, typically operated by utilities or third-party providers, that transmit events or price information. VENs are the hardware that receive the data transmitted by a VTN, and are typically the gateway or end-use devices installed at customer facilities. See OpenADR Alliance's website (http://www.openadr.org/) for more information about OpenADR certified VENs.[1]

There are two ways to comply with the OpenADR certified VEN requirement:

Option A: Install an OpenADR 2.0a or 2.0b certified VEN physically within the building as part of the DR control system (§110.12(a)1A)

If complying using Option A (§110.12(a)1A), the designer of the DR control system(s) must select an OpenADR Alliance Certified VEN, compliant with the OpenADR 2.0a or 2.0b specification.[2] The OpenADR Alliance maintains a list of certified VENs (https://products.openadr.org/). If using Option A, the certified VEN must be installed inside the building at the time of inspection. The building can comply if the DR control system has a certified VEN that is incorporated into a networked system of devices such that the VEN communicates with multiple devices in the network (e.g., a gateway system). Alternately, each demand responsive control device in the building could itself be a certified VEN.

[1] The OpenADR Alliance's Frequently Asked Questions webpage is a helpful resource: http://www.openadr.org/faq.

[2] The OpenADR 2.0a and 2.0b specifications are available on the OpenADR Alliance's website: http://www.openadr.org/specification.

Option B: Install a DR control system that has been certified to the Energy Commission as being capable of communicating with an OpenADR 2.0b certified VEN (§110.12(a)1B)

If complying using Option B (§110.12(a)1B), the designer of the DR control system(s) must select a DR control system that the Energy Commission has approved for the certified list of demand responsive controls. The Energy Commission maintains a list of certified products and instructions on how manufacturers can certify products on their website: http://www.energy.ca.gov/title24/equipment_cert/. If using Option B, the VEN may be separately located on-site, offsite or in the cloud, and is not required to be in operation at the time of permitting. The demand responsive controls must still be programed or configured so any test control strategy defined in the building code can be deployed at the time of permitting.

Option B requires that the manufacturer of the DR control system certify to the Energy Commission that the control system is capable of communicating with an OpenADR 2.0b certified VEN. This requirement does not mean that the DR control system must be connected to a 2.0b certified VEN. When the DR control system is connected to a VEN, it can be connected to either a 2.0a or 2.0b certified VEN.

As discussed in Section 1.3 below, the DR control system must comply with Option A or Option B, but the control system can also include features that allow the control system to use other communications protocols.

When specifying DR control systems, it is recommended that the controls designer check to see which DR programs are currently available in the area and specify controls that are both compliant with Title 24, Part 6 and eligible for the area's DR programs.

1.2 Communication Pathways

§110.12(a)2

DR controls must be capable of using one or more of the following to communicate (i.e., send and receive signals):

- Wi-Fi: for more information see the Wi-Fi Alliance website: https://www.wi-fi.org/.
- ZigBee: for more information see the ZigBee Alliance website: http://www.zigbee.org/.
- BACnet: for more information see http://www.bacnet.org/.
- Ethernet; or
- Hard-wiring.

As described in Section 1.3 below, DR control systems can also support additional communication protocols.

1.3 Additional Communication

§110.12(a)3

Section 110.12(a)3 explicitly states that DR controls are allowed to use communications protocols in addition to the ones required above. This means that the control can communicate with entities that initiate DR signals using different protocols, including but not limited to proprietary protocols and other non-proprietary protocols like the American National Standards Institute (ANSI) / Consumer Technology Association (CTA) Standard for Modular Communications Interface for Energy Management (ANSI/CTA-2035-A), provided that the control also complies with one of the options for OpenADR compatibility. Similarly, the DR control system is allowed to use other physical means of communication provided at least one of the specified methods is supported.

The DR control may use any of its available communication features to participate in DR programs.

2. Other Requirements for DR Controls

2.1 Perform Regular Functions When Not Responding to DR Events

§110.12(a)4

Controls that include demand response with other control functions must perform their regular control functions, as required by other parts of the building code, when the control is not performing DR-related functions. This includes when the controls are not responding to a DR event, when the DR functions are not enabled (see description of DR-enabled in the introduction to this chapter of the compliance manual) or when the DR controls are temporarily disabled or disconnected (e.g., due to a network outage).

For example, if the building owner/operator never enables the DR controls or enrolls in a DR program, the building control system(s) must comply with all other applicable controls requirements and continue to provide those control functions. Similarly, if the building owner/operator does enable the DR controls and is enrolled in a DR program, the building control system(s) must perform as required by the applicable building code requirements whenever the building is not participating in a DR event. The DR control functionality is an additional control feature on top of all of the other required building controls.

2.2 Certification Requirements for DR Thermostats

§110.12(a)5

DR thermostats must comply with the technical specifications described in Joint Appendix 5 (JA5). According the requirement in JA5, manufacturers of DR thermostats must submit documentation to the Energy Commission to certify that the thermostat meets the code requirements. See the Energy Commission's website for a list of certified products and for instructions to manufacturers that wish to certify products: http://www.energy.ca.gov/title24/equipment_cert/.

3. DR Controls for HVAC Systems

3.1 HVAC Systems with DDC to the Zone Level

§110.12(b)

As specified in §120.2(j), the Energy Standards require certain buildings to have Direct Digital Control (DDC) to the zone level (See Chapter 4 Section 4.5.1.9 of the nonresidential compliance manual). When the building has DDC to the zone level, either to comply with the Energy Standards or if DDC was installed voluntarily, the HVAC system must also have a DR control system that complies with the requirements in §110.12(a) and (b).

At the time of inspection, the DR control system must be programmed so it automatically initiates the test control strategy described below. The DR control system must pass this test to comply with code, regardless of what control strategy the building operator intends to use. If a building owner/operator enables the DR controls and enrolls in a DR program (see description of these terms in the introduction to this chapter), they have the option of deploying alternate control strategies consistent with their program. The strategy described in the Energy Standards is simply a test to confirm the DR control system is installed correctly and can perform its function, while also being suitable for leaving in place after testing.

Test control strategy:

When the person performing the acceptance test manually simulates the condition where the HVAC control system receives a DR signal and a DR Period is beginning, the HVAC system must initiate the following response:

1. When in cooling mode, increase the operating cooling temperature set points by 4ºF or more in all non-critical zones and maintain the set points throughout the DR Period.
2. When in heating mode, decrease the operating heating temperature set points by 4ºF or more in all non-critical zones and maintain the set points throughout the DR Period.
3. Maintain the temperature and ventilation set points in all critical zones throughout the DR Period.

When the person performing the acceptance test manually simulates a condition where the DR Period has concluded, the control system must restore the temperature set points in non-critical zones to the settings that were in place before the DR Period began.

In addition, the controls must be able to provide an adjustable rate of temperature change when the temperature is adjusted at the beginning and the end of the DR Period.

The control strategy calls for adjustments to temperature setpoints in non-critical zones while maintaining setpoints in critical zones. The Energy Standards define 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 computer rooms, data centers, telecom and private branch exchange (PBX) rooms, and laboratories.” Non-critical zones are defined as “a zone that is not a critical zone.”

(Note that the connection between the entity that initiates the DR signal and the control system within the building is not evaluated as part of the test.)

In addition to demonstrating compliance with the test condition, the DR controls for HVAC systems with DDC to the zone level must allow an authorized facilities operator to: 1) disable the DR controls, and 2) manually adjust heating and cooling setpoints from a centralized location on either the HVAC control system or the building’s energy management control system.

An acceptance test is necessary to ensure that the system was programmed as required. See Nonresidential Appendix 7.5.10 and Chapter 13 of this compliance manual for more information on the acceptance test requirements.

3.2 HVAC Systems without DDC to the Zone Level

§120.2(b)4

In buildings that do not have DDC to the zone level, thermostatic controls for single zone air conditioners and heat pumps must be DR thermostats, also called Occupant Controlled Smart Thermostats (OCSTs). There are two exceptions to this requirement:

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:
    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

When OCSTs are required, they must comply with the technical specifications described in Joint Appendix 5 (JA5). According the requirement in JA5, manufacturers of OCSTs must submit documentation to the Energy Commission to certify that the thermostat meets the code requirements. See the Energy Commission's website for a list of certified products and for instructions to manufacturers that wish to certify products: http://www.energy.ca.gov/title24/equipment_cert/.

4. DR Controls for Lighting Systems

§110.12(c)

Buildings larger than 10,000 square feet (ft^2) must be equipped with DR controls for indoor lighting systems that comply with §110.12(a) and (c). There are two exceptions that impact the calculation of the 10,000 ft^2 threshold and impact where DR controls can must be installed. Specifically, spaces that fall into these two categories do not need to have DR lighting controls and do not need to be included in the calculation of the 10,000 ft^2 threshold:

1. Spaces with a lighting power density of 0.5W/ ft^2 or less; and
2. Spaces where health or life safety statute, ordinance, or regulation does not permit lighting to be reduced.

At the time of inspection, the DR control system must be programmed to automatically initiate the test control strategy described below. The DR control must pass this test to comply with code regardless of what control strategy the building operator intends to use. If a building owner/operator enables the DR controls and enrolls in a DR program (see description of these terms in the introduction to this chapter), they have the option of deploying alternate control strategies consistent with their program. There is no acceptance test to verify such alternate control strategies. The strategy described in the Energy Standards is simply a test for confirming the DR control system is installed correctly and can perform its function, while also being suitable for leaving in place after testing.

Test control strategy

When the acceptance tester manually simulates the condition where the lighting control system receives a DR signal, the lighting system must automatically reduce lighting power so that the lighting power of the non-excluded spaces is reduced by a minimum of 15 percent below the total installed lighting power. Lighting shall be reduced in a manner consistent with uniform level of illumination requirements in Table 5-1 in Chapter 5 of this compliance manual (Table 130.1-A of the Energy Standards).

(Note that the connection between the entity that initiates the DR signal and the control system within the building is not evaluated as part of the test.)

An acceptance test is necessary to ensure that the system is installed correctly and includes a basic, functional level of programming. See Nonresidential Appendix 7.6.3 and Chapter 13 of this compliance manual for more information on the acceptance test requirements.

Example 4-1 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 DR 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.

Example 4-2 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 DR 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 DR 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 4-3 Compliance Method 3 – 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. DR Controls for Electronic Message Centers

§110.12(d)

Electronic Message Centers (EMCs) that have a lighting load greater than 15kW must have demand responsive controls unless a health or life safety statute, ordinance, or regulation does not permit EMC lighting to be reduced. The DR controls must meet the requirements in §110.12(a) (as explained in Section 1 above) and be capable of reducing the lighting power by a minimum of 30 percent during a DR Period.

6. DR Controls for Power Distribution Systems

§130.5(e)

If DR controls are installed as part of the power distribution system (e.g., circuit-level controls), the controls must meet the requirements in §110.12(a) (as explained in Section 1 above).

DR controls for HVAC, lighting, or sign lighting equipment may be installed at the circuit level; in this case, the DR controls must meet the complete requirements for that application.

7. Energy Management Control Systems (EMCS) / Home Automation Systems

Required thermostatic and lighting control functions (including DR control functions) can be incorporated into and performed by an Energy Management Control System. Using an EMCS to perform these control functions complies with Title 24 provided that all of the criteria that would apply to the control are met by the EMCS.

A Home Automation Systems that manages energy loads (such as HVAC and lighting systems) is considered a type of Energy Management Control System and, as such, can similarly incorporate the ability to provide required control functions.