

2016

RESIDENTIAL COMPLIANCE MANUAL

FOR THE 2016 BUILDING
ENERGY EFFICIENCY
STANDARDS

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



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Eurlyne Geiszler
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Building Standards Office

David Ashuckian
Deputy Director
Efficiency Division

Robert P. Oglesby
Executive Director

Acknowledgments

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

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

The 2016 Energy Standards revision and the supporting documents were conceptualized, evaluated and justified through the excellent work of Energy Commission staff and consultants working under contract to the Energy Commission, supported by the utility-organized Codes and Standards Enhancement (CASE) Initiative, and shaped by the participation of over 150 stakeholders and the contribution of over 1,000 formal public comments. We would like to acknowledge Commissioner Andrew McAllister and his adviser, Patrick Saxton, P.E. for their unwavering leadership throughout the standards development. Maziar Shirakh, P.E., who served as the project manager and senior engineer; Bill Pennington, Special Advisor to the Efficiency Division, who provided overall guidance and contributed to the technical content of the Standards documents; Eurlyne Geiszler, who served as the Manager for the Buildings Standards Office; Peter Strait, who served as the supervisor for the Standards Development Unit; Pippin Brehler and Galen Lemei, who provided legal counsel; and technical staff contributors of the Building Standards office including Mark Alatorre, P.E.; Payam Bozorgchami, P.E.; Todd Ferris; Hilary Fiese; Larry Froess, P.E.; Simon Lee P.E.; Jeff Miller, P.E.; Farakh Nasim; Adrian Ownby; Dee Anne Ross; Michael Shewmaker; Alexis Smith; Danny Tam; Gabriel Taylor, P.E.; RJ Wichert. The Standards Implementation office which includes Andrea Bailey; Randy Brumley; Suzie Chan; Tav Commins; Paula David; Gary Fabian; James Haile; Joe Loyer; Rashid Mir, P.E.; Javier Perez; Alex Pineda; Heriberto Rosales; Alex Wan; Courtney Ward; Daniel Wong; Nelson Peña; Energy Commission editors including Carol Robinson and Gaylene Cooper, and the Energy Commission Hotline staff and Web Team. Key Energy Commission and CASE consultants included NORESKO, Bruce Wilcox, Taylor Engineering, Proctor Engineering, Benya Lighting Design, Chitwood Energy Management, Davis Energy Group, EnerComp, McHugh Energy, Energy Solutions, E3, RASENT Solutions LLC, L'Monte Information Services, and TRC Solutions. The CASE Initiative is supported by a consortium of California utility providers which includes the Pacific Gas and Electric Company, Southern California Edison Company, San Diego Gas and Electric Company, Southern California Gas Company, the Sacramento Metropolitan Utility District, and the Los Angeles Department of Water and Power.

Abstract

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

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

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

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

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

Keywords:

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

Links to Chapters

Chapter 1.....	Introduction
Chapter 2.....	Compliance and Enforcement
Chapter 3.....	Building Envelope
Chapter 4.....	Building HVAC
Chapter 5.....	Water Heating
Chapter 6.....	Lighting
Chapter 7.....	Solar Ready
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Chapter 9.....	Additions, Alterations, and Repairs
Appendix A.....	Compliance Documents
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1. Introduction

This compliance manual is intended to help plans examiners, inspectors, owners, designers, builders, and energy consultants comply with and enforce California's *2016 Building Energy Efficiency Standards* (Energy Standards) for low-rise residential buildings. The lighting and domestic hot water requirements in this compliance manual also apply to high-rise residential buildings. The manual is written as a reference and an instructional guide and can be helpful for anyone that is directly or indirectly involved in the design and construction of energy-efficient low-rise residential buildings.

The compliance manual has nine chapters:

Chapter 1 introduces the Energy Standards and discusses the application and scope of the Standards for low-rise residences.

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

Chapter 3 addresses the requirements for the building envelope.

Chapter 4 covers the requirements for heating, ventilation, and air-conditioning (HVAC) systems.

Chapter 5 covers the water heating systems requirements, including the requirements for swimming pool systems.

Chapter 6 addresses the requirements for hardwired interior lighting and for outdoor lighting permanently attached to the building.

Chapter 7 addresses the solar-ready requirements for low-rise residential buildings .

Chapter 8 covers the performance approach to compliance.

Chapter 9 covers additions, alterations, and repairs.

1.1 Related Documents

This compliance manual is intended to supplement four other related documents that are available from the California Energy Commission. These are as follows:

- A. *The 2016 Building Energy Efficiency Standards, Title 24, Part 6* (Energy Standards). This compliance manual supplements and explains California's energy efficiency standards for buildings; it does not replace them. Readers should have a copy of the Energy Standards to refer to while reading this manual as well as a copy of the *2016 Reference Appendices*.
- B. 2016 Reference Appendices – The reference appendices have three main subsections: Reference Joint Appendices, Reference Residential Appendices, and Reference Nonresidential Appendices:
 1. The 2016 Reference Joint Appendices contain information common to both residential and nonresidential buildings including, but not limited to, definitions, climate zone listings, weather data, assembly properties, and compliance documentation registration procedures.
 2. The 2016 Reference Residential Appendices contain information for residential buildings only. The Reference Residential Appendices contain Home Energy Rating System (HERS) field verification and/or diagnostic testing procedures for

HVAC equipment, air distribution ducts, and quality insulation installation. .

3. The 2016 Reference Nonresidential Appendices contain information for nonresidential buildings only. The reference nonresidential appendices contain HERS field verification and/or diagnostic testing procedures for HVAC equipment and air distribution ducts, acceptance testing procedures, and luminaire power default values.
- C. *The 2016 Residential Alternative Calculation Method (ACMs or Compliance Software) Approval Manual. The 2016 Residential ACM Approval Manual* describes the process for certifying and decertifying the compliance software programs.
 - D. *The 2016 Residential Alternative Calculation Method Reference Manual* lays out the technical rules for implementing the 2016 performance compliance path in software programs.

Material from related documents is not repeated in this compliance manual; rather, it is referenced. If you are using the electronic version of this compliance manual, there are hyperlinks throughout the manual that will take you directly to the document that is referenced.

1.2 The Technical Chapters

Each of the five technical chapters (Chapters 3 through 7) begins with an overview, followed by a presentation of a specific topic in each subsection. For the building envelope, subsections include fenestration, opaque surfaces (walls, floors, and roofs), air leakage and infiltration, radiant barriers, cool roofs, and HERS quality insulation installation (QII) verification. For HVAC, the subsections include heating equipment, cooling equipment, ducts, and HERS field verification and diagnostic testing. For water heating, subsections include equipment efficiencies and distribution systems. Lighting subsections include high efficacy lighting, LED lighting, switching devices and controls, and recessed luminaires. Mandatory measures and prescriptive requirements (defined in Section 1.6 of this chapter) are described within each subsection or component. Chapter 8 describes the computer performance approach. Chapter 9 covers requirements for additions and alterations. Chapter 2, although not a technical chapter, covers important compliance and enforcement topics.

Each technical chapter or subsection also has a *compliance options* section. The *compliance options* section includes information on how to design a building that goes beyond the *prescriptive* energy efficiency requirements and *mandatory* energy efficiency measures. Compliance options are used for compliance credit through the performance approach. There are also *design recommendations* for which no compliance credit is offered. However, following the recommendations will significantly impact building energy use or peak demand.

Table 1-1: Compliance Options vs. Design Recommendations

<i>Compliance Options</i>	<i>Design Recommendations, such as on-site generation</i>
Credit offered through the performance approach	No credit, but may still impact energy or demand.

1.3 Why California Needs Building Energy Efficiency Standards

Energy efficiency reduces energy costs, increases reliability and availability of electricity, improves building occupant comfort, and reduces impacts to the environment, making the Energy Standards important and necessary for California’s energy future.

1.3.1 Energy Savings

Reducing energy use benefits everyone. Homeowners save money, Californians have a more secure and healthy economy, the environment is less negatively impacted, and the state electrical system can operate in a more stable manner. The 2016 Energy Standards (for both residential and nonresidential buildings) are expected to reduce the growth in electricity use and reduce the growth in natural gas use.

1.3.2 Electricity Reliability and Demand

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

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

1.3.3 Comfort

Comfort is an important benefit of energy-efficient homes. Energy-efficient houses are well-insulated, are less drafty, and use high-performance windows and/or shading to reduce solar gains and heat loss. Poorly designed building envelopes result in houses that are less comfortable. Even with oversized heating and cooling systems, comfort cannot be achieved in older, poorly insulated and leaky homes.

1.3.4 Economics

For the homeowner, energy efficiency helps to ensure that a home is affordable both now and into the future. Banks and other financial institutions recognize the impact of energy efficiency through energy-efficient mortgages; they look at the total cost of owning the home, including paying the utility bills. If the utility bills are lower, lenders can qualify borrowers for a larger loan.

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

1.3.5 Environment

In many parts of the world, energy use has led to oil spills, acid rain, smog, and other forms of environmental pollution that have ruined the natural beauty people seek to enjoy. California is not immune to these problems, but appliance standards, building standards, and utility programs that promote efficiency and conservation help maintain environmental quality. Other benefits include reduced destruction of natural habitats, which helps protect animals, plants, and natural systems.

1.3.6 Global Warming

Burning fossil fuels contributes greatly to global warming; carbon dioxide is being added to an atmosphere already containing 35 percent more than it did two centuries ago. Carbon dioxide and other greenhouse gases create an insulating layer around the earth that leads to global climate change. Energy Commission research shows that most sectors of the state economy face significant risk from climate change, including water resources (from reduced snowpack), agriculture, forests, and the natural habitats of several indigenous plants and animals.

Scientists recommend that actions be taken to reduce emissions of carbon dioxide and other greenhouse gases. While adding scrubbers to power plants and catalytic converters to cars reduces other emissions, they do not limit the carbon dioxide emitted into the atmosphere. Using energy efficiently is a far-reaching strategy that can make an important contribution to reducing greenhouse gases.

The National Academy of Sciences has urged the United States to follow California's lead on such efforts, saying that conservation and efficiency should be the chief element in energy and global warming policy. Its first efficiency recommendation was simple: Adopt nationwide energy-efficient building codes. Energy conservation will not only increase comfort levels and save homeowners money, it will play a vital role in creating and maintaining a healthy environment.

The Energy Standards are expected to have a significant impact on reducing greenhouse gas and other air emissions. Carbon dioxide (CO₂), one of the more prevalent greenhouse gases, would be reduced.

1.3.7 The Warren-Alquist Act

Section 25402 of the Public Resources Code

Section 25402 of the California Public Resources Code (the Code) authorizes the Energy Commission to develop and maintain Energy Standards for new buildings. This section of the code, commonly referred to as the Warren-Alquist Act (the act), is direction from the Legislature on the development of Energy Standards in California.

The act created the Energy Commission in 1974 and gave it authority to develop and maintain building energy efficiency standards for new buildings. The act directs the Energy Commission to “prescribe, by regulation, lighting, insulation, climate control system, and other building design and construction standards which increase the efficiency in the use of energy for new residential and new nonresidential buildings.”

The act also requires that the Energy Standards be cost-effective “when taken in their entirety and amortized over the economic life of the structure,” and it requires that the Energy Commission periodically update the Standards and develop manuals to support them. The act directs local building permit jurisdictions to withhold permits until the building satisfies the Energy Standards.

The Public Resources Code was amended through Senate Bill 5X (Sher, Chapter 7, Statutes of 2001) expands the authority of the Energy Commission to develop and maintain standards for outdoor lighting and signs.

1.4 What's New for 2016

The most significant changes in the *2016 Building Energy Efficiency Standards* affecting residential buildings include the new requirements for high-performance insulation within walls and attics. Other changes for residential buildings include:

1.4.1 Mandatory Measures:

1. Insulation in roof/ceiling construction must be at least R-22 (maximum U-factor of 0.043) (§150.0(a)1).
2. New duct total leakage reduced to 5 percent or less (§150.0(m)11B1).
3. All installed air-conditioner and heat pump systems shall be equipped with liquid line filter driers as specified by manufacturer's instructions (§150.0(h)3B).
4. Storage hot water heaters no longer need to be externally wrapped (§150.0(j)1).
5. All luminaires must be "high-efficacy" (§150.0(k)1A).
6. Isolation valves must be installed on instantaneous water heaters that have a minimum input of 6.8 kBTU/hr (§110.3(c)7).

1.4.2 Prescriptive Compliance:

1. Increased flexibility for envelope compliance (§150.1(c)).
2. Increased roof assembly requirements to include insulation installed either above or below roof deck (§150.1(c)1A).
3. Requirements for water-heating systems in single-family and multifamily buildings have been updated and more options have been added (§150.1(c)8).
4. High-performance attics and ducts in conditioned spaces have been added as option for a space-conditioning distribution system (§150.1(c)9).
5. If a whole house fan (WHF) is required, it must comply with a total air flow of at least 1.5 CFM/ft² and have 1 square foot of attic vent free area for each 750 CFM (§150.1(c)12).

1.4.3 Performance Compliance:

All compliance software programs that are approved by the Energy Commission must use a single interpretation of the performance compliance rules that the Energy Commission has integrated into the public domain software. More information is available in the *2016 Residential ACM Approval Manual* and the *2016 Residential ACM Reference Manual*.

1.4.4 Additions and Alterations:

1. Changes to the prescriptive requirements for the building envelope (specifically wall insulation) for additions (§150.2(a)1).
2. With alterations, the prescriptive requirements for mechanical cooling, water heating, and lighting have been revised (§150.2(b)).
3. More detailed information on additions and alterations in Chapter 9.

1.5 Scope and Application

1.5.1 Building Types

Though the Energy Standards apply to both nonresidential and residential buildings, this compliance manual addresses only the requirements for low-rise residential buildings. A companion compliance manual addresses the requirements for nonresidential buildings, including hotels, motels, and high-rise residential buildings that are four stories or more in height.

- A. **Mixed Low-Rise Residential and Nonresidential Occupancies.** When a building includes both low-rise residential and nonresidential occupancies, the requirements are different depending upon the percentages of the conditioned floor that is occupied by each occupancy type:
1. **Minor Occupancy** (Exception 1 to §100.0(f)). When a residential occupancy occurs in the same building as a nonresidential occupancy, and if one of the occupancies is less than 20 percent of the total conditioned floor area, the smaller occupancy is considered a “minor” occupancy. Under this scenario, optionally, the entire building may be treated as if it is the major occupancy for envelope, HVAC, and water heating. Lighting requirements in §140.6 through §140.8 or §150.0(k) must be met for each occupancy separately. The mandatory measures applicable to the minor occupancy, if different from the major occupancy, would still apply.
 2. **Mixed Occupancy.** When residential occupancy is mixed with a nonresidential occupancy, and if neither occupancy is less than 20 percent of the total conditioned floor area, these occupancies fall under different sets of standards and must be considered separately. Two compliance submittals must be prepared, each using the calculations and forms of the respective standards. Separate compliance for each occupancy, to the respective standards, is an option when one of the occupancies is a minor occupancy, as discussed in the paragraph above.
- B. **The three-story** designation relates to multifamily buildings, since all single-family homes fall under the low-rise residential requirements regardless of the number of stories. An apartment building with three or fewer habitable stories falls under the low-rise residential standards while an apartment building that has more than three habitable stories falls under the nonresidential standards. High-rise residential dwelling units must still comply with the lighting and water heating requirements for low-rise residential buildings; for example, the *Nonresidential Compliance Manual* makes reference to Chapters 5 and 6 of this document.

In multifamily buildings, lighting in common areas is subject to all nonresidential requirements if the common area conditioned floor area (CFA) exceeds 20 percent of the building CFA. Where the common area does not exceed 20 percent of the building CFA, lighting must meet mandatory requirements – a choice of high-efficacy lighting or automatic controls. (See §150.0(k)12.)

- C. The definition of **a habitable story** in the California Building Code (CBC) is used with the Energy Standards. Mezzanines are not counted as separate habitable stories, nor are minor conditioned spaces such as an enclosed entry stair that leads to an apartment or dwelling unit on the next floor. A habitable story is one that contains space in which people may live or work in reasonable comfort and that has at least 50 percent of its volume above grade.

- D. **Live/work buildings** are a special case since they combine residential and nonresidential uses within individual units. Such buildings are a common form of new construction in San Francisco and some other urban areas of the state. Even though live/work spaces may be used for an office or a studio, they are typically heated and/or cooled like a residential building. For this reason the residential standards are more suitable and the Energy Commission has made this determination: Either the low-rise or high-rise residential standards apply, depending on the number of habitable stories.

However, lighting in designated workspaces in live/work lofts must comply with the nonresidential prescriptive lighting requirements. See Chapter 5 of the *Nonresidential Compliance Manual* and §140.6 for more information.

Table 1-2: Building Types Covered by the Low-Rise Residential and Nonresidential Standards

Low-Rise Residential Standards (covered in this compliance manual)	Nonresidential Standards (covered by Nonresidential Compliance Manual)
All low-rise residential occupancies including single-family homes, duplexes, garden apartments, and other housing types with three or fewer habitable stories.	All nonresidential CBC occupancies (Group A, B, E, F, H, M, 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.
<p>Includes:</p> <p>All single-family dwellings of any number of stories (Group R-3)</p> <p>All duplex (two-dwelling) buildings of any number of stories (Group R-3)</p> <p>All multifamily buildings with three or fewer habitable stories (Groups R-1 and R-2)</p> <p>Additions and alterations to all of the above buildings.</p> <p>Lighting requirements for living quarters in high-rise multifamily buildings (more than three stories) and water heating requirements for high-rise multifamily buildings (more than three stories)</p>	<p>Includes:</p> <p>Offices</p> <p>Retail and wholesale stores</p> <p>Grocery stores</p> <p>Restaurants</p> <p>Assembly and conference areas</p> <p>Industrial work buildings</p> <p>Commercial or industrial storage</p> <p>Schools and churches</p> <p>Theaters</p> <p>Hotels and motels</p> <p>Apartment and multifamily buildings with four or more habitable stories (envelope and HVAC requirements)</p> <p>Long-term care facilities (group R-2) with four or more habitable stories</p> <p>Dormitories or other congregate residences, or any building with dormitory-style sleeping quarters, with six or more "guest rooms"</p> <p>Private garages, carports, sheds, and agricultural buildings.</p>

1.5.2 Explanation of Terms

The term building type refers to the classification of buildings defined by the *CBC* and applicable to the requirements of the *Building Energy Efficiency Standards*. This manual is concerned with the Energy Standards that apply to all low-rise residential buildings, which includes all single-family residential and multifamily buildings with three or fewer habitable stories in the entire building. A multifamily building with four or more habitable stories is under the scope of the nonresidential requirements, but the dwelling units must meet the lighting, water heating, and setback thermostat requirements for low-rise residential

buildings. A multifamily building contains multiple dwelling units that share common walls (single-family attached) and may also share common floors or ceilings (apartments).

All residential buildings not in the above low-rise category are covered in the 2016 edition of the Energy Commission's *Nonresidential Compliance Manual*. (See Parts 1.1 and 1.2.)

- A. A **single-family building** is a single dwelling unit of occupancy group R-3, as defined in the *CBC*, that stands separate from other dwelling units but may have an attached garage.
- B. A **multifamily building** is a dwelling unit of occupancy group R, as defined in the *CBC*; that shares a common wall and/or floor/ceiling with at least one other dwelling unit. (See Chapter 8 for more information on multifamily energy compliance.) A single-family attached building is a dwelling unit of occupancy group R that shares a common wall with another dwelling unit.
- C. An **addition** to an existing building increases both the conditioned floor area and volume of a building, which can be new construction or added space conditioning to an existing unconditioned space. See Chapter 9 for more information on energy compliance of additions.
- D. An **existing building** is: "...a building erected prior to the adoption of [the current] code, or one for which a legal building permit has been issued." (*CBC*, Part 2)

1.5.3 Building Orientation

Building orientation can affect the energy use of a building, particularly in cooling-dominated climate zones with a high amount of west-facing glass. Some prescriptive requirements and performance modeling inputs for compliance with the Energy Standards require a description of the building orientation.

- A. East-Facing
"East-facing is oriented to within 45 degrees of true east, including 45°0'0" south of east (SE), but excluding 45°0'0" north of east (NE)." (§100.1)
- B. North-Facing
"North-facing is oriented to within 45 degrees of true north, including 45°0'0" east of north (NE), but excluding 45°0'0" west of north (NW)." (§100.1)
- C. South-Facing
"South-facing is oriented to within 45 degrees of true south, including 45°0'0" west of south (SW), but excluding 45°0'0" east of south (SE)." (§100.1)
- D. West-Facing
"West-facing is oriented to within 45 degrees of true west, including 45°0'0" due north of west (NW) but excluding 45°0'0" south of west (SW)." (§100.1)

1.5.4 Historical Buildings

Exception 1 to §100.0(a)

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

The California Historical Building Code (CHBC) Section 8-102.1.1 specifies that all non-historical additions must comply with the regular code for new construction, including the *Building Energy Efficiency Standards*. CHBC Section 8-901.5 specifies that when new or replacement mechanical, plumbing, and electrical (including lighting) equipment or appliances are added to historic buildings, they should comply with the *Building Energy Efficiency Standards*, including the *Appliance Efficiency Regulations*.

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

Additional information about the CHBC can be found on the following website:

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

Or contact the SHBSB at (916) 445-7627.

Example 1-1

Question

Are additions to historic buildings also exempt?



Answer

If the addition adjoins the qualified historic building, then the enforcement agency at its discretion may exempt those measures which they determine could damage the historical value of the building. However, “additions which are structurally separated” from the historic building are not exempt from the Energy Efficiency Standards and must comply with building codes, including the Historical Building Code, Title 24, Part 8, Section 8-704.



Source: CEC Photographer: Andersen Windows

Example 1-2**Question**

A sunspace addition is designed with no mechanical heating or cooling and a glass sliding door separating it from all existing conditioned space. Under what conditions will the Energy Standards not apply to this addition?

Answer

The mechanical and envelope requirements of the Energy Standards do not apply if a building inspector determines that the space is unconditioned. Whether conditioned or unconditioned, per §100.0(c)2, the sunspace must still comply with the applicable lighting requirements of §150.0(k). The sunspace is unconditioned if:

- The new space is not provided with heating or cooling (or supply ducts); or
- The new space can be closed off from the existing house with weather stripped doors; or
- The addition is not indirectly conditioned space.

A building official may require a sunspace to be conditioned if it appears to be habitable space, in which case the Energy Standards would apply.

1.5.5 Exempt Buildings

The following building types are exempt from the prescriptive and performance standards:

- A. Seasonally occupied agricultural housing limited by state or federal agency contract to occupancy not more than 180 days in any calendar year (Exception 1 to §100.0(e)2D); however, these buildings must comply with the applicable mandatory requirements.
- B. Low-rise residential buildings that use no energy obtained from a depletable source for either lighting or water heating and obtain space heat from wood heating or other nonmechanical system: however, these buildings must comply with the applicable mandatory requirements.
- C. Based on discretion of building officials, temporary buildings, temporary outdoor lighting or temporary lighting in an unconditioned building, or structures erected in response to a natural disaster (Exception 2 to §100.0(a)). These buildings may also be exempt from the mandatory and prescriptive requirements of the Energy Standards.

1.5.6 Building Systems Covered

The low-rise residential standards affect the design of the building envelope; the heating, ventilation and air-conditioning (HVAC) system; the water heating system; and the lighting system. The Energy Standards do not apply to residential appliances (*Appliance Efficiency Regulations* may apply), elevators or dumbwaiters, or portable lighting systems that are plugged into a wall outlet. Only hardwired lighting is regulated, which includes lighting that is a permanent part of the building.

1.5.7 Additions, Alterations, and Repairs

§100.1(b)

§150.2(a)

§150.2(b)

Additions, alterations, and repairs are common construction projects for California homeowners. The Energy Standards apply to both additions and alterations, but not to repairs. See Chapter 9 for details.

- A. **Additions** are changes to an existing building that increase both conditioned floor area and volume.
- B. **Alterations**, that are not additions, are changes to the envelope, space conditioning system, water heating system or lighting system of a building.
- C. **Repairs** are the reconstruction or renewal of any part of an existing building for the purpose of its maintenance and are not under the scope of the Standards. Replacement of any component systems (such as reroofing) or equipment for which there are requirements in the Energy Standards is considered an alteration and not a repair.

Example 1-3

Question

The Energy Standards do not specify whether buildings damaged by natural disasters can be reconstructed to the original energy performance specifications. What requirements apply under these circumstances?

Answer

Buildings destroyed or damaged by natural disasters must comply with the energy code requirements in effect when the builder or owner applies for a permit for those portions of the building that are being rebuilt.

Example 1-4

Question

Do the Energy Standards apply to an addition to a manufactured (“mobile”) home?



Source: CEC Photographer: Brian Vahey

Answer

No. Title 25 requirements, not Title 24, govern manufactured homes, including additions to the unit. Jurisdiction in a mobile home park comes under the authority of the Department of Housing and Community Development. Jurisdiction of a mobile home on private property may come under the authority of the local building department.

Example 1-5

Question

Three stories of residential dwelling units are planned over a first story that includes retail and restaurant occupancies. Do the residential apartments need to comply with the residential standards?

Answer

Yes and No. The building envelope and HVAC equipment must comply with the nonresidential (high-rise residential) standards since the structure contains four habitable stories and, as a whole structure, is a high-rise building. The dwelling units, however, must comply with the lighting and water heating requirements for low-rise residences.

Example 1-6

Question

A four-story single-family townhouse (with no shared walls) has been constructed. Does the townhouse need to comply with the low-rise residential standards?

Answer

Yes. As a group R-3 occupancy, the low-rise residential standards apply. The building is not an apartment house (which, according to the CBC, must be at least three dwelling units).

Example 1-7

Question

A 2,100 ft² manager's residence is being constructed as part of a new 14,000 ft² conditioned warehouse building. Which Energy Standards apply?

Answer

The whole building can comply with the nonresidential standards, and the residential unit is not required to comply separately since it is a subordinate occupancy containing less than 20% of the total conditioned floor area. However, the residential dwelling unit must meet all low-rise residential mandatory measures as well as the lighting and water heating requirements.

Example 1-8

Question

Assume the same scenario as in the previous example, except that the dwelling unit is new and the remainder of the building is existing. Do the residential standards apply?

Answer

Yes. Since 100% of the addition being permitted is a low-rise residential occupancy, compliance under the residential standards is required.

Example 1-9

Question

A residence is being moved to a different location. What are the applicable compliance requirements?

Answer

Because this is an existing conditioned space, the requirements applicable to alterations would apply to any alterations being made. The building does not need to show compliance with the current Energy Standards applicable to new buildings or additions.

Example 1-10

Question

A previously conditioned retail space is remodeled to become a residential dwelling. What are the applicable compliance requirements?

Answer

The remodeled dwelling is treated as if it were previously a residential occupancy. In this case, the rules that apply to residential alterations are applied.

Example 1-11

Question

A 10,000 ft², 16-unit motel is constructed with an attached 1,950 ft² manager's residence. What are the applicable compliance requirements?



Source: <http://www2.sjsu.edu/faculty/wooda/calpark.jpeg>

Answer

The manager's unit is less than 20 percent of the total floor area, so compliance of the whole building as the predominant motel occupancy would satisfy the requirements of the Energy Standards. Either the entire building must comply with the nonresidential (high-rise residential and hotel/motel) standards; or the manager's residence must comply with the low-rise residential standards and the motel occupancy portion of the building must comply with the nonresidential standards.

Example 1-12**Question**

A subdivision of detached homes includes several unit types, each of which may be constructed in any orientation. What are the applicable compliance requirements?

Answer

The low-rise residential standards are applied to each building type. All four cardinal orientations may be shown to comply, or each individual unit in the planned orientation must comply.

Example 1-13**Question**

A four-story apartment building has three stories of apartments and a garage on the first floor. What are the applicable compliance requirements?

Answer

For compliance with the Energy Standards, the low-rise residential standards apply since the building has fewer than four habitable stories. However, for other non-energy codes and standards, this may be considered a four-story building.

Example 1-14**Question**

If in Example 1-13 above, there was a small air-conditioned elevator lobby at the garage floor, what would be applicable compliance requirements?

Answer

§100.1 defines a habitable story as a story that contains space in which people may work or live in reasonable comfort, and that has at least 50 percent of the volume therein above grade. The small elevator lobby does not meet this definition for habitable story; therefore, the low-rise residential standards still apply.

Example 1-15**Question**

If, in Example 1-13 above, there was a receptionist station in the conditioned elevator lobby at the garage floor. What would be the applicable compliance requirements?

Answer

In this case the lobby with the receptionist meets the habitable story definition of §100.1; therefore, the building must be considered a high-rise residential occupancy. The building envelope and HVAC equipment must comply with the nonresidential (high-rise residential) standards, and the dwelling units must comply with the lighting and water heating requirements for low-rise residential buildings .

1.6 Mandatory Measures and Compliance Approaches

In addition to the mandatory measures (Section 1.6.2), the Energy Standards provide two basic methods for complying with low-rise residential energy budgets: the prescriptive approach and the performance approach. The mandatory measures must be installed with

either of these approaches, but mandatory measures may be superseded by more stringent measures under either approach.

1.6.1 Approaches

- A. The **prescriptive approach**, composed of a climate zone dependent prescriptive package (Section 1.6.3), is less flexible but simpler than the performance approach. Each energy component of the proposed building must meet a prescribed minimum efficiency. The prescriptive approach offers relatively little design flexibility but is easy to use. There is some flexibility for building envelope components, such as walls, where portions of the wall that do not meet the prescriptive insulation requirement may still comply as long as they are area-weighted with the rest of the walls, and the average wall performance complies.
- B. The **performance approach** (Section 1.6.4) is more complicated but offers considerable design flexibility. The performance approach requires an approved computer software program that models a proposed building, determines the allowed energy budget, calculates the energy use of the building, and determines when it complies with the budget. Compliance options such as window orientation, shading, thermal mass, zonal control, and house configuration are all considered in the performance approach. This approach is popular with production home builders because of the flexibility and because it provides a way to find the most cost-effective solution for complying with the Energy Standards.

For additions and alterations, see Chapter 9 for details of compliance approaches that are available.

1.6.2 Mandatory Measures

With either the prescriptive or performance compliance paths, there are mandatory measures that must always be installed. Many of the mandatory measures deal with infiltration control and lighting; others require minimum insulation levels and equipment efficiency. New for the *2016 Building Energy Efficiency Standards* are mandatory measures that require higher insulation values for the building envelope, better duct sealing to limit air leakage, and high-efficacy lighting. For detailed information on these changes, see applicable sections within this manual. The minimum mandatory levels are sometimes superseded by more stringent prescriptive or performance approach requirements. For example, if mandatory measures specify R-22 ceiling insulation and the prescriptive approach, Package A, is used, then R-38 ceiling insulation (depending on climate zone) must be installed. Conversely, the mandatory measures may be of a higher efficiency than permitted under the performance approach; in these instances, the higher mandatory levels must be installed. For example, a building may comply using the performance computer modeling only R-7 insulation in a raised floor, but R-19 must be installed because that is the mandatory minimum.

1.6.3 Prescriptive Package A

§150.1(c)

The prescriptive requirements are represented in Package A. The prescriptive package is the simplest but least flexible compliance path. Package A establishes the stringency of the Energy Standards for the performance approach. Approved computer programs model a house with the features of Package A to determine the envelope, space conditioning, and water-heating budgets.

The prescriptive package is a set of predefined performance levels for various building components. Each building component must meet or exceed the minimum efficiency level specified in the package. Package A is presented in Table §150.1-A (and related footnotes) in the Energy Standards and also in Appendix B of this document. These prescriptive requirements require that ducted split-system and packaged air conditioners or heat pumps (for definition, see Reference Joint Appendix JA1) be HERS-tested to verify that they have the correct refrigerant charge.

1.6.4 Performance Approach

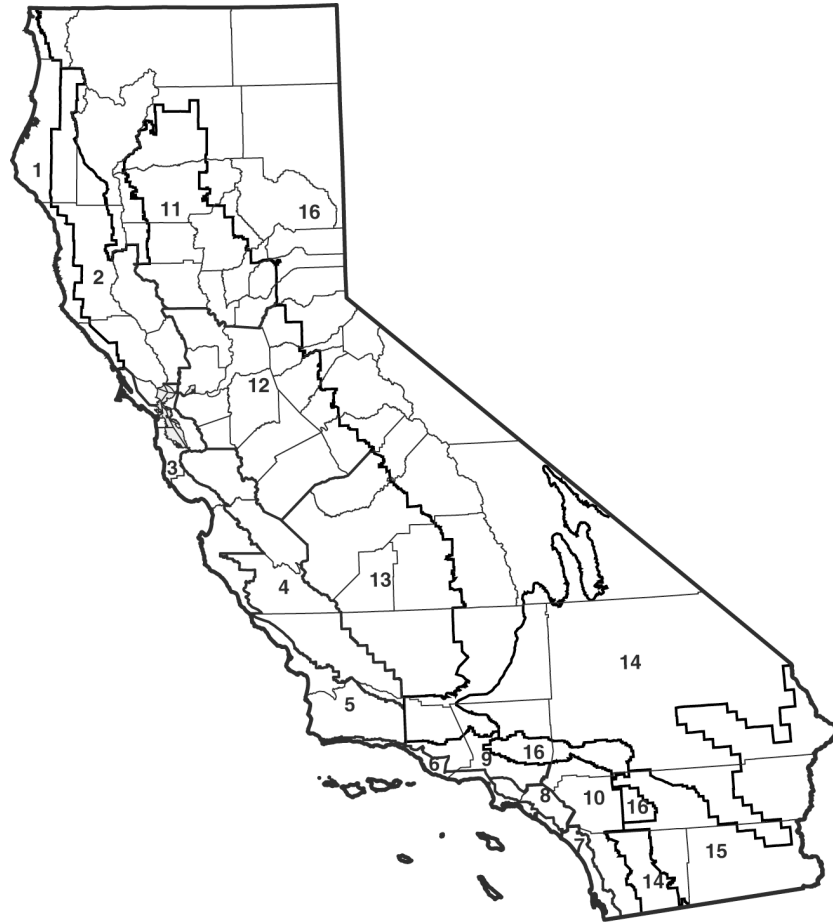
The performance approach, also known as the computer method, requires that the annual Time-Dependent Valuation (TDV) energy be calculated for the proposed building and compared to the standard TDV energy budget. TDV energy is the “currency” for the performance approach. TDV energy not only considers the type of energy that is used (electricity, gas, or propane), but when it is used. Energy saved during periods when California is likely to have a statewide system peak is worth more than energy saved at times when supply exceeds demand. Reference Joint Appendix JA3 has more information on TDV energy.

The use of Energy Commission-approved computer methods represents the most detailed and sophisticated method of compliance. While this approach requires the most effort, it also provides the greatest flexibility. The computer program automatically calculates the energy budget for space conditioning and water heating. The budget is determined from the standard design, a computer model of the building using the Package A prescriptive package. The computer software allows manipulation of the proposed building’s energy features to achieve or surpass the standard energy budget, that is, the proposed energy consumption of the building would be equal to or less than the standard energy budget. See Chapter 8 of this manual for more information on the performance method.

1.7 Climate Zones

To standardize calculations and to provide a basis for presenting the prescriptive requirements, the Energy Commission has established a set of standard climate data for each of the 16 climate zones. More information is provided in *Reference Joint Appendix JA2*, including a listing of climate zones for all California ZIP codes. *Reference Joint Appendix JA2* gives other climate information, such as design temperatures for sizing HVAC equipment. The climate zone definitions and data are the same for both the low-rise residential and the nonresidential standards.

Beginning with the 2013 Energy Standards, ZIP code boundaries have been used to define climate zone boundaries; under these rules, a given ZIP code is always located entirely within a single climate zone.

Figure 1-1: California Climate Zones

Source: California Energy Commission

1.7.1 Building Location Data

Building location data refer to specific outdoor design conditions used in calculating heating and cooling loads. Different from the climate zone used for compliance (see *Climate Zones* above), design data include the typically warmest and coolest outdoor temperatures that a building is likely to experience in an average year in a particular location.

Temperatures are from the ASHRAE publication, *SPCDX, Climatic Data for Region X - Arizona, California, Hawaii, Nevada*, May 1982 edition. (See Appendix C.) For heating, the outdoor design temperature is the Winter Median of Extremes. A higher temperature is permitted but no lower than this value. For cooling, the outdoor design temperatures must be the 1.0 percent Summer Design Dry Bulb and the 1.0 percent Wet Bulb columns.

If a building location is not listed, the local enforcement agency may determine the location for which data are available that is closest in its design characteristics to the actual building site.

1.8 Conditioned Floor Area

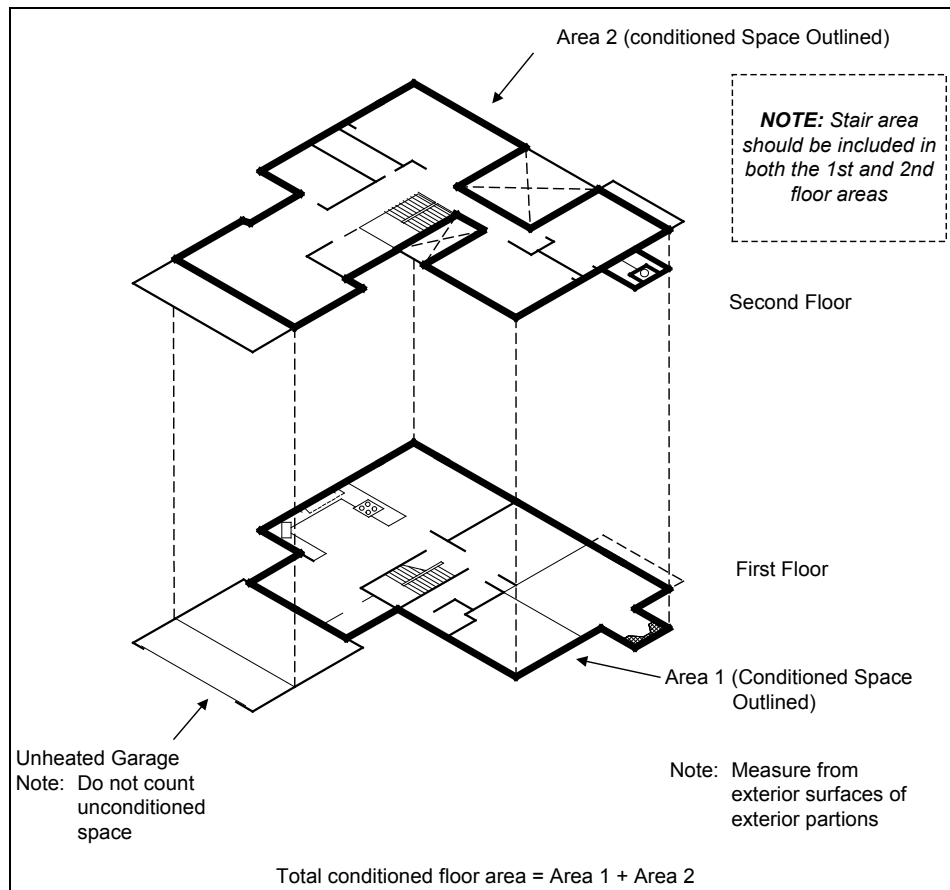
Conditioned floor area (CFA) is the total floor area (in square feet) of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces of exterior walls enclosing the conditioned space (§100.1). This term is also referred to in the Energy Standards simply as the *floor area*.

This is an important value for compliance since annual energy use is divided by this value to obtain the energy budget. In the prescriptive package, the maximum fenestration and west-facing fenestration area requirements are expressed as a percentage of this value.

CFA is calculated from the plan dimensions of the building, including the floor area of all conditioned and indirectly conditioned space on all floors. It includes lofts and mezzanines but does not include covered walkways, open roofed-over areas, porches, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, or parking garages. Unheated basements or closets for central gas-forced air furnaces are also not included, unless shown to be indirectly conditioned.

The floor area of an interior stairway is determined as the CFA beneath the stairs and the tread area of the stairs themselves. See figure 1-2 below for an example of how CFA is calculated.

Figure 1-2: Total Conditioned Floor Area



1.9 Where to Get Help

The Energy Commission has several resources to help designers, builders, homeowners, and others understand and apply the Energy Standards.

1.9.1 Energy Commission Publications and Support

A. Telephone Hotline

If the information contained in the Energy Standards or this compliance manual are not sufficient to answer a specific question concerning compliance or enforcement, technical assistance is available from the Energy Standards Hotline.

You can reach the Energy Standards Hotline on weekdays from 8 a.m. – noon and 1 p.m. – 4:30 p.m.:

(800) 772-3300

(916) 654-5106

B. Publications

Publications, including the *2016 Building Energy Efficiency Standards*, the *2016 Reference Appendices*, and the *2016 Residential ACM Approval and Reference Manuals*, and others are available from the Energy Commission's website at <http://www.energy.ca.gov/title24>. Paper copies may also be ordered from:

Publications Unit

California Energy Commission

1516 Ninth Street, MS-13

Sacramento, CA 95814

(916) 654-5200

C. Blueprint

The Energy Commission publishes the *Blueprint*, a newsletter that answers questions and addresses issues related to enforcement and compliance. The *Blueprint* also provides updated information on technical assistance and computer compliance programs and lists training opportunities offered throughout the state. The *Blueprint* is available online at <http://www.energy.ca.gov/efficiency/blueprint>.

Figure 1-3: Energy Commission Blueprint Newsletter



In This Issue

- » 2016 Energy Standards Approved
- » Alpha Versions of CBECC 2016 Now Available
- » CBECC-Com Version 3c
- » Water Heater Energy Factor Reference Guide
- » CALCTP Lighting Controls Certificates of Acceptance
- » Q&A
 - Natural Ventilation
 - Bypass Ducts
 - Heat Pump Water Heating Systems

2016 Energy Standards Approved

The California Energy Commission (Energy Commission) unanimously approved the 2016 Building Energy Efficiency Standards (Energy Standards), except the nonresidential lighting alterations language, at the June 10, 2015 Business Meeting. The 2016 Energy Standards will reduce energy costs, save consumers money, and increase comfort in new and upgraded homes and other buildings.

Single family homes built with the Energy Commission's 2016 Energy Standards will use about 28 percent less energy for lighting, heating, cooling, ventilation, and water heating than those built to the 2013 Energy Standards.

The 2016 Energy Standards, which take effect on January 1, 2017, focus on three key areas: updating residential requirements to move closer to California's zero net energy goals; updating nonresidential and high-rise residential requirements; and improving the clarity and consistency of existing regulations. Based on a 30-year mortgage, the Energy Commission estimates the 2016 Energy Standards will add about \$11 per month for the average home, but will save consumers \$31 on monthly heating, cooling, and lighting bills.

In addition to simplifying the language, other major improvements include:

Residential

- » High performance attics: extra insulation at the roof deck in addition to ceiling insulation will reduce the attic temperature by 35 degrees or more on hot summer days.
- » High performance walls: builders can choose from different wall assemblies to reduce heating and cooling needs in the home year round.
- » Lighting: installation of high quality lighting with controls that nearly halve the energy required for lights in new homes.
- » Water heating: installation of tankless water heaters that reduce energy use by about 35 percent.

Nonresidential

- » Envelope: revision of envelope requirements for all nonresidential and high-rise residential buildings.
- » Lighting: update power for lights to align with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) standards. This allows for the installation of newer, more efficient luminaires which are widely available and commonly used for outdoor lighting applications.
- » Elevators: require controls to shut off lights and fans when an elevator is empty. Installation of these controls enables communication with building energy management systems, allowing managers to tailor the building's energy demands and prevent waste.
- » Escalators and moving walkways: require controls on escalators and moving walkways in transit areas to run at a lower, less energy-consuming speed when not in use.
- » Windows and doors: require interlock controls that turn off cooling and heating systems if a door or window is left open for more than five minutes. This allows occupants to take advantage of outside temperatures and save on heating and cooling costs.

For more information about the 2016 Energy Standards, view the [frequently asked questions](#) and [infographic](#).

Please note that Sections 141.0(b)(2), J, K, and L, related to nonresidential lighting alterations, were not adopted at the June 10, 2015 Business Meeting. Adoption of these sec-

D. Appliance Standards

Appliances, as defined by the Energy Commission, include everything from dishwashers and refrigerators to air conditioners and boilers. The performance of some appliances, such as air conditioners, water heaters, and furnaces, is critical to the *Building Energy Efficiency Standards*. The energy efficiency of other appliances, such as refrigerators, dishwashers, and clothes dryers, is important to homeowners but does not affect the *Building Energy Efficiency Standards*, since these are considered home furnishings.

The Energy Commission has comprehensive standards that affect the performance of many appliances. *Appliance Standards* information is available from the Energy Commission website at <http://www.energy.ca.gov/appliances/>.

E. Appliance Directories

The Energy Commission publishes information on the energy efficiency of appliances. Energy Commission-approved directories can be used to determine if appliances meet

the mandatory measures and/or the prescriptive requirements. Data may also be used in performance calculations. The Energy Standards Hotline can verify certification of appliances and provide information on appropriate directories.

The complete appliance database (including manufacturer, brand codes, rated efficiencies, and so forth) can be searched from the Energy Commission's website at

<http://www.appliances.energy.ca.gov/>

F. Directory of Certified Insulation Materials

Manufacturers whose insulating materials are certified for sale in California are listed in the Department of Consumer Affairs's *Consumer Guide and Directory of Certified Insulation Material*. Each building department receives a copy of this directory. If an insulating product is not listed in the directory, or to purchase a directory, contact the Department of Consumer Affairs, Bureau of Electronic Appliance and Repair, Home Furnishings and Thermal Insulation (BEARHFTI), at (916) 999-2041.

1.9.2 Training Opportunities

California utilities, organizations of energy consultants, building industry, trade associations, and organizations that serve building officials often sponsor or conduct classes on compliance and enforcement of the Energy Standards. These classes are often listed in the *Blueprint* or posted on the Energy Commission's website at <http://www.energy.ca.gov/title24>.

Energy Code Ace offers free tools, training, and resources to help identify the compliance documents, installation techniques, and standards relevant to building projects in California. Energy Code Ace resources provide fact sheets, trigger sheets and checklists to help readers understand when Title 24, Part 6 is "triggered" and how to correctly comply when it is.

This program is funded by California utility customers under the auspices of the California Public Utilities Commission and in support of the Energy Commission.

<http://energycodeace.com/>

1.9.3 Energy Consultants

The California Association of Building Energy Consultants (CABEC) maintains a directory of consultants who provide compliance assistance. The listing is available at <http://www.cabec.org>.

1.9.4 Online Videos

The Energy Commission has a series of streaming videos that explain energy efficiency concepts and the application of the Energy Standards. These videos cover topics including plan checking, field inspection, HVAC, HERS, water heating, building envelope, and renewable energy. They can be viewed at <http://www.energyvideos.com>.

1.9.5 HERS Raters and Providers

To comply with the Energy Standards, some buildings require third-party diagnostic testing or field verification of energy-efficient systems or devices. HERS Raters are required to be hired by the builder or building owner to perform this work. Installing contractors may hire the HERS Rater for HVAC changeouts only if the homeowner agrees that the installing contractor may do so on his or her behalf. The Energy Commission approves HERS providers who train, certify, and monitor HERS Raters. For a list of the current HERS providers, please go the Energy

Commission website at <http://www.energy.ca.gov/HERS/>. To find a Rater, go to the website of the approved HERS provider available on the Energy Commission's website at the link above, or contact the Energy Standards Hotline at (800) 772-3300 (for calls within California) or (916) 654-5106 for assistance.

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2. Compliance and Enforcement

2.1 Overview

The local enforcement agency, typically associated with a city or county government, has primary responsibility for complying with and enforcing the California Energy Commission's *Building Energy Efficiency Standards* (Energy Standards). Low-rise residential buildings must obtain a permit from the local enforcement agency before a new building is constructed, before an addition is constructed, and before alterations are made to existing buildings. Before a permit is issued, the local enforcement agency examines the plans and specifications for the proposed building to verify compliance with all applicable codes and standards. Verification of compliance with the Energy Standards, which is done by comparing the requirements specified on the certificate of compliance (CF1R) with the plans and specifications for the building, is the enforcement agency's plan check responsibility. The enforcement agency's plans examiner verifies that the plans and specifications for the building comply with all other applicable building codes and standards.

Once the enforcement agency has determined that the proposed building (as represented in the 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 proposed building. This is the first significant milestone in the compliance and enforcement process. Once construction starts, the enforcement process begins for the Inspector who will verify that the installed building components (HVAC equipment, fenestration, lighting, insulation, and so forth) match the energy components documented on the certificate of compliance (CF1R) during each respective phase of construction (that is, footing/foundation, rough frame, insulation, and so forth). After construction is complete, the local enforcement agency performs the final inspection and issues the certificate of occupancy. If the enforcement agency's final inspection determines that the building conforms to the plans and specifications approved during plan check, which includes all applicable certificates of installation (CF2R) and certificates of verification (CF3R), forms are registered and submitted for verification, and that it complies with all applicable codes and standards, then the enforcement agency may approve the building permit. The enforcement agency's final approval is also significant.

While the permit and the certificate of occupancy are significant, the compliance and enforcement processes are significantly more involved and require participation from other people and organizations, including the architect or building designer, specialty engineers (mechanical, electrical, civil, and so forth), energy consultants, contractors, the owner, third-party inspectors (Home Energy Rating System [HERS] Raters), and many others. This chapter describes the overall compliance and enforcement process and identifies the responsibilities for each person or organization throughout the permit process.

2.1.1 Compliance Document Registration

§10-103;
Reference Residential Appendix RA2;
Reference Joint Appendix JA7

Registration of compliance documentation is required for the construction and alteration of residential buildings for which HERS verification is required for compliance. Registration requirements will be described in this chapter and elsewhere in this manual, where applicable. Also, *Reference Residential Appendix RA2 and Reference Joint Appendix JA7* provide detailed descriptions of document registration procedures and responsibilities for registration of certificate(s) of compliance (CF1R), certificate(s) of installation (CF2R), and certificate(s) of verification (CF3R).

Registration will be required for all low-rise residential buildings for which compliance requires HERS field verification. For the 2016 Energy Standards, HERS verification will be required, with some exceptions, for all newly constructed homes, so registration will be required for most of these building types. When registration is required, persons responsible for completing and submitting compliance documents are required to submit the compliance form(s) electronically to an approved HERS Provider data registry for registration and retention.

Compliance documents submitted to the registry shall be certified by the applicable responsible person (§10-103). The registry will 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 HERS Provider data registry will retain the registered document, and copies of the unique registered document(s) will be made available via secure Internet website access to authorized users of the HERS Provider data registry. These are used in making electronic or paper copies of the registered document(s) for submittals to the enforcement agency as required and for any other applicable purposes such as posting copies in the field for enforcement agency inspections and providing copies to the building owner. (See Section 2.2.9.)

Examples of authorized users of the HERS Provider data registry may include energy consultants, builders, building owners, construction contractors and installers, HERS Raters, 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 registry will be granted read/write access rights to only the electronic data that pertains to their project(s).

Note: Documents submitted to public agencies for code compliance are considered public information.

2.2 Compliance Phases

2.2.1 Compliance and Enforcement

Complying with and enforcing the Energy Standards in residential buildings involve many parties. Those involved may include the architect or designer, builder/developer, purchasing

agent, general contractor, subcontractor/installer, energy consultant, plan checker, inspector, Realtor, and owner/first occupant. All these parties must communicate and cooperate for the compliance and enforcement process to run efficiently.

The Energy Standards specify detailed reporting requirements that are intended to provide design, construction, and enforcement parties with required information to complete the building process and ensure that the energy features are properly installed. Each party is accountable for ensuring that the energy features of the building are correctly installed in the area of responsibility. This section outlines each phase of the process and discusses responsibilities and requirements associated with them.

The energy compliance documentation has been revised and reorganized. Prescriptive versions of the certificate of compliance (CF1R) have been designed to be used specifically with:

1. Residential Newly Constructed Buildings (CF1R-NCB-01).
2. Residential Additions (CF1R-ADD-01).
3. Residential Alterations (CF1R-ALT-01).
4. Residential HVAC Changeouts (CF1R-ALT-02).
5. Solar (CF1R-SRA-01).

The certificate of installation (CF2R) is separated into:

1. Envelope (CF2R-ENV).
2. Lighting (CF2R-LTG).
3. Mechanical (CF2R-MCH).
4. Plumbing (CF2R-PLB).
5. Solar (CF2R-SPV and CF2R-STH).

These categories and most compliance measures have a separate CF2R form that is specific to a particular installation. CF2R forms also incorporate references to applicable mandatory measures. The HERS certificate of verification (CF3R) forms are categorized and organized in the same way as the certificate of installation (CF2R) forms. Refer to Appendix A of this manual for more information about the forms or to view samples of the forms. Additional information about use of the compliance forms will be provided in applicable sections of this chapter and throughout this manual.

When HERS verification is required for compliance, the Energy Standards require residential energy compliance documents to be registered with a HERS Provider data registry prior to submittal to an enforcement agency. This accomplishes retention of a completed and signed copy of the submitted energy compliance documentation. To simplify the permit process for HVAC changeouts, §10-103 of the Energy Standards allows the registered CF1R-ALT-02 document to be submitted to an enforcement agency at final inspection and not before obtaining a permit. Refer to Chapter 9 of this manual for more details. Document retention is vital to compliance and enforcement follow-up and other quality assurance follow-up processes that ensure realization of energy savings from installed energy features. Refer also to Reference Residential Appendix RA2 and Reference Joint Appendix JA7 for more detailed descriptions of these document registration

procedures that apply to each phase of the building energy code compliance and enforcement process.

2.2.2 Design Phase

§10-103(a)2

This phase sets the stage for the type and style of building to be constructed. In addition to issues concerning zoning, lot orientation, and infrastructure, the overall design and energy features of the building are documented in the construction documents and/or specifications. Parties associated with this phase must ensure that the building complies with the Energy Standards and that the significant features required for compliance are documented on the plans and/or specifications.

During the design process, an energy consultant or other professional will typically assist the building designer by providing energy calculations that determine the effect of building features being proposed for the design to ensure that the final building design plans and specifications submitted to the enforcement agency will comply with the Energy Standards. Throughout the design phase, energy consultants or the documentation author may suggest recommendations or alternatives to help the designer achieve compliance.

The building design plans submitted to the enforcement agency must include the specifications for the building energy features needed to achieve compliance, including insulation levels, window performance, equipment performance, lighting fixture types and controls, exhaust fan performance, envelope sealing, weather-stripping requirements, and any other feature that was used for compliance or is mandatory. The building design plans and specifications must be consistent with respect to the energy efficiency features information on the certificate of compliance (CF1R) submitted to the enforcement agency. Any change in the building plans or specifications, during any phase of design or construction, that changes the energy feature specifications for the design necessitates recalculation of the building energy compliance and issuance of a revised certificate of compliance (CF1R) that is consistent with the revised plans and specifications for the proposed building. If recalculation indicates that the building no longer complies, alternate building features must be selected that brings the design back into compliance with the Energy Standards.

2.2.3 Permit Application

§10-103(a)2
§10-103(a)1C

When the design is complete, the construction documents are prepared, and other approvals (planning department, water, and so forth) are secured, the owner or contractor applies for a building permit. This is generally the last step in a long process of planning and design. At this point, the infrastructure (streets, sewers, water lines, electricity, gas, and so forth) is in place or is being constructed, and it is time to begin constructing the building(s).

To help the enforcement agency verify that the proposed building complies with the Energy Standards, a set of compliance documents is submitted with the building permit application. These documents consist of a certificate of compliance (CF1R), which is required by the

Energy Standards (see §10-103). The length and complexity of the documentation can vary considerably depending on the number of buildings that are being permitted, whether an orientation-independent permit is being requested, whether the performance approach or the prescriptive approach is being used, and many other factors. An energy consultant who understands the code and is able to help the builder or owner comply with the standards in the most cost-effective manner often prepares the certificate of compliance documentation.

The administrative regulations §10-103(a)2 require that documentation be submitted with permit applications that will enable the plans examiner to verify the compliance of the building. The forms used to demonstrate compliance must be readily legible and shall conform to a format and informational order and content approved by the Energy Commission. If registration is required, the CF1R that is submitted to the enforcement agency must be a registered copy from an approved HERS Provider data registry.

2.2.4 Plan Check

The registration process requires the builder or designer to submit the certificate of compliance information and an electronic signature to an approved HERS Provider data registry to produce a completed, signed, and dated electronic certificate of compliance (CF1R) that is retained by the registry. The CF1R is assigned a unique registration number, and then copies of the unique registered CF1R are made available to authorized users of the HERS Provider data registry for use in making electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required.

Local enforcement agencies check plans to ensure that the building design conforms to the building standards. This check includes health and safety requirements, such as fire and structural, and the building energy efficiency requirements. Vague, missing, or incorrect information items on the construction documents are identified by the plans examiner, and when necessary, the permit applicant is required to make corrections or clarifications and then resubmit revised plans and specifications for verification by the plans examiner. When the permit applicant submits accurate, clearly defined plans and specifications, it helps speed up the plan check process, because this provides the plans examiner with all the information needed to complete the plan check review. If the plans examiner must go back to the applicant to request more information, it can be a time-consuming process that would be simplified when complete and accurate construction documents are submitted for plan check approval.

With regard to energy code concerns, from the enforcement agency's perspective, the plan checker's responsibility is to verify that the information contained on the construction documents is consistent with the requirements specified on the energy efficiency compliance documents (the CF1R). Some examples of how the plans examiner will verify that the energy efficiency features detailed on the certificate of compliance (CF1R) forms are specified in the respective sections of the building plans include:

1. Verifying the window and skylight U-Factor and Solar Heat Gain Coefficient (SHGC) values from the CF1R on the structural/architecture plans in a window/skylight schedule, window/skylight legend for the floor plan.

2. Verifying the HVAC equipment SEER, EER, AFUE, and other efficiency values from the CF1R on the Title 24 plans, mechanical plans, and so forth 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.

Since personnel that purchase building materials and the building construction craftsmen in the field may rely solely on a copy of the approved plans and specifications for direction in performing their responsibilities, it is of utmost importance that the building design represented on the approved plans and specifications complies with the Energy Standards as specified on the certificate(s) of compliance (CF1R).

The enforcement agency plans examiner must also verify that the compliance documents do not contain errors. When the compliance documents are produced by Energy Commission-approved computer software applications, there is less chance that there will be computational errors, but the plans examiner must still verify that the building design represented on the plans is consistent with the building energy features represented on the certificate of compliance (CF1R) documents. To obtain a list of Energy Commission-approved energy code compliance software applications, visit the Energy Commission website at <http://www.energy.ca.gov/title24/2013standards/index.html>

Or call the Efficiency Standards Hotline at 1-800-772-3300.

With production homes, where a builder may be constructing several identical houses at roughly the same time, the compliance documentation may be prepared in such a way that a house or model can be constructed in any orientation. In these instances, the plans examiner shall verify that the home complies facing all four main compass points (north, south, east, and west) on the CF1R form.

2.2.5 Building Permit

After the plans examiner has approved the plans and specifications for the project, the enforcement agency may issue the building permit at the builder's request. Issuance of the building permit is the first significant milestone in the compliance and enforcement processes. The building permit is the green light for the contractor to begin the work. In some cases, the building permits are issued in phases. Sometimes there is a permit for site work and grading that precedes the permit for actual building construction.

2.2.6 Construction Phase

Upon receiving a building permit from the local enforcement agency, the contractor begins construction. The permit requires the contractor to construct the building in accordance with the plans and specifications, but often there are variations. Some of these variations are formalized through change orders. When change orders are issued, it is the responsibility of the permit applicant and the local jurisdiction to verify that compliance with the code is not compromised by the change order. In some cases, it will be clear if a change order would compromise compliance, for instance, when an inexpensive single glazed window is substituted for a more expensive high performance window. It may be difficult, however, to determine if a change order would compromise compliance; for instance, when the location

of a window is changed, or when the orientation of the house is changed. Field changes that result in noncompliance require enforcement agency approval of revised plans and revised energy compliance documentation to confirm that the building still complies with the Energy Standards.

During construction the general contractor or specialty subcontractors are required to complete various certificate(s) of installation (CF2R). These certificates verify that the contractor is aware of the requirements of the Energy Standards and that they have followed the Energy Commission-approved procedures for installation, and to identify the energy efficiencies and features of the installed building components. The certificate(s) of installation (CF2R) are a collection of energy compliance information forms that are applicable to each regulated energy feature that may be included in the construction. The certificates are required to be completed by each of the applicable specialty contractors when they install regulated energy features such as windows, water heater and plumbing, HVAC ducts and equipment, lighting, and insulation.

The licensed person responsible for the building construction, or for installation of an energy-related feature, must ensure their construction or installation work is done in accordance with the approved plans and specifications for the building, and must complete and sign a certificate of installation (CF2R) to certify that the installed features, materials, components or manufactured devices for which they are responsible conform to the plans and specifications and the certificate of compliance (CF1R) documents approved by the enforcement agency for the building. A copy of the completed, signed, and dated CF2R must be posted at the building site for review by the enforcement agency in conjunction with requests for final inspection for the building, and copies of the registered CF2R forms shall be provided to the homeowner.

When any HERS verification is required for compliance, all of the CF2R forms must be registered from an approved HERS Provider data registry. When registration is required, the builder or installing contractor must submit information to an approved HERS Provider data registry to produce a completed, signed and dated electronic certificate of installation (CF2R) that is retained by the registry for use by authorized users of the registry. After the information to complete the CF2R document is transmitted to the data registry and the form is electronically signed, the CF2R is assigned a registration number, and copies of the unique registered CF2R are made available to authorized users of the HERS Provider data registry for use in making electronic or paper copies of the registered document(s) for submittal to the enforcement agency as required. The builder or installing contractor responsible for the installation must provide a copy of the completed, signed, and registered certificate of installation to the HERS Rater and post a copy at the building site for review by the enforcement agency in conjunction with requests for final inspection, and provide copies of the registered CF2R forms to the homeowner.

For additional information and details regarding the registration of CF2R documents, refer to Reference Residential Appendix RA2 and Reference Joint Appendix JA7.

2.2.7 Enforcement Agency Field Inspection

§10-103(d)

Local enforcement agency representatives inspect all new buildings to ensure compliance with the Energy Standards. Field construction changes and noncomplying energy features require parties associated with previous phases to repeat and revise their original energy compliance documents, or reinstall building components that meet the building specifications and energy compliance documents.

Enforcement agencies generally make multiple visits to a building site to verify construction. The first visit is typically made just before it is time to pour the slab or the building foundation. At this visit, the building inspector verifies that the proper reinforcing steel is in place and that necessary wiring and plumbing that will be embedded in the slab meet the requirements of the standards. The inspector should verify features that are to be installed in concrete slab floors, such as slab edge insulation or hot water recirculation loops that involve piping that must be installed in the slab. The inspector should also verify the front orientation and floor assembly types (such as slab on grade, raised floor, and others) of the building during this phase of construction. Details of how the inspector should verify these components will be discussed further in Chapter 3 of this manual.

The second visit generally occurs after the walls have been framed, and the HVAC equipment and ducting, fenestration, lighting cans, electrical wiring, plumbing, and other services have been constructed or installed. This inspection is recommended to be made before the insulation is installed, since it is the best time to assure the completion of sealing and caulking around windows, and the caulking and sealing of any holes bored through the framing members for installation of hot and cold water piping and electrical wiring. During the rough frame inspection, it is also best for the inspector to verify the installation of the high-efficacy lighting (or the applicable lighting control alternatives) so that the contractor has ample time to make any necessary corrections before the final inspection, and to avoid having to remove drywall, insulation, and so forth to remove an incandescent can. The inspector should also verify the window/skylight U-factor and SHGC values, the proper sealing/installation of HVAC ducts and duct insulation R-value, the installation of exhaust fan housing and ducting in bathrooms and kitchens (ASHRAE 62.2.), installation of a radiant barrier and/or cool roof when required for compliance. during this phase of construction. Details of how the inspector should verify these components will be discussed further in the respective chapters of this manual.

The third visit is the insulation inspection, which takes place after the wall, ceiling, and floor insulation have been installed. This inspection occurs before the drywall is installed to verify that the insulation R-value matches the CF1R form, and that the insulation has been properly installed without compressions, voids, or gaps. The inspector should verify that insulation is installed correctly around and behind piping, and that all exterior walls are insulated (especially behind obstructing objects like a bathtub). Details of how the inspector should verify these components will be discussed further in Chapter 3 of this manual.

The next visit is usually a drywall inspection, where the inspector verifies that the drywall is installed properly to limit infiltration and exfiltration, especially at locations surrounding lighting cans, HVAC registers and vents, electrical sockets, and so forth.

The final inspection is conducted after the walls have been closed and the final electrical and plumbing fixtures are in place. The inspector should verify HVAC efficiency values, water heating efficiency values, exhaust fan cfm and sone (noise level) ratings in bathrooms and kitchens (ASHRAE 62.2), exterior lighting and controls, weatherstripping on exterior/demising doors, etc. during this phase of construction. The inspector will also verify that all required CF2R and CF3R forms have been completed, signed, and registered (when applicable), and that copies of all of these forms have been provided to the building owner. Details of how the inspector should verify these components will be discussed further in the respective chapters of this manual.

The typical enforcement agency inspection sequence can vary from jurisdiction to jurisdiction, and it can be difficult for the enforcement agency to verify every energy efficiency measure required to be installed in the building. For example, exterior wall insulation will likely not be installed at the time of the framing inspection; if the enforcement agency does not include the insulation inspection in its field inspection process, the exterior wall insulation would be concealed from an inspector's view at the time of the final inspection.

For this and other reasons, the certificate(s) of installation (CF2R) and, when required, the certificate(s) of verification (CF3R) are crucial. When inspection of an installed energy feature would be impossible because of subsequent construction, the enforcement agency may require the CF2R for the concealed feature to be posted at the site or made available to the inspector upon completion/installation of the feature. In these instances, to simplify the inspection, the inspector would reference the efficiency values and building components specified on the submitted CF2R form to verify compliance with the Energy Standards.

When registration is required, all certificate(s) of installation (CF2R) must be registered copies from an approved HERS Provider data registry. For all measures requiring field verification, a registered certificate of verification (CF3R) shall also be made available to the building inspector.

2.2.8 Field Verification and/or Diagnostic Testing

Some building features require field verification and/or diagnostic testing completed by a third party-inspector, called a HERS Rater, as a condition for compliance with the standards. The Energy Commission has established the California Home Energy Rating System (HERS) program to train and certify HERS Raters who are considered special inspectors by enforcement agencies. When compliance with the Energy Standards is based on energy features that require third-party (HERS) verification, a certified HERS Rater is required to perform field verification and/or diagnostic testing according to the procedures in Reference Residential Appendix RA2 using the protocols specified in Reference Residential Appendix RA3.

There are mandatory measures, prescriptive measures, and performance credits that require HERS field verification and/or diagnostic testing. Most of the typical measures that require HERS field verification and/or diagnostic testing involve air-conditioning equipment and forced air ducts that deliver conditioned air to the dwelling. Examples of measures requiring HERS verification are refrigerant charge measurement and duct sealing.

The Energy Standards mandate that all newly constructed homes have duct sealing (leakage testing), duct system airflow and fan watt draw (and installed HSPP/PSPP), and exhaust fans/systems (ASHRAE 62.2.) verified by a HERS Rater when those systems are installed. Details about these specific HERS measures and others will be discussed in the HVAC chapter (Chapter 4) of this manual.

Additional measures requiring field verification include reduced duct surface area, increased duct R-value, high EER cooling equipment, and quality installation of insulation. For a full list of measures requiring field verification and/or diagnostic testing, refer to Table RA2-1 of the *2016 Reference Residential Appendices*. The requirements for field verification and/or diagnostic testing apply only when equipment or systems are installed. For example, if a house has no air distribution ducts, then a HERS Rater does not have to test them.

The HERS Rater must verify the required features and transmit all required data describing the feature and the results of the verification or diagnostic test to an approved HERS Provider data registry. The HERS Rater must also confirm that the installed energy feature being verified is consistent with the requirements for that feature as specified on registered copies of the CF1R approved by the enforcement agency for the dwelling, and that the information on the CF2R is consistent with the CF1R. The test results reported on the CF2R by the person responsible for the installation must be consistent with the test results determined by the HERS Rater's diagnostic verification and meet the criteria for compliance with the standards. A copy of the registered CF2R must be posted at the building site for review by the enforcement agency and made available for all applicable inspections. A copy of the registered CF2R must also be left in the dwelling for the homeowner at occupancy.

Results from the rater's field verification or diagnostic test are reported to the HERS Provider data registry with either a "pass" or "fail." If the results indicate "pass," the HERS Provider data registry will make available a registered copy of the certificate of verification (CF3R). A copy of the registered CF3R must be posted at the building site for review by the enforcement agency and made available for all applicable inspections. A copy of the CF3R must be provided to the builder, and a copy must also be left in the dwelling for the homeowner at occupancy. If field verification and /or diagnostic testing indicates "fail," that failure must be entered into the HERS Provider data registry. HERS Providers shall not permit any user of the registry to print or access electronically CF3R forms for noncompliance entries unless the CF3R form contains a watermark with the word "FAIL" or "FAILURE," making it abundantly clear the result of the test was a failure. Corrective action shall be taken by the builder or installer on the failed measure, and the measure shall be retested by the HERS Rater to verify that the corrective action was successful. Once determined to be corrected, the passing measure shall be entered into the HERS Provider data registry.

2.2.9 Approval for Occupancy

In multifamily dwellings of three or more units, the final step in the compliance and enforcement process is the issuance of an occupancy permit by the enforcement agency. This is the "green light" for occupants to move in. Single-family homes and duplexes may be approved for occupancy without an occupancy permit being issued. Often a signed-off final inspection serves as an approval for occupancy. When HERS verification is required before

occupancy approval, the HERS Rater must post a signed and registered CF3R in the field for the building inspector to verify at final inspection. The HERS Rater must also provide a copy of the registered CF3R to the builder, and a copy must be left in the building for the building owner at occupancy. Only registered CF3R documents are allowed for these document submittals. Handwritten versions of the CF3R are not allowed for document submittals.

2.2.10 Occupancy

At the occupancy phase, the enforcement agency shall require the builder to leave inside the building all completed, signed, and dated compliance documentation, which includes at a minimum the CF1R and all applicable CF2R forms. When HERS field verification is required, a copy of the registered CF3R is also required to be left on site with the compliance documentation. When registration is required, the CF1R and all required CF2R compliance documentation shall be registered copies as well. The builder is required to provide the homeowner with a manual that contains instructions for operating and maintaining the features of his or her building efficiently. See Section 2.3.5 for more details.

2.3 Compliance Documentation

Compliance documentation includes the forms, reports, and other information that are submitted to the enforcement agency with an application for a building permit. It also includes documentation completed by the contractor or subcontractors to verify that certain systems and equipment have been installed correctly. It may include reports and test results by third-party inspectors (HERS Raters). Ultimately, the compliance documentation is included with a homeowner's manual so that the end user knows what energy features are installed in the house.

Compliance documentation is completed at the building permit phase, the construction phase, the field verification and diagnostic testing phase, and at the final phase. The required forms and documents are shown in Table 2-1 and described in the rest of this section in more detail. When registration is required, all of the compliance documentation shall be registered copies from an approved HERS Provider data registry.

Table 2-1: Documentation Requirements, Prescriptive and Performance Compliance Methods

Phase	Method	Documentation Required When Applicable
Building Permit	Performance	CF1R-PRF-E, Certificate of Compliance
	Prescriptive	CF1R-NCB-01-E, Certificate of Compliance
	Prescriptive	CF1R-ADD-01-E, Certificate of Compliance Additions less than 1,000 ft2)
	Prescriptive	CF1R-ALT-01-E, Certificate of Compliance (Residential Alterations)
	Prescriptive	CF1R-ALT-02-E, Certificate of Compliance (Alterations to HVAC systems)
	Prescriptive	CF1R-ENV-02-E, Worksheet for area weighted average
	Prescriptive	CF1R-ENV-03-E, Worksheet for solar heat gain coefficient (SHGC)
	Prescriptive	CF1R-ENV-04-E, Worksheet for cool roofs and SRI
	Prescriptive	CF1R-SRA-01-E, Worksheet solar ready areas
	Prescriptive	CF1R-SRA-02-E, Worksheets for minimum solar zone area
	Prescriptive	CF1R-PLB-01-E, Worksheet for hydronic heating systems
	Prescriptive and Performance	CF1R-STH-01-E, Worksheet for OG 300 solar water heating systems
	Prescriptive and Performance	CF1R-STH-02-E, Worksheet for OG 100 solar water heating systems
Construction	Prescriptive and Performance	CF2R-E, Certificate of Installation
	Prescriptive and Performance	CF2R-H, HERS Certificate of Installation
Field Verification and/or Diagnostic Testing	Prescriptive and Performance	CF3R-H, Certificate of Verification (HERS Rater)
Field Verification and/or Diagnostic Testing	Performance	CF3R-EXC-20-H, Certificate of Verification for Existing Conditions (HERS Rater)
Refer to Appendix A of this manual for a complete list and samples of all energy compliance forms.		

2.3.1 Building Permit Phase Documentation

§10-103(a)

The compliance documentation required at the building permit phase consists of the certificate of compliance (CF1R) on the building plans and, depending on the compliance approach, the energy compliance documentation package may also include the area weighted average calculation worksheet (CF1R-ENV-02-E), the solar heat gain coefficient

(SHGC) worksheet (CF1R-ENV-03-E), the cool roof and SRI worksheet (CF1R-ENV-04-E) and the solar worksheets (CF1R-SRA-02-E, CF1R-STH-01-E, and CF1R-STH-02-E). Blank copies of these documents are included in Appendix A of this manual for use with the prescriptive compliance requirements. When the performance approach is used, only the CF1R-STH worksheets are needed since the Energy Commission-approved software performs the calculations and provides the necessary documentation contained in all other worksheets. However, when the performance approach is used, only the CF1R forms are required on the building plans.

The compliance documentation enables the plans examiner to verify that the building design shown in the plans and specifications complies with the Energy Standards and enables the field inspector to identify which building features are required for compliance and will be verified in the field.

2.3.2 Certificate of Compliance (CF1R)

The Energy Standards require the certificate of compliance to be incorporated into the plans for the building and submitted to the enforcement agency. The CF1R form identifies the minimum energy performance specifications selected by the building designer or building owner for compliance and may include the results of the heating and cooling load calculations.

To meet the requirement for filing a copy of the CF1R with the plans for the building, builders/contractors should ask the local enforcement agency for information about their preferences or requirements for document submittal procedures. Most local jurisdictions may require the CF1R to be embedded in the building design computer-aided drafting (CAD) file for plotting on sheets that are the same size as the plan set sheets of the building design; thus, the CF1R documentation would be submitted as energy compliance design sheets integral to the entire plan set for the building. On the other hand, some jurisdictions may allow taping CF1R document sheets to the submitted design drawings for the building, while others may allow simply attaching 8-½-inch x 11-inch printed CF1R document reports to the submitted design drawing package.

When the prescriptive approach is used for additions and alterations, a shorthand version of the certificate of compliance shall be submitted with the building plans or with the permit application when no plans are required. In these instances, a CF1R-ADD form is required to be submitted for additions, a CF1R-ALT-01 form is required for alterations, and a CF1R-ALT-02 form is required for HVAC changeouts. (See Chapter 9 for more details.)

For low-rise residential buildings for which compliance requires field verification, the CF1R submitted to the enforcement agency must be a registered copy from an approved HERS Provider data registry. Refer to Reference Residential Appendix RA2 and Reference Joint Appendix JA7 for more information about document registration.

2.3.3 Construction Phase Documentation (CF2R)

§10-103(a)3

The certificate(s) of installation (CF2R) are separated into Envelope (CF2R-ENV), Lighting (CF2R-LTG), Mechanical (CF2R-MCH), Plumbing (CF2R-PLB), and Solar (CF2R-SPV and CF2R-STH) categories, and most compliance measures have a separate CF2R form that is specific to a particular installation. The CF2R forms must be completed during the construction or installation phase of the compliance and enforcement process. The CF2R documents must be completed by the applicable contractors who are responsible for installing regulated energy features such as windows (fenestration), the air distribution ducts and the HVAC equipment, the exhaust fans/ventilation system, the measures that affect building envelope tightness, the lighting system, and the insulation. The CF2R must be posted at the job site in a conspicuous location (for example, in the garage) or kept with the building permit and made available to the enforcement agency upon request.

When field verification and/or diagnostic testing of a feature is required for compliance (as shown in the HERS Required Verification section of the CF1R), the builder or the builder's subcontractor must perform the initial field verification or diagnostic testing of the installation to confirm and document on the applicable CF2R compliance with the standards using the applicable procedures specified in Reference Residential Appendix RA3. The builder, the builder's subcontractor, or authorized representative must submit the CF2R information to an approved HERS Provider data registry. All CF2R information submittals must be done electronically (registration) when HERS verification/testing is required.

2.3.4 Field Verification and/or Diagnostic Testing Documentation (CF3R)

§10-103(a)5

Within the Energy Standards, some of the mandatory measures, some of the prescriptive requirements, and some of the measures that may be used for compliance in the performance approach may require field verification and/or diagnostic testing. This testing must be performed by a third-party inspector who is specially trained and independent from the builder or general contractor. The Energy Commission recognizes HERS Raters for this purpose.

When field verification and/or diagnostic testing is required, the HERS Rater must complete, register, and sign/certify the certificate of verification (CF3R). The CF3R documents include information about the measurements, tests, and field verification results that were required to be performed. The HERS Rater must verify that the requirements for compliance have been met.

The HERS Rater chosen for the project must transmit the CF3R information to an approved HERS Provider data registry. This must be the same HERS Provider data registry through which the previous compliance documents (CF1R, CF2R) for the project were registered. The HERS Rater used for the project must be certified by the HERS Provider into whose registry the project has been entered. A registered CF3R from the provider that has been signed or certified by the Rater is made available to the enforcement agency and to the builder when HERS verification confirms compliance. The builder is ultimately responsible

for ensuring that the enforcement agency has received the CF3R prior to the occupancy permit or final inspection.

Raters shall provide a separate registered CF3R form for each house that the Rater determines has met the verification or diagnostic requirements for compliance. The HERS Rater shall not sign a CF3R for a house that does not have a registered CF2R that has been signed/certified by the installer. If the building was approved as part of a sample group, the CF3R will include additional information that identifies whether the building was a “tested” or a “not tested” building from the sample group. The CF3R form for the “tested” home of a sample group will include the test/verification results, but the “not tested” homes will not. CF3R forms for “not tested” homes in a sample group will still have a registration number, date, time, and so forth. and a watermark of the HERS Provider’s seal. Refer to Reference Residential Appendix RA2 for more details on HERS verification and CF3R documentation procedures.

2.3.5 Compliance, Operating, Maintenance, and Ventilation Information to Be Provided by Builder

§10-103(b)

The final documentation in the compliance and enforcement process is the information that is provided to the homeowner. At the completion of construction and before occupancy, the enforcement agency shall require the builder to leave in the building the applicable completed, signed and dated compliance documentation including, at a minimum, the applicable CF1R forms, CF2R forms, and, if compliance required HERS verification, the applicable CF3R forms. When registration is required, all these compliance documents shall be registered copies. In addition to the compliance documentation, the builder must leave in the building all operating and maintenance information for all installed features, materials, components, and manufactured devices. The operating and maintenance information must contain the details needed to provide the building owner/occupant with instructions on how to operate the home in an energy-efficient manner and to maintain it so that it will continue to work efficiently into the future. For individually owned units in a multifamily building, the documentation must be provided to the owner of the dwelling unit or to the individual(s) responsible for operating the feature, equipment, or device. Information must be for the appropriate dwelling unit or building. (Paper or electronic copies of these documents are acceptable.)

Example 2-1

Question

What are the plan checking/field inspection requirements related to the CF-2R?

Answer

The CF2R (certificate of installation) is not submitted with compliance documentation at the time of permit application but rather is posted or made available for field inspection after installation. A field inspector should check the equipment that is actually installed against what is listed on the CF2R and compare the CF2R and CF1R for consistent equipment characteristics. The field inspector should do this for all installed building components indicated on a CF2R form (HVAC, fenestration, insulation, water heating, and so forth).

When HERS verification is required for compliance, the field inspector should check the HERS required verification listings on the CF1R to identify the required installer tests and verify that these tests were performed and documented on the applicable certificate(s) of installation (CF2R).

The enforcement agency may request additional information to verify that the installed efficiency measures are consistent with the approved plans and specifications. When material properties or equipment efficiencies greater than the minimum requirements are shown on the CF1R, the enforcement agency may have procedures for verifying the actual material or equipment specifications. For example, the enforcement agency may require the installer to provide a copy of the applicable page(s) from a directory of certified equipment.

Example 2-2

Question

What happens to the CF2R after the final inspection?

Answer

§10-103(b) requires the builder to leave a copy of the CF2R in the building for the building owner at occupancy.

Example 2-3

Question

As a general contractor, when I have finished building a home, is there a list of materials I am supposed to give to the building owner?

Answer

Section 10-103(b) requires that at final inspection the enforcement agency shall require the builder to leave compliance, operating, maintenance, and ventilation information in the building for the “building owner at occupancy,” which includes the:

1. Certificate of compliance (CF1R).
2. Certificate(s) of installation (CF2R).
3. Certificate(s) of verification (CF3R) if applicable.
4. Operating information for all applicable features, materials, components, and mechanical devices installed in the building.
5. Maintenance information for all applicable features, materials, components, and manufactured devices that require routine maintenance for efficient operation.

Example 2-4

Question

I built some multifamily buildings and have some questions about the information I must provide to the building owner at occupancy (as required by §10-103(b)). Specifically:

If the building is a condominium, can I photocopy the same CF1R information for all units?

When the building is an apartment complex (not individually owned units), who gets the documentation?

If an apartment is converted to condominiums, does each owner/occupant receive copies of the documentation?

Answer

Photocopied information is acceptable. It must be obvious that the CF1R documentation applies to that dwelling unit. That is, the features installed must match the features shown on the certificate(s) of installation (CF2R). If the CF1R compliance documentation is for a “whole building,” a photocopy of the CF1R compliance form for that building must be provided. If individual compliance is shown for each unique dwelling unit, a photocopy of the documentation that applies to that dwelling unit must be provided. The copies may be in paper or electronic format.

The documentation and operating information are provided to whoever is responsible for operating the feature, equipment, or device (typically the occupant). Maintenance information is provided to whoever is responsible for maintaining the feature, equipment or device. This is either the owner or a building manager (§10-103(b)).

If, during construction, the building changes from an apartment to condominiums, each owner at occupancy would receive the documentation. If an existing apartment building changes to condominiums at a later date, the documentation requirements are triggered only by a building permit application requiring compliance with the Energy Standards. (Changing occupancy does not trigger compliance with the standards.)

2.4 Roles and Responsibilities

2.4.1 Designer

5537 and 6737.1 of California Business and Professions Code

The designer is the person responsible for the overall building design. As such, the designer is responsible for specifying the building features that determine compliance with the Energy Standards and other applicable building codes. The designer is required to provide a signature on the certificate of compliance (CF1R) to certify that the building has been designed to comply with the Energy Standards.

The designer may personally prepare the certificate of compliance documents or may delegate preparation of the energy analysis and certificate 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 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 his or her responsibility for the information submitted on the certificate of compliance.

The designer may be an architect, engineer or other California-licensed professional; however, a licensed design professional may not always be required for low-rise residential buildings. *The California Business and Professions Code* allows unlicensed designers to prepare design documentation for wood-framed single-family residential building as long as the dwellings are no more than two stories high, not counting a possible basement. Two-story, wood-framed multifamily buildings may also be designed by unlicensed designers as long as the building has four or fewer dwelling units. For homes that do not require a licensed design professional, the builder may sign the certificate of compliance (CF1R) in the “Responsible Building Designer’s” signature block. When the designer is a licensed professional, the signature block on the certificate of compliance must include the designer's license number.

When certificate of compliance document registration is required, the certificate of compliance must be submitted to an approved HERS Provider data registry. All submittals to the HERS Provider data registry must be made electronically.

2.4.2 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 of compliance documentation to a building energy consultant or documentation author. A completed Certificate of Compliance must be submitted to the enforcement agency during the building permit phase. The certificate of compliance demonstrates to the enforcement agency plan checker that the building design complies with the Energy Standards; thus, the building energy features information submitted on the certificate of compliance must be consistent with the building design features defined in the plans and specifications for the building submitted to the enforcement agency.

The documentation author is not subject to the same limitations and restrictions of the *Business and Professions Code* as is the building designer because the documentation author is not responsible for specification of the building design features. The documentation author may provide the building designer with recommendations for building energy features, and if those recommendations are approved by the building designer, the features 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 of compliance certifies that the documentation he or she has prepared is accurate and complete but does not indicate documentation author responsibility for the specification of the features that define the building design. The documentation author provides completed certificate of compliance documents to the building designer, who must sign the certificate of compliance before submitting the certificate of compliance to the enforcement agency at plan check.

If registration of the certificate of compliance is required, the certificate of compliance must be submitted to the HERS Provider data registry and signed electronically by both the designer and documentation author before submitting to the enforcement agency. When document registration is required, only registered certificates of compliance that display the registration number assigned to the certificate by an approved HERS Provider data registry are acceptable for submittal to the enforcement agency at plan check.

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

2.4.3 Builder or General Contractor

Chapter 9 of the *Business and Professions Code* specifies that for that chapter, the term "contractor" is synonymous with the term "builder." This manual uses the term "builder" to similarly refer to the general contractor responsible for construction. For production homes, the builder may also be the developer with responsibility for arranging financing, acquiring the land, subdividing the property, securing the necessary land planning approvals, and attending to the other necessary tasks that are required before actual construction. Many

production builders are also involved in the marketing and sales of homes after they are constructed.

During the construction process, the builder or general contractor usually hires specialty subcontractors to provide specific services, such as installing insulation, designing and installing HVAC systems, installing windows and skylights, installing water heating systems, and other services. For homes that do not require a licensed design professional, the builder may sign the certificate of compliance (CF1R) in the “Responsible Building Designer’s” signature block.

The builder or general contractor must ensure that certificate(s) of installation (CF2R) are submitted to the enforcement agency by the person(s) responsible for the construction/installation of regulated features, materials, components, or manufactured devices. The builder or general contractor may sign the certificate of installation on behalf of the specialty subcontractors they hire, but generally, certificate of installation preparation and signature responsibility reside with the specialty subcontractor who provided the installation services. The certificate of installation identifies the installed features, materials, components, or manufactured devices detailed in the plans and specifications, and the certificate(s) of compliance approved by the local enforcement agency. If the installation requires field verification and diagnostic testing by a HERS Rater, the certificate of installation must report the results of the installer’s testing of the regulated installations to measure performance, and the CF2R shall be submitted to an approved HERS Provider data registry. A copy of the registered certificate 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 CF1R information to an approved HERS Provider data registry. The builder or general contractor must arrange for the services of a certified HERS Rater if the certificate of compliance indicates that third-party field verification and diagnostic testing by a HERS Rater is required. The builder or general contractor must ensure that a copy of the certificate of compliance that was approved by the designer/owner and submitted to the enforcement agency during the permitting phase is transmitted to the HERS Provider data registry and made available to the HERS Rater who will perform any required field verification and diagnostic testing.

When installation work is complete, the builder or general contractor must ensure that the persons responsible for the installation have transmitted/submitted the required certificate of installation information to the HERS Provider data registry. Moreover, the builder must ensure that the HERS Rater receives a copy of the completed certificate of installation (CF2R) or provide access into the data registry that has been registered and signed by the builder or subcontractors responsible for the installation. When registration of the certificate of installation is required, the completed and signed copies that are posted at the building site for review by the enforcement agency, in conjunction with requests for final inspection, are required to be registered copies.

At final inspection, the builder or general contractor is required to leave in the building all applicable completed, signed, dated, and registered (when applicable) compliance

documents for the building owner at occupancy. Such information must, at a minimum, include information indicated on the following forms: certificate of compliance (CF1R); certificate(s) of installation (CF2R); and for buildings for which compliance requires HERS field verification, certificate(s) of verification (CF3R). These forms must be in paper or electronic format and must conform to the applicable requirements of §10-103(a).

2.4.4 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 systems, 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 (CF2R) forms. The licensed specialty subcontractor, however, should be expected to complete and sign/certify all applicable certificate(s) of installation that document the completion of the installation work they have performed for the builder. The subcontractor's responsibility for certificate of installation documentation should include providing a registered (when applicable) and signed copy of all applicable CF2R's to the builder, posting a registered (when applicable) and signed copy of all applicable CF2Rs at the building site for review by the enforcement agency, and making available to the HERS Rater the registered and signed copies of the applicable CF2Rs if HERS third-party field verification is required for compliance, as specified on the certificate of compliance (CF1R).

When the standards require document registration, all copies of the certificate(s) of installation documentation submitted to the builder, the enforcement agency, and the HERS Rater are required to be registered copies prepared in accordance with the procedures described in Reference Residential Appendix RA2, Reference Joint Appendix JA7, and Section 2.3 of this manual.

2.4.5 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.

2.4.5.1 Plan Check

The enforcement agency performs plan check review of the certificate(s) of compliance documentation and of the plans and specifications that define the building design submitted to the enforcement agency at the building permit phase. During plan check, the enforcement agency compares certificate of compliance documentation to the plans and specifications for the building design to confirm that the building features that describe the building are specified consistently in all of the documents submitted. If the specification for building design features shown on the certificate of compliance does not conform to the specifications shown on the designer's submitted plans and specifications for the building,

the designer must revise the submitted documents to make the design specification consistent in all documents. Thus, if the certificate of compliance indicates the building complies, and the features on the certificate of compliance are consistent with the features given in the plans and specifications for the building design, then the plan check process can confirm that the building design complies with the building energy code. If the enforcement agency determines that the building design complies with the building energy code, in addition to all of the other building codes, it may issue a building permit. When the standards require document registration, the certificate of compliance documentation that is submitted to plan check must be a registered document from an approved HERS provider data registry. The one exception to this requirement is for the CF1R-ALT-02-E that is used for HVAC change-outs. If approved by the enforcement agency, permit applicants may use unregistered CF1R-ALT-03-E or CF1R-ALT-04-E documents (dependent upon climate zone) to apply for permits and present the registered CF1R-ALT-02-E to the inspector at the time of the final permit.

2.4.5.2 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 house are consistent with the requirements given in the plans and specifications for the building approved during plan check, that the installed features are described accurately on the certificate(s) of installation; and that 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 dwelling unit until the enforcement agency has received all applicable certificate(s) of installation. When the standards require registration of the energy compliance documents, the certificate(s) of installation documentation must be registered with an approved HERS Provider data registry.

2.4.5.3 Corroboration of Field Verification and Diagnostic Testing Procedures

As described in Reference Residential Appendix Section RA2.4.4, at its discretion, the enforcement agency may require that field verification and diagnostic testing performed by the builder or subcontractors or the certified HERS Rater must be scheduled to be performed at a time when the enforcement agency's field inspector can observe the verification or test procedures to corroborate the results reported/documented on the certificate(s) of installation (CF2R) and/or the certificate(s) of verification (CF3R).

2.4.5.4 Sampling Within Enforcement Agency Jurisdictions

When sampling is used for HERS verification compliance for newly constructed buildings, all dwellings in a designated sample group must be located within the same enforcement agency jurisdiction and subdivision or multifamily housing development, as specified in Reference Residential Appendix Section RA2.6.3.1

When sampling is used for HERS verification compliance for alterations, the dwellings in a designated sample group are not required to be located within the same enforcement agency jurisdiction, and the building owner may choose for the field verification and diagnostic testing to be completed as part of a designated sample group composed of dwelling units for which the same installing company has completed the work that requires field verification and diagnostic testing for compliance, as specified in Reference Residential Appendix Section RA2.8. However, to enable the enforcement agency to schedule testing to accomplish the corroboration described in the previous section, the enforcement agency may choose to require that a separate dwelling unit from the sample group that is located within the respective jurisdiction be tested.

2.4.5.5 Final Approval

The enforcement agency may approve the dwelling at the final inspection phase if the enforcement agency field inspector determines that the dwelling conforms to the requirements of the plans and specifications of the building and certificate of compliance documents approved by the enforcement agency at plan check, and meets the requirements of all other applicable codes and standards. For dwelling units that have used an energy efficiency compliance feature that requires certificate of installation documentation, the enforcement agency shall not approve the dwelling unit until the enforcement agency has received a certificate of installation that meets the requirements of §10-103(a) that has been completed, signed, and registered (when applicable) by the builder or subcontractor.

For dwelling units that require third-party HERS field verification and diagnostic testing for compliance, the enforcement agency shall not approve the dwelling unit until the enforcement agency has received a registered copy of the certificate of verification that meets the requirements of §10-103(a) and has been signed and dated by the HERS Rater. The builder must ultimately take responsibility to ensure that all such required energy compliance documentation has been completed properly and posted at the job site or submitted to the enforcement agency in conjunction with any of the enforcement agency's required inspections. However, the enforcement agency, in accordance with §10-103(d), as a prerequisite to approval of the building, must examine all required copies of certificate(s) of installation (CF2R) documentation and certificate(s) of verification (CF3R) documentation posted at the site or made available with the building permits for the required inspections. This is to confirm that they have been properly prepared and are consistent with the plans and specifications and the certificate of compliance documentation approved by the enforcement agency for the building at plan check.

When an alteration has been performed by a participating Third Party Quality Control Program (TPQCP) contractor (see Section 2.4.8 of this manual), the enforcement agency may conditionally approve the building based on the certificate of installation (CF2R) if the TPQCP data checking has indicated that the installation complies. However, if subsequent HERS compliance verification procedures determine that resampling, full testing, or corrective action is necessary for such conditionally approved dwellings in the group, the corrective work must be completed. Refer to Reference Residential Appendix RA2.4.3, RA2.7, and RA2.8 for additional information on TPQCP requirements.

2.4.5.6 Corroboration of Information Provided for the Owner/Occupant

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

Compliance documents for the building shall, at a minimum, include information indicated on forms: certificate of compliance (CF1R), certificate(s) of installation (CF2R), and, for buildings for which compliance requires HERS field verification, certificate(s) of verification (CF3R). These forms 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, such information shall be provided to the person(s) responsible for operating the feature, material, component, or mechanical device installed in the building. This operating information shall be in paper or electronic format.

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.

Example 2-5

Question

We are an enforcement agency with jurisdiction over the replacement of the outdoor compressor/condenser unit of an HVAC unit (an alteration), and the HVAC contractor who pulled the permit for replacing the unit has requested that we approve the final inspection and close out the permit based only on the certificate of installation (CF2R) for this job. This job requires HERS verification, and I thought it was necessary to receive the HERS Rater's completed and signed certificate of verification (CF3R) before the job could be considered to be in compliance as a condition to final approval of the installation. Is there an allowance for compliance based only on the CF2R?

Answer

Yes. The enforcement agency may provide a "conditional" final approval of the installation based upon the CF2R for alterations jobs only, and only if the installing contractor is an approved Third Party Quality Control Program (TPQCP) installing contractor. The conditional final approval is allowed if TPQCP data checking has scrutinized the diagnostic test data submitted by the approved contractor's diagnostic test for the installation, and such data checking indicates the installation complies as shown on the CF2R.

The permittee is still required to complete all HERS verification procedures and comply with all HERS verification criteria, and a CF3R is still required to be submitted to the enforcement agency, builder, and homeowner for the documentation procedure to be complete. If HERS verification of the approved TPQCP contractor's installation work determines that resampling, full testing, or corrective action is necessary to bring the installation into compliance, such work must be completed before issuance of the CF3R. Sampling procedures for HERS verification for installation work performed by an approved TPQCP contractor allows for testing of one sample from a designated group of up to 30 dwellings/installations for which the work was performed by the same approved TPQCP installing contractor. Refer to Reference Residential Appendix Sections RA2.4.3, RA2.7 and RA2.8 (and Chapter 9 of this manual) for additional information on Third Party Quality Control Programs and conditional approvals for alterations that use approved TPQCP contractors.

2.4.6 HERS Provider

<http://www.energy.ca.gov/HERS/providers.html>

A HERS Provider is an organization that the Energy Commission has approved to administer a HERS program. A HERS Provider has responsibility to certify and train Raters and maintain quality control over the activities performed by the HERS Raters who provide third-party field verification and diagnostic testing on installed energy efficiency features in dwellings when required for compliance with the Energy Standards. Visit the Energy Commission website for the most current list of approved HERS Providers.

The HERS Provider must maintain a database (data registry) that incorporates an Internet website-based user interface that has sufficient functionality to accommodate the needs of the authorized users of the data registry who administer HERS compliance, document registration, and Energy Standards enforcement. The data registry must receive and record information that can adequately identify and track measures that require HERS verification in a specific dwelling, and must have the capability to determine compliance based on the information input from the results of applicable testing or verification procedures reported as input to the data registry for the dwelling. When the requirements for compliance are met, the data registry must make available a unique "registered" certificate for use in complying with document submittal requirements to enforcement agencies, builders, building owners, HERS Raters, and other interested parties. The data registry must have the capability to simplify electronic submittal of the registered certificates to an Energy Commission document repository for retention of the certificates for use in regulations enforcement.

The HERS Provider must make available via phone or Internet communications interface a way for building officials, builders, HERS Raters, and other authorized users of the Provider's data registry to verify the information displayed on copies of the submitted compliance documentation. Refer to Reference Residential Appendices Section RA2.4.2 and Reference Joint Appendix JA7 for additional information describing the HERS Provider's role and responsibilities.

2.4.7 HERS Rater

The HERS Rater is trained and certified by an Energy Commission-approved HERS provider to perform the field verification and diagnostic testing that may be required to demonstrate and document compliance with the Energy Standards. HERS Raters receive special training in diagnostic techniques and building science as part of the HERS Rater certification administered by the HERS Provider; thus, HERS Raters are to be 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 recognize that some enforcement agencies charge a fee for special inspectors in their jurisdictions. Because HERS Raters are deemed to be special inspectors for the enforcement agency, a HERS Rater may be disciplined (for example, prohibit a HERS Rater from conducting field verifications/testing in a local jurisdiction) if the enforcement agency determines that a HERS Rater willingly or negligently does not comply with the Energy Standards. HERS Raters may also be required to attain business licenses in some jurisdictions.

If the documentation author who produced the Certificate of Compliance documentation for the dwelling is not an employee of the builder or subcontractor, the documentation author for the dwelling 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, and is associated with one of the Energy Commission-approved HERS Providers.

If requested to do so by the builder or subcontractor, the HERS Rater may help the builder or subcontractor transmit/submit the certificate(s) of installation (CF2R) information to the HERS Provider for registration. However, the HERS Rater may not certify the information on a Certificate of Installation. The builder or subcontractor responsible for the installation must provide the certificate of installation certification/signature to confirm the information submitted to the HERS Provider data registry, even if the HERS Rater has helped transmit the data. Refer to Reference Residential Appendix Section RA2.5 and Reference Joint Appendix JA7 for more information that describes these procedures for document registration for which the HERS Rater may assist the builder or subcontractor.

The HERS Rater is responsible for conducting the field verification and diagnostic testing of the installed special features when required by the certificate of compliance (CF1R). The HERS Rater must transmit the results of the field verification and diagnostic testing to the HERS Provider data registry. The HERS Rater must provide to the data registry all information required to complete the Certificate(S) Of Verification (CF3R) form and must submit a certification/signature to the data registry. Whereupon, the data registry will make

available registered copies of the certificate(s) of verification (CF3R) to the HERS Rater, the builder, the enforcement agency, and other authorized users of the HERS Provider's data registry. Printed copies, electronic or scanned copies, and photocopies of the completed, signed, and registered certificate(s) of verification (CF3R) are allowed for document submittals, subject to verification that the information contained on the copy conforms to the registered document information on file in the HERS provider data registry for the dwelling. A completed, signed, and registered copy of the certificate(s) of verification (CF3R) must be posted at the building site or made available to the inspector for review by the enforcement agency in conjunction with requests for final inspection for each dwelling unit.

For more information on the roles and responsibilities for HERS Raters, refer to Reference Residential Appendix Section RA2.4.2.

Example 2-6**Question**

May a certified HERS Rater who does the field verification and completes and signs the CF3R for a dwelling also perform the testing required of the builder or installer to certify compliance with the Title 24, Part 6 installation requirements on the CF2R?

Answer

Yes. This approach is allowed when the HERS Rater is doing field verification for every dwelling (100 percent testing), but it is not allowed when the HERS Rater performs verification using a designated sample group of dwellings. When 100 percent testing is used for HERS verification, the builder or the installer may use the information from the HERS Rater's verification or diagnostic test results when completing the CF2R. When doing so, however, builders or installers must be aware that when they sign the certification statement on the CF2R, they are assuming responsibility for the information content on the CF2R and are certifying that the installation conforms to all applicable codes and regulations. The HERS RATER may not sign the CF2R form and cannot be assigned the responsibilities of the builder or installer, as stated on the CF2R form and in regulations.

If the HERS Rater determines that the compliance requirements are not met, the HERS Rater will submit the data of the failed verification/testing into a HERS Provider data registry for retention, and the builder or installer must make whatever corrections are necessary. Once corrections have been made and the HERS Rater determines that all compliance requirements are met, the builder or installer may certify the work by completing and signing the applicable section of the CF2R, and the HERS Rater can complete the CF3R documentation for the dwelling.

Example 2-7**Question**

I heard that there are conflict-of-interest requirements that HERS Raters must abide by when doing field verification and diagnostic testing. What are these requirements?

Answer

HERS Raters are expected to be objective, independent third parties when they are fulfilling their duties as field verifiers and diagnostic testers. In this role, they are serving as special inspectors for local enforcement agencies. By law, HERS Raters must be independent entities from the builder or subcontractor installer of the energy efficiency features being tested and verified. They can have no financial interest in the installation of the improvements. HERS Raters cannot be employees of the builder or subcontractor whose work they are verifying. Also, HERS Raters cannot have a financial interest in the builder's or contractor's business, or advocate or recommend the use of any product or service that they are verifying.

The Energy Commission expects HERS Raters to enter into a contract with the builder (not with subcontractors) to provide independent, third-party diagnostic testing and field verification. The procedures adopted by the Energy Commission call for direct reporting of results to the builder, the HERS Provider, and the building official. Although not recommended by the Energy Commission, a “three-party contract” among builder, HERS Rater and subcontractor is possible, provided that the contract delineates both the independent responsibilities of the HERS Rater and the responsibilities of a subcontractor to take corrective action in response to deficiencies that are found by the HERS Rater. Such “three-party contracts” may also establish the role for a subcontractor to serve as administrator for the contract, including scheduling the HERS Rater, invoicing, and payment, provided the contract ensures that money paid by the builder to the HERS Rater can be traced through audit. It is critical that such “three-party contracts” preserve the Rater's independence in carrying out the responsibilities specified in Energy Commission-adopted HERS field verification and diagnostic testing procedures. Even though such “three-party contracts” are not on their face in violation of the requirements of the Energy Commission, the closer the working relationship between the HERS Rater and the subcontractor whose work is being inspected, the greater the potential for compromising the independence of the HERS Rater.

Compliance cannot be shown using sampling if a "three-party contract" is used. One hundred percent of homes must be tested by a HERS Rater when a three-party contract is used. HERS Raters must use their own diagnostic equipment (cannot use the installing contractor's diagnostic equipment) when verifying work performed when a three-party contract is used.

(See *Blueprint #66*, pp. 1-2, and *Blueprint #67*, p. 7.)

HERS Providers must provide ongoing monitoring of the propriety and accuracy of HERS Raters in the performance of their duties and to respond to complaints about HERS Rater performance. In cases where there may be real or perceived compromising of HERS Rater independence, they are responsible for providing increased scrutiny of the HERS Rater and taking action to ensure objective, accurate reporting of diagnostic testing and field verification results, in compliance with Energy Commission-adopted procedures.

Enforcement agencies have authority to require HERS Raters to demonstrate their competence to the satisfaction of the building official. Therefore, in situations where the independence of the HERS Rater is in question, building officials can prohibit a particular HERS Rater from being used in their jurisdiction or disallow HERS Rater practices that the building official believes will compromise the HERS Rater's independence. Building officials may require the use of a three-party contract. For additional information about three-party contracts, please contact the Energy Commission Hotline.

2.4.8 Third-Party Quality Control Program

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. Train installers, participating program installing contractors, installing technicians, and specialty third-party quality control program subcontractors regarding compliance requirements for measures for which diagnostic testing and field verification is required.
- B. Collect data from participating installers for each installation completed for compliance credit.
- C. Perform data checking analysis of information from diagnostic testing performed on participating TPQCP contractor installation work to evaluate the validity and accuracy of the data and to independently determine whether compliance has been achieved.
- D. Provide direction to the installer to retest and correct problems when data checking determines that compliance has not been achieved.

- E. Require resubmission of data when retesting and correction is directed.
- F. Maintain a database of all data submitted by the participating TPQCP contractor in a format that is acceptable and made available to the Energy Commission upon request.

The HERS Provider must arrange for the services of an independent HERS Rater to conduct independent field verifications of the installation work performed by the participating TPQCP contractor and third-party quality control program. 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 dwellings for which the same participating TPQCP contractor has performed the installation. For alterations, the installation work performed by TPQCP contractors may be approved at the enforcement agency's discretion, based upon a properly completed certificate of installation (CF2R) as described in Section 2.4.5, on the condition that if subsequent HERS compliance verification procedures determine that resampling, full testing, or corrective action is necessary for such conditionally approved dwellings in the group, the corrective work must be completed. If the standards require registration of the certificate of installation, the certificate must be a registered copy from a HERS Provider data registry.

Refer to Reference Residential Appendix RA2.4.3, RA2.7, and RA2.8 for additional information about the third-party quality control program and for additional information about document registration.

2.4.9 Owner

Building owner means the owner of the dwelling unit. In the context of production homes, the owner is the person or family that the builder sells the house to. In custom homes and remodels, the owner may be the “builder” or developer, and a general contractor, architect, or engineer, and so forth. may be in their employment.

As part of the compliance process, the owner must receive compliance, operating, maintenance, and ventilation information documents at the time of occupancy. The enforcement agency must require the builder to leave this information in the building for the building owner at occupancy as specified in §10-103(b).

Example 2-8

Question

What is my responsibility with respect to the CF2R (certificate of installation) as (a) an enforcement agency inspector and (b) as a builder?

Answer

(a) The enforcement agency field inspector is responsible for verifying that the required CF2R form(s) are filled out completely and in conformance with the requirements of §10-103(d) during applicable site inspections, which includes verifying the CF2R is registered when required by the standards, and confirming that the person responsible for the installation has signed the certificate. Inspectors must verify that the installed features conform to the plans and specifications and the certificate of compliance approved by the enforcement agency.

The CF2R is required to be posted at the job site or kept with the building permit, and must be made available for all applicable inspections. The enforcement agency field inspector should verify certificate(s) of installation during the applicable site inspections (for example, verifying the certificates of installation for quality insulation installation, QII, at the framing and insulation inspections). It is not advisable to wait until the final inspection to check all CF2R documentation.

(b) The general contractor or his/her agent (for example, the installing contractor) must take responsibility for completing and signing the CF2R form for the work performed. A homeowner acting as the general contractor for a project is authorized to sign the CF2R; however, the installing contractor should provide the certification since the CF2R certification statement is an installer's assurance to the owner that the work has been completed properly and in compliance with applicable codes and regulations. The CF2R certification statement and signature indicates that the equipment or feature 1) was installed properly, and it confirms that the information provided on the form properly identifies the installed building component or equipment; 2) is equivalent or more efficient than required by the approved plans (as indicated on the CF1R); and 3) meets all relevant certification or performance requirements.

Refer to §10-103(a)3 for more information about certificate of installation requirements.

2.5 HERS Field Verification and Diagnostic Testing

This section describes some of the procedures and requirements for field verification and/or diagnostic testing of energy efficiency features.

Field verification and diagnostic testing are performed by special third-party inspectors called Home Energy Rating System (HERS) Raters. The Energy Commission has given this responsibility to the HERS Raters, who must be specially trained and certified to perform these services. HERS Raters cannot be employees of the builder or contractor whose work they are verifying. Also, HERS Raters cannot have a financial interest in the builder's or contractor's business, or advocate or recommend the use of any product or service that they are verifying. The training, quality assurance, and general oversight of HERS Raters are conducted by Energy Commission-approved HERS providers.

2.5.1 Measures Requiring HERS Field Verification and Diagnostic Testing

Field verification and diagnostic testing are required only when certain regulated efficiency measures or equipment features are installed. If such efficiency measures or equipment features are not installed, then field verification and diagnostic testing are not required. For example, if a dwelling that must comply with the standards does not have air distribution ducts, then HERS verification of duct leakage is not required for compliance.

The following features require field verification and/or diagnostic testing:

- a. Duct sealing
- b. Supply duct location, surface area and R-value
- c. Low-leakage ducts in conditioned space
- d. Low-leakage air handlers
- e. Verification of return duct design
- f. Verification of air filter device design
- g. Verification of bypass duct prohibition
- h. Refrigerant charge in ducted split-system and ducted packaged unit air conditioners and heat pumps, and mini-split systems

- i. Refrigerant charge indicator display (CID)
- j. Verified system airflow
- k. Air handler fan efficacy
- l. Verified energy efficiency ratio (EER)
- m. Verified seasonal energy efficiency ratio (SEER)
- n. Maximum rated total cooling capacity
- o. Evaporatively cooled condensers
- p. Ice storage air conditioners
- q. Continuous whole-building mechanical ventilation airflow
- r. Intermittent whole-building mechanical ventilation airflow
- s. Building envelope air leakage
- t. High-quality insulation installation (QII)
- u. Quality insulation installation for spray polyurethane foam
- v. PV field verification protocol
- w. Verified pipe insulation credit
- x. Verified parallel piping
- y. Central fan integrated ventilation cooling systems
- z. Zonal controls
- aa. Verified compact hot water distribution system
- bb. Verified point of use
- cc. Demand recirculation: manual control
- dd. Demand recirculation: sensor control
- ee. Multiple recirculation loop design for DHW systems serving multiple dwelling units

2.5.2 Verification, Testing, and Sampling

At the builder's option, HERS field verification and diagnostic testing may be completed either for each dwelling unit or for a sample of dwelling units. Sampling is permitted only when multiple dwelling units of the same type are constructed within the same subdivision by the same subcontractor. Sampling may also be used for alterations for groups composed of dwellings having the same measure installed that requires HERS verification, and where the same installing contractor has installed the measures. More detail on the sampling procedures is provided in Reference Residential Appendix Section RA2.6 and RA2.8.

The builder or subcontractor must provide to the HERS Rater a copy of the certificate of compliance approved/signed by the principal designer/owner and a copy of the certificate(s) of installation (CF2R) signed/certified by the builder or subcontractors as specified in Reference Residential Appendix Section RA2.5.

When compliance requires document registration, prior to performing field verification and diagnostic testing, the HERS Rater must verify that transmittal to the HERS Provider data registry of the certificate of compliance information and the certificate(s) of installation (CF2R) information has been completed for each dwelling unit for which compliance requires HERS verification.

For all HERS verification procedures, the HERS Rater must confirm that the certificate(s) of installation (CF2R) have been completed as required and that the installer's diagnostic test results and all other certificate(s) of installation (CF2R) information show compliance consistent with the requirements given in the plans and specifications and certificate of compliance approved by the local enforcement agency for the dwelling.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS Rater shall transmit the test results and Rater certification/signature to the HERS Provider data registry, whereupon the Provider shall make available a registered copy of the completed and signed certificate of verification (CF3R) to the HERS Rater, the builder, the enforcement agency, and other approved users of the HERS Provider data registry. Printed copies, electronic or scanned copies, and photocopies of the completed, signed and registered certificate of verification (CF3R) shall be allowed for document submittals, subject to verification that the information contained on the copy conforms to the registered document information currently on file in the HERS Provider data registry for the dwelling. A completed, signed and registered copy of the certificate of verification (CF3R) must be posted at the building site or made available for review by the enforcement agency in conjunction with requests for final inspection for each dwelling unit.

The HERS Provider shall make available via phone or Internet communications interface a way for building officials, builders, HERS Raters, and other authorized users of the Provider data registry to verify that the information displayed on copies of the submitted certificate(s) conforms to the registered document information on file in the provider data registry for the dwelling unit.

Note: If the builder chooses the sampling option, the procedures described in Reference Residential Appendix Sections RA2.6 and RA2.8 must be followed.

2.5.3 Initial Model Field Verification and Diagnostic Testing

The HERS Rater must diagnostically test and field verify the first dwelling unit of each model within a subdivision or multifamily housing development. To be considered the same model, dwelling units must have the same basic floor plan layout, energy design, and compliance features as shown on the certificate of compliance for each dwelling unit. Variations in the basic floor plan layout, energy design, compliance features, zone floor area, or zone volume, that do not change the HERS features to be tested, the heating or cooling capacity of the HVAC unit(s), or the number of HVAC units specified for the dwelling units shall not cause dwelling units to be considered a different model. For multifamily buildings, variations in exterior surface areas caused by location of dwelling units within the building shall not cause dwelling units to be considered a different model.

The initial model testing allows the builder to identify and correct any potential construction flaws or practices in the build out of each model. If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS Rater will transmit the test results to the HERS Provider data registry, whereupon the provider will make available a registered copy of the certificate of verification (CF3R) to the HERS Rater, the builder, the enforcement agency, and other authorized users of the HERS Provider data registry.

2.5.4 Group Sample Field Verification and Diagnostic Testing

After the initial model field verification and diagnostic testing are completed, the builder or the builder's authorized representative determines which sampling procedure is to be used for the group of dwellings that require HERS field verification. There are two procedures for HERS verification compliance using group sampling: (1) sampling of a "closed" group of up to seven dwellings; and (2) sampling of an "open" group of up to five dwellings. The group sampling requirements for each procedure will be discussed in this section.

Transmittal/submittal of the certificate(s) of installation information, for at least one dwelling, to the HERS Provider data registry is required to "open" a new group. Additional dwellings may be entered into the registry and included in an "open" group over a specific period, subject to transmittal/submittal of the certificate(s) of installation information to the registry for each additional dwelling. However, the group shall not remain "open" to receive additional dwellings for a period longer than six months from the earliest date shown on any certificate of installation for a dwelling included in a group. A group may be "closed" at any time after the group has been "opened" at the option of the builder or builder's authorized representative, thus the size of a "closed" group may range from a minimum of one dwelling to a maximum of seven dwellings. When a group becomes classified as "closed," no additional dwellings shall be added to the group.

A. Sampling of a "closed" group of up to seven dwellings requires the following conditions to be met as prerequisite to receiving HERS compliance verification for the group:

1. All of the dwelling units contained in the sample group have been identified. Up to seven dwellings are allowed to be included in a "closed" sample group for the HERS compliance verification.
2. Installation of all the measures that require HERS verification has been completed in all the dwellings that are entered in the group, and registration of the certificate(s) of installation for all the dwellings entered in the group has been completed.
3. The group has been classified as a "closed" group in the HERS Provider data registry.
4. At the request of the builder or the builder's authorized representative, a HERS Rater will randomly select one dwelling unit from the "closed" sample group for field verification and diagnostic testing. If the dwelling unit meets the compliance requirements, this "tested" dwelling and each of the other "nontested" dwellings in the group will receive a registered certificate of verification (CF3R).

B. Sampling of an "open" group of up to five dwellings requires the following conditions to be met as prerequisite to receiving HERS compliance verification for the group:

1. At least one dwelling unit from the sample group has been identified. Up to five dwellings are allowed to be included in an "open" sample group for the HERS compliance verification.

2. Installation of all the measures that require HERS verification shall be completed in all the dwellings that are entered in the group, and registration of the certificate(s) of installation for all the dwellings entered in the group has been completed.
3. At the request of the builder or the builder's authorized representative, a HERS Rater will randomly select one dwelling unit from those entered into the "open" sample group for field verification and diagnostic testing. If the dwelling unit meets the compliance requirements, the "tested" dwelling and each of the other "nontested" dwellings entered into the group shall receive a registered certificate of verification (CF3R). If fewer than five dwelling units have been entered into the group, the group shall be allowed to remain "open" and eligible to receive additional dwelling units. Dwelling units entered into the "open" group subsequent to the successful HERS compliance verification of the "tested" dwelling shall also receive a registered certificate of verification (CF3R) as a "nontested" dwelling subject to receipt of the registered certificate(s) of installation by the HERS Provider data registry for the dwelling. The group shall be "closed" when it reaches the limit of five dwellings, when the six-month limit for "open" groups has been exceeded, or when the builder requests that the group be closed.

The HERS Rater must confirm that the certificate(s) of installation have been completed as required and that the installer's diagnostic test results and the certificate(s) of installation show compliance consistent with the certificate of compliance for the dwelling unit.

The HERS Rater must diagnostically test and field verify the selected dwelling unit, and enter the test and/or field verification results into the HERS PROVIDER data registry regardless of whether the results indicate a pass or fail. If the test fails, then the failure must be entered into the Provider's data registry, even if the installer immediately corrects the problem. In addition, any applicable procedures for resampling, full testing, and corrective action must be followed as described in Section 2.5.5 below.

If field verification and diagnostic testing determine that the requirements for compliance are met, the HERS Rater will enter the test results into the HERS Provider data registry, whereupon the provider will make available to the HERS Rater, the builder, the enforcement agency, and other approved users of the HERS Provider data registry a registered copy of the certificate of verification (CF3R) for the "tested" dwelling, and for all other "nontested" dwelling units entered in the group at the time of the sample test. So as to not create confusion by placing test results on nontested dwelling units, the HERS Provider data registry will not report the testing/verification results of the tested home on the certificate of field verification and diagnostic testing (CF3R) for nontested dwelling units in a sample group. The testing/verification results will be reported only on the CF3R for the tested dwelling unit of the sample group. However, CF3R forms for nontested dwelling units will still have a registration number and date and a watermark of the HERS Provider's seal and so forth and will specify the dwelling unit was not tested and is part of a sample group.

The HERS Provider is required to "close" any "open" group within six months after the earliest signature date shown on any certificate of installation for a dwelling entered in the group. When such group closure occurs, the HERS Provider shall notify the builder that the group has been "closed" and require that a sample dwelling be selected for field verification

and diagnostic testing by a HERS Rater if field verification has not yet been conducted on a sample dwelling entered in the group.

2.5.5 Resampling, Full Testing, and Corrective Action

When a failure is encountered during sample testing, the failure must be entered into the HERS Provider data registry for retention by the HERS Rater. Corrective action must then be taken on the failed dwelling unit, and the dwelling unit must subsequently be retested to verify that corrective action was successful and the dwelling complies. Corrective action and retesting on the dwelling unit must be repeated until the testing determines that the dwelling complies and the successful compliance results have been entered into the HERS Provider data registry. Whereupon, a registered certificate of verification (CF3R) for the dwelling 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 must resample and test a second randomly selected dwelling within the sample group to assess whether the first failure in the group is unique, or if the rest of the dwelling units in the group are likely to have similar failings. "Resampling" refers to the procedure that requires testing of additional dwellings within a group when the initial selected sample dwelling from a group fails to comply with the HERS verification requirements.

When resampling in a "closed" group, if the testing of a second randomly selected dwelling in the group confirms that the requirements for compliance credit are met for that unit, then the dwelling unit with the initial failure is not considered to be an indication of failure in the remaining untested dwelling units in the group, and a copy of the certificate of verification (CF3R) will be made available for the remaining dwelling units in the group, including the dwelling unit in the resample. If the second sample results in a failure, the HERS Rater must report the second failure to the HERS Provider data registry, and all the nontested dwelling units in the group must thereafter be individually field verified and diagnostically tested.

Additional information describing the procedures for resampling of closed groups of up to seven dwellings, and the procedures for resampling for open groups of up to five dwellings are described in Reference Residential Appendix RA2.6.

2.5.6 Installer Requirements and HERS Procedures for Alterations

When compliance for an alteration requires field verification and diagnostic testing by a certified HERS Rater, the building owner may choose for the field verification and diagnostic testing to be completed for each dwelling unit, or as part of a designated sample group of dwelling units for which the same installing company has completed work that requires testing and field verification for compliance. Generally speaking, the only alterations that will require HERS testing/verification are HVAC changeouts. The building owner or agent of the building owner must complete the applicable portions of a shorthand version of the certificate of compliance (the CF1R-ALT) form for his or her climate zone. When compliance requires HERS verification, the building owner or agent must arrange for transmittal/submittal of the certificate of compliance information to the HERS Provider data registry, identifying the altered HVAC system and measures that require HERS verification.

The building owner must also arrange to submit an approved/signed copy of the certificate of compliance to the HERS Rater.

When the installation is complete, the person responsible for the performance of the installation must complete the certificate(s) of installation (CF2R). All required certificate(s) of installation must be registered with an approved HERS Provider data registry when field verification and diagnostic testing are required.

After verifying that the certificate of compliance (CF1R-ALT) and all required certificate(s) of installation are completed, signed, and registered, the HERS rater must verify HERS compliance. If group sampling is used for compliance, the sampling procedures described in Reference Residential Appendix RA2.6.3.3 and RA2.8, for sampling of a "closed" group of up to seven dwellings must be used, requiring that all dwelling units (HVAC systems) within the group have been serviced by the same installing company. The installing company may request a group for sampling that is smaller than seven dwelling units (HVAC systems). Resampling, full testing, and corrective action must be completed, if necessary, as specified by Reference Residential Appendix RA2.6.4.

Note: Whenever the HERS Rater for the group is changed, a new group must be established.

The enforcement agency cannot approve the alteration until the enforcement agency has verified completed, signed and registered certificate of compliance (CF1R-ALT), certificate(s) of installation (CF2R), and certificate(s) of verification (CF3R) documentation for the altered HVAC system. The enforcement agency shall also verify that the installing contractor provides copies of all of these forms to the homeowner.

TPQCP, as specified in Reference Residential Appendix RA2.7, may also be used with alterations and must be limited to "closed" sample group sizes of 30 dwelling units (HVAC systems) or fewer. When a TPQCP is used, the enforcement agency may approve compliance based on the certificate(s) of installation (CF2R), where data checking has indicated that the unit complies, on the condition that if the required HERS verification procedures determine that resampling, full testing, or corrective action is necessary, such work shall be completed.

2.5.7 For More Information

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

1. Reference Joint Appendix JA7 – Data Registry Requirements
2. Reference Residential Appendix RA2 – Residential HERS Verification, Testing, and Documentation Procedures
3. Reference Residential Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols

Example 2-9**Question**

Given a multifamily building that has used the duct sealing HERS credit for compliance for all the dwelling units in the building, what is the correct sampling procedure for HERS field verification and diagnostic testing for the air distribution ducts?

Answer

If the builder of a multifamily building chooses to comply using sampling, then the sampling is done using groups composed of dwelling units that have used the same HERS measures for compliance. Dwellings that do not have the same HERS measures specified for compliance are not allowed to be placed in the same HERS sample group. If the whole-building compliance approach has been used, all dwellings in the building, by default, have the same HERS features specified. However, if unit-by-unit compliance approach has been used, and all dwellings do not use the same HERS features for compliance, then only the dwellings that have used the same HERS features may be grouped together.

For this example, since duct testing is the only HERS measure specified for all the dwelling units, all the dwelling units in the building can be grouped together for HERS verification requirements. The procedures for assigning dwellings to groups and the HERS verification of a sample from each group must follow the same procedure as for single-family dwellings described in Section 2.5.2 earlier in this chapter and in Reference Residential Appendix RA2. The first dwelling unit for each model floor plan in the building must be verified by the HERS Rater before the start of formation of sample groups. For multifamily buildings, variations in exterior surface areas caused by location of dwelling units within the building do not cause dwelling units to be considered a different model floor plan. When verifying a dwelling unit, all the duct systems associated with every HVAC unit in the dwelling must be tested to determine compliance for that dwelling. After the HERS verification of the first dwelling of each model floor plan is complete, the HERS Rater must randomly select a sample dwelling unit from each group of dwellings that have been formed, and these samples must be tested according to applicable procedures in Reference Residential Appendix RA3 and documented according to procedures in Reference Residential Appendix RA2. In a sampled dwelling unit that is to be tested to confirm compliance, the duct system associated with every HVAC unit in that dwelling unit must be tested. However duct systems do not have to be tested in dwelling units that are not selected for sampling (nontested dwelling), provided the dwelling that was tested complies. If the tested dwelling in the group complies with the HERS verification, the remaining dwellings in the sample group are certified for compliance based on the results of the sample dwelling test result. Testing must be done on every duct system in a dwelling unit, regardless of whether it appears that the HVAC and duct system are in conditioned space. This is akin to a single-family residence with one HVAC unit serving upstairs with ducts in the attic and another serving downstairs with ducts between floors.

Defining duct location as "inside" or "outside" for leakage purposes is not described by the locations of walls or the number of stories. The boundary between inside and outside for leakage purposes is defined by the air boundary, typically drywall, between inside and outside. Spaces between floors and spaces in walls (including interior walls) are often "outside" from an air leakage perspective because they are not sealed effectively to form an air barrier and communicate to the outside.

Duct insulation is not required for ducts in directly conditioned space because there is an expectation that there will be reduced conduction losses for these ducts. But to get full credit for ducts in conditioned space, duct leakage must be tested and meet the requirements for duct sealing. In a multifamily building, for compliance credit to be taken for ducts in conditioned space, all the duct systems in the building must be in conditioned space unless compliance is documented for each dwelling unit separately. To meet the mandatory requirements, all HVAC units must have ducts made of UL 181 approved materials (that is, cased coils). Coils enclosed by sheetrock do not meet the mandatory requirements.

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3. Building Envelope Requirements

This chapter describes the requirements that affect the design of the building envelope for low-rise residential buildings. The design and choices made for individual components for the building can significantly affect the energy demand needed to meet heating and cooling loads to maintain the desired inside comfort temperature of the building. Heating and cooling load calculations are used to determine the mechanical system design needed for space heating and cooling. The principal components of heating loads are infiltration and conduction losses through building envelope components, including walls, roofs, floors, slabs, windows, and doors. Cooling loads, on the other hand, are dominated by solar gains through windows, skylights, and roof/attic assemblies.

3.1 Organization

This chapter is organized by building system or building envelope component, and includes the following subject areas:

Section 3.2 What's New for 2016

- Changes for 2016 include more flexibility for prescriptive compliance and changing the minimum mandatory insulation level to R-22 for roof/ceiling.
- Provisions allowing the Energy Commission to approve new products, methods, and procedures for compliance

Section 3.3 Compliance Options

- A summary of the general requirements affecting compliance with the *2016 Building Energy Efficiency Standards*

Section 3.4 Key Envelope Compliance Terms

- Terms used most often related to the building envelope for compliance

Section 3.5 Fenestration

- Detailed explanation of the mandatory requirements, and prescriptive and performance compliance approaches for fenestration

Section 3.6 Envelope Features

- Detailed explanation of the mandatory requirements, and prescriptive and performance compliance approaches for the building envelope

Section 3.7 Advanced Assembly Systems

- Discussion of design techniques that when used in more innovative ways can improve building energy efficiency and receive compliance energy credit

Section 3.8 Compliance and Enforcement

- Discussion of issues to aid compliance and enforcement for elements of the building envelope

Section 3.9 Glossary/References

- Key terms and reference information most often used for the building envelope

3.2 What's New for 2016

The *2016 Building Energy Efficiency Standards* for residential buildings include increased efficiencies for several envelope measures, and there are improvements that have been made to better aid the designer, builder, and building official.

1. Mandatory minimum roof/ceiling construction insulation level must be at least R-22 (maximum U-factor of 0.043).
2. Increased flexibility for prescriptive compliance.
3. The prescriptive requirement of high-performance attics, which includes:
 - a. Insulation installed either above or below the roof deck. (This dramatically lowers the attic temperature, which can typically exceed 150° F by preventing the heat from getting into the conditioned space below and reducing HVAC load.)
 - b. Verified ducts in conditioned space.

3.3 Compliance Options

Public Resources Code, Section 25402.1(b) requires the California Energy Commission to establish a formal process for certifying compliance options of new products, materials, designs or procedures that can improve building efficiency levels established by the *Building Energy Efficiency Standards*. §10-109 of the Energy Standards allows for the introduction of new calculation methods and measures that cannot be properly accounted for in the current approved compliance approaches. This process for approval of new products, materials, procedures, and calculation methods is called *compliance options* and helps improve building efficiency levels set by the Energy Standards.

The Energy Commission encourages the use of energy-saving techniques and designs for complying with the Energy Standards. The compliance options process allows the Energy Commission to review and gather public input regarding the merits of new compliance techniques, products, materials, designs, or procedures to demonstrate compliance for newly constructed buildings, additions, and alterations to existing buildings. Approved compliance options are generally carried for use with the newer energy code when revisions are made to the Energy Standards, and information regarding the use and eligibility and/or installation criteria are incorporated in compliance and reference manuals.

When the Energy Commission approves a new compliance option, it is listed in the Special Cases section of the Energy Commission's website based on the adoption year of the Energy Standards: http://www.energy.ca.gov/title24/2008standards/special_case_appliance/

3.3.1 Mandatory Features and Devices

§150.0

Mandatory requirements are necessary to support the long-term goal of zero-net-energy buildings. When compliance is being demonstrated with either the prescriptive or performance compliance paths, there are *mandatory measures* that must be installed. Minimum mandatory measures must be met regardless of the method of compliance being used. For example, when using the performance modeling software, it may assume that an assembly meets compliance with a U-factor of U-0.065 in a wood-framed attic roof. However, it does not comply because the mandatory requirement of U-0.043 has not been met per §150.0.

3.3.2 Prescriptive Compliance Approach

Energy Standards Table 150.1-A

The *prescriptive approach* is the simplest way to comply with the building envelope requirements but generally offers limited flexibility; however, the 2016 revisions have added increased flexibility for prescriptive compliance. If every prescriptive requirement is met, the building envelope complies with the Energy Standards. The prescriptive envelope requirements are prescribed in §150.1, which includes Table 150.1-A.

The prescriptive compliance approach consists of meeting specific requirements for each envelope component, plus meeting all minimum mandatory requirements, such as mandatory levels of insulation. Prescriptive requirements apply to:

1. Fenestration.
2. Roofs and ceilings, including exterior roofing products.
3. Exterior walls.
4. Floors.

3.3.3 Performance Compliance Approach

§150.1

The prescribed mandatory measures and prescriptive requirements affect the design and operation of the building. Mandatory measures, prescriptive requirements, and operational schedules establish a minimum performance level that can be exceeded by other design measures and construction practices, resulting in greater energy savings.

The *performance approach* is a more sophisticated compliance method, and it offers greater design flexibility than the prescriptive approach. The performance approach may be used for any unique design element(s) that the user of a compliance modeling software believes could contribute to the overall energy use of the building.

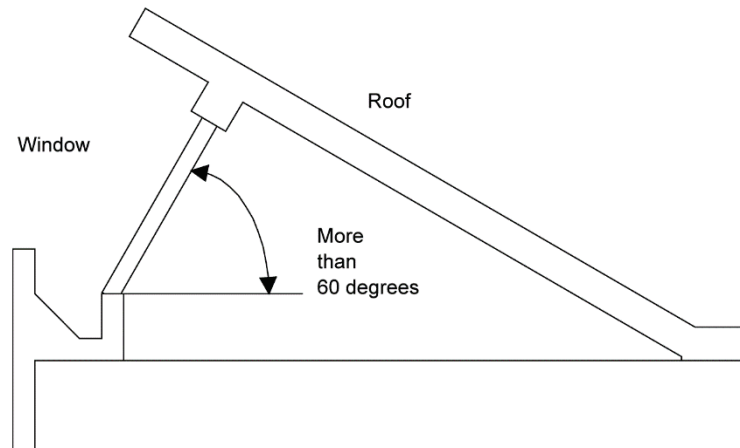
The performance approach allows for more energy tradeoffs between building features, such as increasing HVAC equipment efficiency to allow more fenestration area. See Section 3.8 and Chapter 8 for a more complete discussion of the performance approach.

3.4 Key Envelope Compliance Terms

Elements of the building envelope significantly contribute to the related energy efficiency. Several features are important to note when a method is chosen to demonstrate compliance. Components of the building envelope include walls, floors, the roof and/or ceiling, and fenestration. Details for compliance of fenestration are addressed in Section 3.5 below. Envelope and other building components are listed in §100.1 of the 2016 Energy Standards and the Reference Appendices (RA).

- A. **Envelope** requirements vary by envelope component and are a function of the type of construction, orientation and space conditions on either side of the envelope surface. Additional envelope component definitions are:
1. **Exterior partition or wall** is an envelope component (roof, wall, floor, window, and others) that separates conditioned space from ambient (outdoor) conditions.
 2. **Demising partition or wall** is an envelope component that separates conditioned space from an unconditioned space.

- B. **Conditioned space** is either directly conditioned or indirectly conditioned. (See §100.1 for full definition.) An indirectly conditioned space has less thermal conductance to a directly conditioned space than to the outside. An *unconditioned space* is enclosed space within a building that is not directly conditioned, or indirectly conditioned.
- C. **Plenum** is a space below an insulated roof and above an uninsulated ceiling. It is an indirectly conditioned space as there is less thermal conductance to the directly conditioned space below than to the ambient air outside. By comparison, an 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. A plenum can also be the space between the underside of a raised floor and the slab or grade below and is sometimes used as an air supply for the building when the exterior foundation is sealed to the outside. A plenum can also be the space between the underside of an insulated ceiling and demising partitions or walls separating the attic from the conditioned space below.
- D. **Sloping surfaces** are considered either a wall or a roof, depending on the slope. (See Figure 3-1.) If the surface has a slope of less than 60° from horizontal, it is considered a roof; a slope of 60° or more is a wall. This definition extends to fenestration products, including windows in walls and any skylight types in roofs.
- E. Floors and roof/ceilings do not differentiate between demising and exterior. Thus an **exterior roof/ceiling** "is an exterior, or demising element, that has a slope less than 60 degrees from horizontal, and that has conditioned space below," ambient conditions or unconditioned space above.
This definition does not include an exterior door or skylight.
- F. **Roof deck** is the surface of an exterior roof that is directly above the roof rafter and below exterior roofing materials.
- G. Similarly, an "exterior floor/soffit is a **horizontal exterior element**, or a horizontal demising element, under conditioned space" and above an unconditioned space or ambient (outdoor) conditions.
- H. **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. During cold weather, the inside of the house is warm and moist (from breathing, showers, and so forth), and the outside is cold and dry. Moisture moves from moist to drier conditions and from warm to cold. When the moisture (in vapor form) reaches a point in a wall or roof assembly that has a temperature below the dew point, it will condense into water. Water build up can cause structural damage, create mold that may contribute to indoor air quality problems, and can cause the insulation to lose effectiveness.
- I. **Fenestration (Windows)** are considered part of an exterior wall because the slope is typically over 60°. Where the slope of fenestration is less than 60°, the glazing indicated as a window is considered a **skylight**.

Figure 3-1: Slope of a Wall or Window (Roof or skylight slope is less than 60°)

Source: California Energy Commission

J. Roofing Products (Cool Roof)

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. Roof radiative properties are rated and listed by the Cool Roof Rating Council (CRRC) (www.coolroofs.org/).

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 specify radiative properties that represent minimum “cool roof performance” qualities for roofing products:

1. Solar reflectance—the fraction of solar energy that is reflected by the roof surface
2. Thermal emittance—the fraction of thermal energy that is emitted from the roof surface

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.

The Energy Standards prescribe cool roof radiative properties for low-sloped and steep-sloped roofs (§150.1(c)11). A *low-sloped roof* is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizon), while a *steep-sloped roof* is a surface with a pitch greater than 2:12. Low-sloped roofs receive more solar radiation than steep-sloped roofs in the summer when the sun is higher in the sky.

Example 3-1

Question:

I am a salesperson and represent some roofing products, and many of them are on the U.S. Environmental Protection Agency's (EPA) ENERGY STAR® list for cool roofing materials. Is this sufficient to meet the Energy Standards?

Answer:

No. ENERGY STAR has different requirements for reflectance and *no* requirements for emittance. Per §10-113, the Cool Roof Rating Council (www.coolroofs.org) is the only entity recognized by the Energy Commission to determine what qualifies as a cool roof.

Example 3-2

Question:

How does a product get CRRC cool roof certification?

Answer:

Any party wishing to have a product or products certified by the CRRC should contact the CRRC. To get started, call toll-free (866) 465-2523 from inside the United States or (510) 485-7176, or email info@coolroofs.org. CRRC staff will walk interested parties through the procedures. Working with CRRC staff is strongly recommended. In addition, the CRRC publishes the procedures in *CRRC-1 Program Manual*, available for free on www.coolroofs.org or by calling CRRC.

Example 3-3

Question:

I understand reflectance, but what is emittance?

Answer:

Even a material that reflects the sun's energy will still absorb some of that energy as heat; there are no perfectly reflecting materials being used for roofing. That absorbed heat undergoes a physical change (an increase in wavelength) and is given off – emitted – to the environment in varying amounts depending on the materials and surface types. This emittance is given a unitless value between 0 and 1, and this value represents a comparison (ratio) between what a given material or surface emits and what a perfect blackbody emitter would emit at the same temperature.

A higher emittance value means more energy is released from the material or surface; scientists refer to this emitted energy as *thermal radiation* (as compared to the energy from the sun, solar radiation, with shorter wavelength). Emittance is a measure of the relative efficiency with which a material, surface, or body can cool itself by radiation. Lower-emitting materials become relatively hotter for not being able to get rid of the energy, which is heat. Roof materials with low emittance therefore hold onto more solar energy as heat, get hotter than high-emittance roofs, and, with the help from the laws of physics, offer greater opportunity for that held heat to be given off downward into the building through conduction. More heat in the building increases the need for air conditioning for comfort. A cool roof system that reflects solar radiation (has high reflectance) and emits thermal radiation well (has high emittance) will result in a cooler roof and a cooler building with lower air-conditioning costs.

K. 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. Ventilation, on the other hand, is the

intentional replacement of conditioned air with unconditioned air through open windows and skylights or mechanical systems.

Reducing infiltration in the building envelope can result in significant energy savings, especially in climates with more severe winter and summer conditions. It also can result in improved occupant comfort, reduced moisture intrusion, and fewer air pollutants.

L. **Advanced Assemblies**

Common strategies for exceeding the minimum energy performance level set by the 2016 Energy Standards include the use of better components such as:

- Higher insulation levels
- More efficient fenestration
- Reducing building infiltration
- Use of roofing products
- Better framing techniques (such as the use of raised-heel trusses that accommodate more insulation)
- Reduced thermal bridging across framing members
- Greater use of nonframed assemblies or panelized systems (such as SIPs and ICFs)
- More efficient heating, cooling and water heating equipment

The Energy Commission encourages the use of energy-saving techniques for showing compliance with the Energy Standards. Innovative designs and practices are discussed in Section 3.6.3.4.

M. **Advanced Building Design**

The design of a building, floor plan, and site design layout all affect energy use. A passive solar building uses elements of the building to heat and cool itself, in contrast to relying on mechanical systems to provide the thermal energy needs of the building. Passive solar strategies encompass several advanced high performance envelope techniques, such as:

1. Carefully choosing the size, type and placement of fenestration and shading.
2. Providing and controlling fresh air ventilation during the day and night.
3. Having internal and external thermal mass components that help store useful heat and cooling energy.
4. Having highly insulated envelope assemblies.
5. Using high performing roofing materials (cool roofs) and radiant barriers.
6. Having very low air leakage.

Some measures designed as part of an advanced assembly system may require specific installation procedures or field verification and diagnostic testing to ensure proper performance. Field verification and diagnostic testing are ways to ensure that the energy efficiency features used in compliance calculations is realized as an energy benefit to the occupants.

3.5 Fenestration

Fenestration products such as windows, glazed doors, dynamic glazing, window films, and skylights have a significant impact on energy use and heating and cooling loads in a home. The size, orientation, and types of fenestration products can dramatically affect the overall energy performance of a house. Glazing type, orientation, shading and shading devices not only play a major role in the energy use of a building, but can affect the operation of the HVAC system and the comfort of occupants.

3.5.1 Fenestration Types

When choosing a window (new or replacement), it is always best to look for a National Fenestration Rating Council (NFRC) label on the window. The *Energy Performance Ratings* label is designed to help consumers identify the thermal resistance (U-factor) and solar heat gain (SHGC), which are factors that affect the energy performance of a window. This will help the consumer or designer compare the energy efficiency of window and glazed door products of different brands and manufacturers.

The following NFRC label provides information about the energy performance rating by listing identifiers such as: U-factor, solar heat gain coefficient (SHGC), visible transmittance (VT), and air leakage (AL), which helps provide accurate information for the consumer or designer:

A. **U-factor** measures the rate of heat loss through a product. The lower the U-factor, the lower the amount of heat loss. In cold climates where heating bills are a concern, choosing products with lower U-factors will reduce the amount of heat that escapes from inside the house.

B. **The solar heat gain coefficient (SHGC)** measures the percentage of radiant heat that passes through a fenestration product. The lower the SHGC, the lower the amount of solar heat gain through a window. In hot climates where air conditioning bills are a concern, choosing products with a lower SHGC will reduce the amount of heat that comes in from the outside.

C. **Visible transmittance (VT)** measures the percentage of light that comes through a fenestration product. The higher the VT rating, the more light is allowed through a window or glazed door. Skylights allow significantly more lighting and can be as efficient as vertical windows.

D. **Air leakage (AL)** is a measurement of heat loss and gain by infiltration through cracks in the window assembly, which can affect occupant comfort. The lower the AL, the lower the amount of air that will pass through cracks in the window assembly.

		World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Argon Fill • Low E Product Type: Vertical Slider	
ENERGY PERFORMANCE RATINGS			
U-Factor (U.S./I-P)		Solar Heat Gain Coefficient	
0.30		0.30	
ADDITIONAL PERFORMANCE RATINGS			
Visible Transmittance		Air Leakage (U.S./I-P)	
0.51		0.2	
<small>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</small>			

There are three primary categories of fenestration:

A. 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. New advances in framing material such as composites, fiberglass, and vinyl help improve the energy efficiency of fenestration products. New technology has advanced the glass industry to include reflective coatings such as silver, gold, bronze, low-e, low-e², or low-e³, which can be applied to clear and tinted glass.

B. GLAZED DOORS

Glazed door is an exterior door having a glazed area of 50 percent or more of the area of the door. These doors are typically installed in exterior walls that separate conditioned space from exterior ambient or unconditioned space. When the door has less than 50 percent glazing material, it is no longer considered a glazed door but just a conventional door. But whatever the glazed area, it will still have to be counted toward the overall glazed area of the conditioned space in any calculations.

C. SKYLIGHTS/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. On the other hand, 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 as efficient as any vertical windows used.

The following is a list of subcategories of fenestration:

- 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. **Field-fabricated** 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 weatherstripping 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).
- C. **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.
- D. **Dynamic glazing** is a glazing system that can reversibly change the performance properties, specifically the SHGC, VT, and, rarely, the U-factor. These may include, but are not limited to, chromogenic glazing systems and integrated shading systems. Dynamic glazing systems may include internally mounted or externally mounted

shading devices that attach to the window framing/glazing and may be removable (but only if they are part of the original window, door, or skylight assembly, and the assembly is labeled as such).

- E. **Window films** were originally developed in the early 1950s and are made mostly of polyester substrate that is durable and highly flexible. It absorbs little moisture and has both high aridity and low temperature resistances. Polyester film offers high clarity and can be pretreated to accept different types of coatings for energy control and longterm 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 it is a film specifically designed for the exterior window surface.

3.5.2 Relevant Sections in the Energy Standards for Fenestration

- A. §10-111 (Administrative Standards) establishes the rules for rating and labeling fenestration products and establishes the NFRC as the supervising authority.
- B. §110.6(a)1 sets air leakage requirements for all manufactured windows, doors, and skylights whether they are used in residential or nonresidential buildings.
- C. §110.6(a)2 through 4 requires that the U-factor, solar heat gain coefficient (SHGC), and visible transmittance (VT) for manufactured fenestration products be determined using NFRC procedures or use default values.
- D. §110.6(a)5 requires that manufactured fenestration products have both a temporary and permanent label. The temporary label shall show the U-factor, SHGC, and the VT and verify that the window complies with the air leakage requirements.
- E. §110.6(b) field-fabricated fenestration that do not have an NFRC rating shall use the Energy Commission default U-factors, SHGC, and optional VT values.
- F. §110.7 requires that openings around windows, skylights and doors be caulked, gasketed, weatherstripped, or otherwise sealed to limit air leakage.
- G. §150.0(q) requires a mandatory U-factor of 0.58 or a maximum weighted average U-factor of 0.58 for windows and skylights separating conditioned space from unconditioned space or the outdoors. An exception allows the greater of 10 ft² or 0.5 percent of the conditioned floor area to exceed 0.58 U-factor.
- H. §150.1(c)3 and 4 are the prescriptive requirements for fenestration and shading in low-rise residential buildings. These include requirements for maximum glazing area, maximum U-factor, and, for some climate zones, a maximum SHGC requirement.
- I. §150.1(c)3A, in addition to the basic fenestration allowance of 20 percent of conditioned floor area (CFA), Exception 1 allows each dwelling unit to have up to 3 ft² of glazing installed in doors and up to 3 ft² of tubular daylighting device with dual-pane diffusers to have an assumed U-factor and SHGC equivalent to the package requirements.
- J. §150.1(c)3A, in addition to the basic fenestration allowance of 20 percent of CFA, Exception 2 allows up to 16 ft² of the skylights to have up to 0.55 U-factor and up to 0.30 SHGC in each dwelling.
- K. §150.1(c)3A Exception 3 allows automatically controlled chromogenic glazing (a type of dynamic glazing) to assume the lowest labeled U-factor and SHGC when connected to automatic controls that modulate the amount of heat flow into space in multiple steps in response to solar intensity. Chromogenic glazing shall be considered separately from other fenestration and must not be weight-averaged with other fenestration.

- L. §150.1(c)3A Exception 4 specifies that if a contains a combination of manufactured and site-built fenestration; only the site-built fenestration can be determined by using NA6; however, all fenestration, including site-built, can also default to Tables 110.6-A or B.
- M. §150.1(c)3B establishes a prescriptive limit in which the prescriptive maximum total fenestration area shall not exceed the percentage of CFA indicated in Table 150.1-A. Total fenestration includes skylights and west-facing glazing.
- N. §150.1(c)3C states that when west-facing glazing is limited by Package A, west-facing includes skylights tilted in any direction when the pitch is less than 1:12.
- O. §150.2(a) sets the prescriptive fenestration area requirements for residential additions, as well as other prescriptive requirements for new fenestration. Performance compliance options (existing plus addition) are also available.
- P. §150.2(b) establishes the prescriptive requirements for replacement fenestration in existing residential buildings. Performance compliance options (existing plus alteration) are also available.

3.5.3 Mandatory Measures, Features, and Devices

§110.6(a)1; §110.7

3.5.3.1 Air Leakage

Manufactured fenestration products, including exterior doors, must be tested and certified to leak no more than 0.3 cubic feet per minute (cfm) per ft² of the window area.

This mandatory measure applies to all manufactured windows that are installed in newly constructed residential (including high-rise) buildings or newly installed in existing buildings. To determine leakage, the standard test procedure requires manufacturers to use either NFRC 400 or ASTM E283 at a pressure differential of 75 Pascal (or 1.57 pounds/ft²).

- A. **Site-Built Products.** There are no specific air leakage requirements for site-built fenestration products, but the Energy Standards require limiting air leakage by weatherstripping and caulking.
- B. **Field-Fabricated Products.** No air leakage testing is required for field-fabricated fenestration products; however, the Energy Standards still require limiting air leakage by weatherstripping and caulking.
- C. **Exterior Doors.** Exterior doors, which includes pet doors, must meet the following requirements:
 - 1. Manufactured exterior doors must be certified as meeting an air leakage rate of 0.3 cfm/ft² of door area at a pressure differential of 75 Pascal, which is the same as windows.
 - 2. Field-fabricated exterior doors must comply with the requirements of §110.7, as described by “Other Openings”; for example, they must be caulked and weatherstripped.
 - 3. Any door with a surface area greater than 50 percent glass is considered a glazed door and must comply with the mandatory and applicable prescriptive and performance requirements of §150.0, §150.1, and §150.2.
 - 4. For any door with a surface area less than or equal to 50 percent glass, the area may be exempt in accordance with one of the exceptions of §150.0, §150.1, and §150.2.

3.5.3.2 U-Factor and SHGC Rating Mandatory Requirements

§110.6(a)2 and §110.6(a)3; Table 110.6-A and Table 110.6-B

Requiring that U-factor and SHGC be calculated using standardized procedures ensures that the thermal performance or efficiency data for fenestration products is accurate. Furthermore, the data provided by different manufacturers within each fenestration type (windows, doors, skylights, TDDs) can be easily compared to others within that type and can be independently verified.

For manufactured fenestration products, the mandatory requirements are that the U-factor and solar heat gain coefficient (SHGC) be rated by NFRC and be listed in NFRC's Certified Product Directory (CPD). The test procedure for U-factor is NFRC 100, and for SHGC and VT is NFRC 200 and NRC-202 or ASTM E972 for translucent panels, and NFRC-203 for tubular daylighting device skylights (TDDs) and for certain type of other skylights.

At the field inspection, the field inspector verifies that the fenestration U-factor and SHGC values meet the energy compliance values by checking the NFRC label sticker on the product.

When manufacturers do not rate the thermal efficiencies by NFRC procedures, the Energy Commission default values must be used and documented on a temporary default label (See Figure 3-2).

Note: If no labels are available on site for verification, the field inspector should not allow any further installation of fenestration until proof of efficiency (label) is produced. In cases when proof is not met, the field inspector should not allow construction until the designer or builder can produce such labels.

The Energy Commission default U-factors are listed in Table 110.6-A of the Energy Standards, and the default SHGC values are listed in Table 110.6-B (also in Appendix B of this compliance manual).

Note: While there is no minimum VT value requirement for residential compliance, the value may be shown on the temporary label for information only. A listing of NFRC certified ratings is available at <http://www.nfrc.org/>.

Energy Commission default values in Table 110.6-A and Table 110.6-B in the Energy Standards lists the worst performing values that can be assumed when fenestration is not rated by NFRC. For example, a single-pane, operable, metal-framed fenestration product has a U-factor of 1.28. To get credit for high-performance window features such as low-e (low-emissivity) coatings and thermal break frames, the window manufacturer must have the window tested, labeled, and certified according to NFRC procedures.

- A. **Site-Built Fenestration Products.** For special cases in low-rise residential construction in which site-built products are installed, the site-built products shall be treated the same as manufactured products: proof of U-factor and SHGC values must come from NFRC ratings or from the default Table 110.6-A and Table 110.6-B of the Energy Standards, or alternatively use of Reference Nonresidential Appendix NA-6 for nonrated site-built fenestration if the area of the site built is less than 250 ft².

Note: When unrated site-built fenestration is used in a residential application, there is an alternative procedure to calculate the default U-factor and SHGC values. When using area-weighted averaging, the alternative may not result in meeting the prescriptive values as required by Table 150.1-A. The alternative calculation can be found in NA6, or it may be necessary to use the performance approach to meet energy compliance.

B. Field-Fabricated Products §110.6(b). Field-fabricated fenestration must always use the Energy Commission default U-factors from Table 110.6-A and SHGC values from Table 110.6-B of the energy standards. There is no minimum requirement for VT, as it is used for informational purposes.

Acceptable methods of determining U-factor and SHGC are shown in Table 3-1A and Table 3-1B, respectively.

Table 3-1A: Methods for Determining U-Factor

Fenestration Category					
U-factor 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
Standards Default Table 110.6-A	✓	✓	✓	✓	✓
NA6 ²	N/A	N/A	✓	N/A	N/A
1. The NFRC Residential CMA method is an option that may be in the Energy Standards. 2. The Alternative Default U-factors from Nonresidential Reference Nonresidential Appendix NA6 may be used only for site-built vertical and skylights having less than 1,000ft ² .					

Table 3-1B: Methods for Determining SHGC

Fenestration Category					
SHGC Determination Method	Manufactured Windows	Manufactured Skylights	Site-Built Fenestration (Vertical & Skylight)	Field-Fabricated Fenestration	Glass Block
NFRC's Component Modeling Approach (CMA) ¹	✓	✓	✓	N/A	N/A
NFRC-200	✓	✓	✓	N/A	N/A
Standards Default Table 110.6-B	✓	✓	✓	✓	✓
NA6 ²	N/A	N/A	✓	N/A	N/A
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 be used only for site-built vertical and skylights having less than 1,000ft ² .					

3.5.3.3 Labeling Mandatory Requirements

§10-111(a); §110.6(a)5

A. Default Temporary Label

The manufacturer can choose to use Energy Commission default values from Table 110.6-A for U-factors and Table 110.6-B for SHGC of the Energy Standards. If default values are used, the manufacturer must attach a temporary label meeting the following specific requirements. (Permanent etching labels are not required.) The product shall meet the air infiltration requirements of §110.6(a)1, U-factor criteria of §110.6(a)2, and SHGC criteria of §110.6(a)3 in the Energy Standards.

Although there is no exact format for the default temporary label, it must be clearly visible and large enough for the enforcement agency field inspectors to read easily; it must include all information required by the Energy Standards. 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 as noted in Figure 3-2:

“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.”

The manufacturer ensures the U-factor and SHGC default values should be labeled large enough to be readable from four feet away. The manufacturer ensures the appropriate checkboxes are checked and indicated on default label.

Figure 3-2: Sample of Default Temporary Label

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

Source: California Energy Commission

B. Certified Temporary and Permanent Labels

§10-111

1. Certified Manufactured Fenestration Products

The Energy Standards require that manufactured fenestration have both temporary and permanent labels. The temporary label shows the U-factor and SHGC for each rated window unit. The label must also show that the product meets the air infiltration criteria. The temporary label must not be removed before inspection by the enforcement agency.

2. The **permanent label** must, at a minimum, identify the certifying organization and have an ID number or code to allow tracking back to the original information on file with the certifying organization, NFRC. The permanent label can also be inscribed on the spacer, etched on the glass, engraved on the frame, or otherwise located so as not to affect aesthetics.

3. **Field-Fabricated Fenestration** A label is not required for field-fabricated fenestration products, but the default values in Table 110.6-A and Table 110.6-B of the Energy Standards must be used and documented on the Fenestration Certificate, NRCC-ENV-05-E form.

Example 3-4**Question:**

My new home will have a combination of window types, including fixed, operable, wood, metal, and so forth, some of which are field-fabricated. What are the options for showing compliance with the standards?

Answer:

First, all windows must meet the mandatory requirements of §110.6 and §110.7, unless exempted.

For field-fabricated windows, you must select U-factors and SHGC values from the default tables (Table 110.6-A and Table 110.6-B of the Energy Standards). Windows that are not field-fabricated must be labeled with NFRC-certified or default efficiencies. If the U-factors or SHGC values do not comply with the prescriptive requirements, the performance method must be used. To simplify data entry into the compliance software, you may choose the U-factor from Table 110.6-A of the Energy Standards that is the highest of any of the windows planned to be installed, and use this for all windows for compliance. However, you must use the appropriate SHGC from Table 110.6-B for each window type being installed.

Example 3-5**Question:**

When windows are labeled with a default value, are there any special requirements that apply to the label?

Answer:

All windows must meet the mandatory requirements by §110.6 and §110.7, unless exempted.

There are two criteria that apply to fenestration products labeled with default values.

First, the administrative regulations (§10-111) require that the words “CEC Default U-factor” and “CEC Default SHGC” appear on the temporary label in front of or before the U-factor or SHGC (in other words, not in a footnote).

Second, the U-factor and SHGC for the specific product must be listed. If multiple values are listed on the label, the manufacturer must identify, in a permanent manner, the appropriate value for the labeled product. Marking the correct value may be done in one of the following ways only:

1. Circle the correct U-factor and SHGC (permanent ink).

2. Black out all values except the correct U-factor and SHGC (permanent ink).
3. Make a hole punch next to the appropriate values.

Example 3-6

Question:

Which U-factor do I use for an operable metal framed, glass block? Which SHGC do I use for clear glass block? Does it need a label?

Can I use the default clear glass SHGC values for tinted glass block?

Answer:

For glass block, use the U-factor and SHGC values from Table 110.6-A and Table 110.6-B of the Energy Standards for the frame type in which the glass blocks are installed. The worst-case scenario would be metal-framed glass. The U-factor for metal-framed glass block is from Table 110.6-A is 0.87. The SHGC depends on whether the glass block has a metal or non-metal frame, and is operable or fixed or clear or tinted. For this example, the glass block is operable and clear; therefore, the SHGC is 0.70. Glass block is considered a field-fabricated product and therefore does not need a label.

Yes, the default tables for glass block do not include tinted glass.

Example 3-7

Question:

Is there a default U-factor for the glass in sunrooms?

Answer:

Yes. For the horizontal or sloped portions of the sunroom glazing, use the U-factor for skylights. For the vertical portions, use the U-factors for fixed windows, operable windows, or doors, as appropriate. As a simple alternative, the manufacturer may label the entire sunroom with the highest U-factor of any of the fenestration types within the assembly.

Example 3-8

Question:

How are various door types treated in compliance documentation for U-factor and SHGC? How can I determine a U-factor and SHGC for doors when less than 50 percent of the door area is glass?

Answer:

All doors with glass area greater than 50 percent of the door area, which includes French doors, are defined as fenestration products and are covered by the NFRC Rating and Certification Program. The U-factor SHGC for doors with glass area greater than 50 percent may be determined in one of two ways:

1. Use the NFRC rated and labeled values.
2. Refer to Table 110.6-B of the Energy Standards. The values are based upon glazing and framing type.
3. In special cases where site-built fenestration is being installed in a residential application, the site-built windows can use an alternative method to calculate the U-factor and the SHGC by using the manufacturer's center-of-glass values (COG). The COG values are calculated in accordance with NA6. The maximum allowed of site-built fenestration is less than 1,000 ft².

Doors with less than 50 percent glass areas are treated as a door with fenestration installed within the door. The glass area is calculated as the sum of the glass areas plus two inches on all sides (to account for framing). For prescriptive or performance approaches, use one of the following options for U-factor and SHGC of the glass:

- The NFRC label if one is available
- The default values from Tables 110.6-A and 110.6-B of the Energy Standards

The opaque part of the door is ignored in the prescriptive approach. If the performance approach is used, a default SHGC value of 0.50 must be assumed for the opaque portion of the door. Alternatively, if NFRC values for U-factor and SHGC for the entire door are available, the door may be considered a fenestration product.

Example 3-9

Question:

As a manufacturer of fenestration products, I place a temporary label with the air infiltration rates on my products. Can you clarify which products must be tested and certified?

Answer:

Each product line must be tested and certified for air infiltration rates. Features such as weather seal, frame design, operator type, and direction of operation affect air leakage. Every product must have a temporary label certifying that the air infiltration requirements are met. This temporary label may be combined with the temporary U- factor, SHGC, and VT label.

Example 3-10

Question:

Is a custom window “field-fabricated” for meeting air infiltration requirements?

Answer:

No. Most custom windows are manufactured and delivered to the site either completely assembled or “knocked down,” which means they are a manufactured product. A window is considered field-fabricated when the windows are assembled at the building site from the various elements that are not sold together as a fenestration product (such as glazing, framing, and weatherstripping). 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).

Example 3-11

Question:

What constitutes a “double-pane” window?

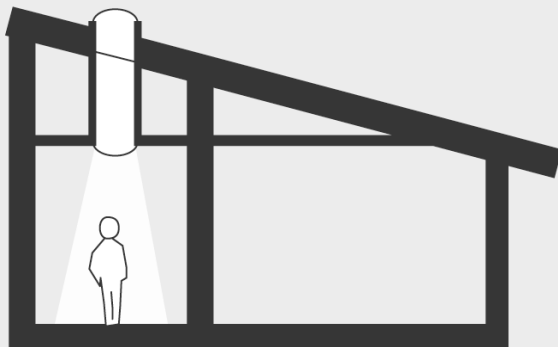
Answer:

Double-pane (or dual-pane) glazing is made of two panes of glass (or other glazing material) separated by 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.

Example 3-12

Question:

To get daylight into a room in my new house, I plan on installing a tubular daylighting device and will be using the performance approach for compliance. The skylight has a clear plastic dome exterior to the roof, a single pane ¼-inch (6 mm)-thick acrylic diffuser mounted at the ceiling, and a metal tube connecting the two. How do I determine the U-factor and SHGC that I will need to determine if I can comply with the Energy Standards, if U_c is 1.20 and $SHGC_c$ is 0.85?

**Answer:**

Tubular daylighting device (TDD) skylights are an effective means of bringing natural light indoors, as are traditional skylights.

There are three methods available for determining the thermal efficiencies for TDDs:

The first is to use the default U-factor from Table 110.6-A of the Energy Standards. This tubular product would be considered a metal frame, fixed, single-pane skylight resulting in a U-factor of 1.19, which must appear on a label preceded by the words “CEC Default U-factor.” (A tubular daylighting device would have to have two panes of glazing with an air space of less than 2 inches (50 mm) between them at the plane of the ceiling insulation for it to be considered double-pane.)

The second method is to determine the U-factor from NA6, Equation NA6-1. The U-factor for this tubular daylighting device would be based on metal with no curb (Table NA6-5). The U-factor for this skylight, using Equation NA6-1, is 1.25, where $U_t = (0.195 + (0.882 \times 1.20))$. This must appear on a label stated as “CEC Default U-factor 1.25.”

The third and best method, applicable if the product has been tested and certified pursuant to NFRC procedures, requires a label that states: “Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures NFRC 100,” followed by the U-factor.

There also are three methods available for determining SHGC. The first is to use the default table SHGC in Table 110.6-B of the Energy Standards. This tubular daylight device would be considered a metal frame, fixed, clear, single-pane skylight resulting in an SHGC of 0.83, which must appear on a label stated as “CEC Default SHGC 0.83.”

The second method also determines the SHGC from NA6, Equation NA6-2. The SHGC for this skylight using Equation NA6-2 is 0.81, where

$SHGC_t = (0.08 + (0.86 \times 0.85))$. This must appear on a label stated as “CEC Default SHGC 0.81.”

The third method, applicable if the skylight has been tested and certified pursuant to NFRC procedures, requires a label that states, “Manufacturer stipulates that this rating was determined in accordance with applicable NFRC procedures.”

Example 3-13**Question:**

How would the U-factor and the SHGC be determined if the tubular daylighting device in the example above has a dual-pane diffuser (instead of single-pane) mounted at the ceiling?

Answer:

The procedure would be exactly the same as the example above, except that the double-pane U-factor and SHGC values from Tables 110.6-A and 110.6-B of the Energy Standards would be used instead of single-pane values. Up to 3 ft² of tubular daylighting device is assumed to have the U-factor and SHGC required by Package A for prescriptive performance compliance (Exception 1 to §150.1(c)3A).

Example 3-14: Through the wall pet doors**Question:**

How do I account for a pet door installed in an exterior wall in a newly constructed residential building design?

Answer:

Pet doors must meet all door requirements.

First a U-factor must be determined by an NFRC accredited testing lab using NFRC 100 U-factor requirements; otherwise, non-rated pet doors will assume no more than the maximum U-factor of 0.99 based on a nonmetal single pane door U-factor (See Table 110.6-A of the Energy Standards). Second, the rated pet door shall not exceed 0.3 cfm/ft² air leakage when tested using ASTM E283. Third, use the performance compliance approach to determine the weighted average U-factor of the wall assembly including the pet door. The proposed U-factor shall not exceed the mandatory minimum U-factor of 0.102 that results in installing R-13 cavity insulation in a 2x4 wood framed wall or a U-factor of 0.074 that results in installing R-19 cavity insulation in a 2x6 wood framed wall.

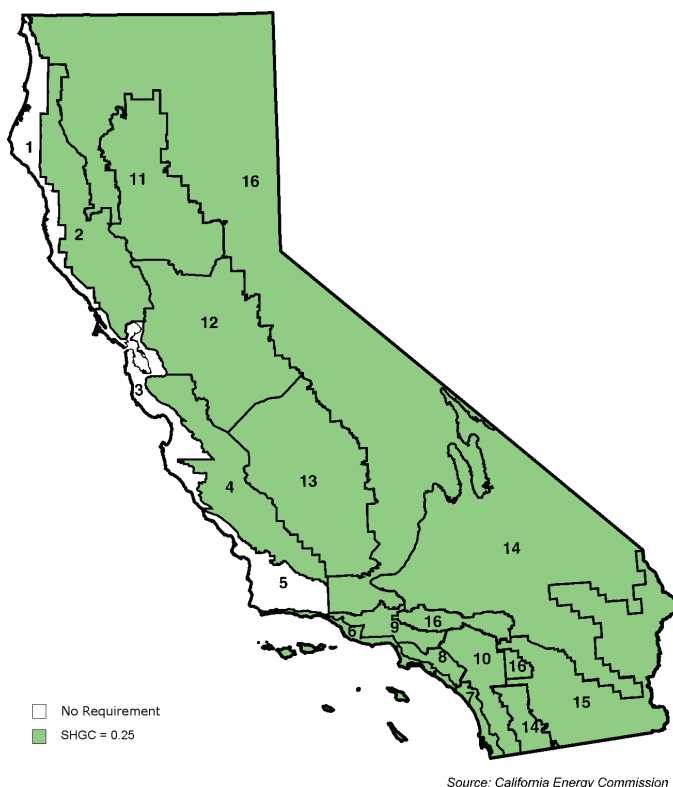
Note: Additional insulation may be added to the wall if unable to meet the mandatory minimum U-factor. See Reference Joint Appendix JA4, Table JA4.3.1 for other nominal wood framing size and Table JA4.3.4 for other nominal metal framing size.

3.5.3.4 Fenestration U-factor

§150.0(q)

For fenestration products, the mandatory maximum U-factor is 0.58. This is based on the worst case scenario for a double-pane, vinyl-framed fenestration product including skylights. Area-weighted averaging can be used to allow flexibility for the placement of a fenestration product with a U-factor greater than 0.58. Up to 10 ft² or 0.5 percent of conditioned floor area (whichever is greater) is exempt from the maximum U-factor requirement.

Figure 3-3: Package A, SHGC Criteria by Climate Zone



3.5.4 Prescriptive Requirements

§150.1(c)3

Prescriptive requirements described in this chapter typically refer to Package A or Table 150.1-A. The maximum U-factor required by prescriptive Package A for all climate zones is 0.32, and the maximum SHGC is 0.25 for residences in Climate Zones 2, 4, and 6-16. Homes constructed in Climate Zones 1, 3, and 5 have no SHGC requirements. The requirements apply to fenestration products without consideration of insect screens or interior shading devices. With some exceptions, some fenestration products may exceed the prescriptive requirement as long as the U-factor and SHGC of windows, glazed doors, and skylights can be area weight-averaged together to meet the prescriptive requirement using the WS-2R form in Appendix A of this manual.

Table 3-2: Maximum U-Factors, SHGC, and Fenestration Area by Climate Zone in Package A (from Table 150.1-A of the Energy Standards)

Climate Zone	1, 3, 5	2,4,6-16
Maximum U-factor	0.32	0.32
Maximum SHGC	NR	0.25
Maximum Fenestration Area	20%	20%
Maximum West-Facing Fenestration	NR	5%

3.5.5 Fenestration Prescriptive Exceptions

§150.1(c)3A through §150.1(c)3C

A. Doors and Tubular Daylighting Device

In each dwelling unit, up to 3 ft² of the glazing area installed in doors and up to 3 ft² of tubular daylighting devices area with dual-pane diffusers at the ceiling are exempt from the prescriptive U-factor and SHGC requirements, where glazed door and TDD area is included in the maximum of 20 percent fenestration area. However, the U-factor shall not exceed a maximum of 0.58. See §150.0(q) and Exception 1 of §150.1(c)3A.

B. Skylights

Each new dwelling unit may have up to 16 ft² of skylight area; the total area of skylights is included in the maximum of 20 percent fenestration area and meets a maximum 0.55 U-factor and a maximum SHGC of 0.30. See Exception 2 of §150.1(c)3A.

Aside from the specific exceptions to the fenestration prescriptive requirements, U-factors and SHGCs for skylights can be significantly higher than they are for windows so long as the area weight-averaged U-factor and SHGC do not exceed the 0.55 U-factor and is not greater than the 0.30 SHGC when large numbers of skylights are used for prescriptive compliance. Alternatively, the performance approach should be used for meeting energy compliance.

C. Dynamic Glazing

If a dwelling unit includes a type of dynamic glazing that is electric-chromatic, chromogenic, or an integrated shading device, and the glazing is automatically controlled, use the lowest U-factor and lowest SHGC to determine compliance with prescriptive Package A fenestration requirements. Since this type of product has compliance ratings that vary, it cannot be weight averaged with nonchromogenic products as per Exception 3 of §150.1(c)3A.

D. Site-Built Fenestration

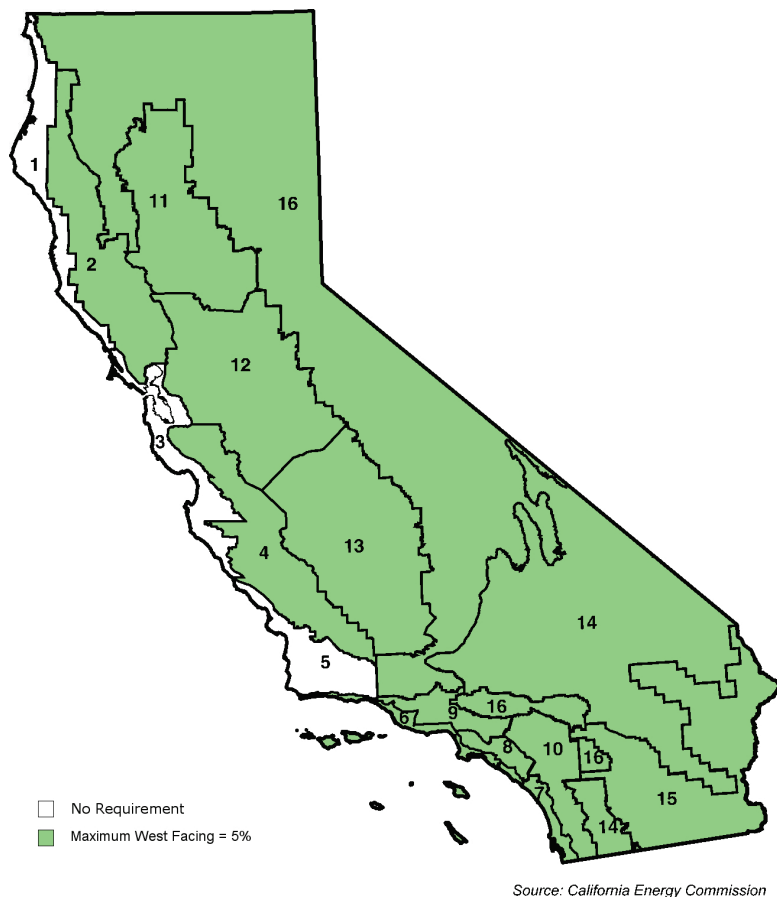
When a residential dwelling unit contains a combination of manufactured and site-built fenestration; only the site-built fenestration values can be determined by using NA6; however, all fenestration, including site-built, can default to Tables 110.6-A or B.

E. Maximum Area

The prescriptive requirements limit total glass area to a maximum of 20% of the conditioned floor area in all climate zones; however, there are exceptions to the prescriptive requirements for alterations in §150.2(b)1A which allow additional glass area beyond the 20% limitation, including west-facing glass.

F. Greenhouse Windows/Garden Windows

Compared to other fenestration products, the NFRC-rated U-factor for greenhouse windows are comparatively high. §150.0(q) includes an exception from the U-factor requirement for dual-glazed greenhouse or garden windows that total up to 30 ft² of fenestration area.

Figure 3-4: Package A, Prescriptive West-Facing Window Area Limits by Climate Zone

3.5.6 Fenestration Shading Types

A. Shading

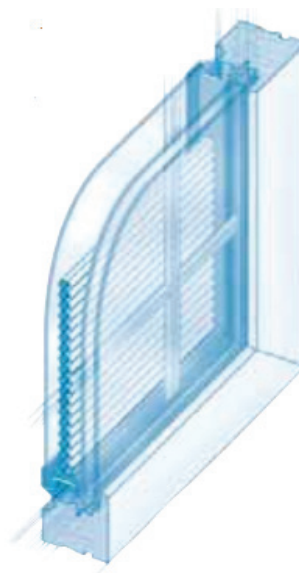
While a low emissivity (low-e) coating on the glass is one of the most common ways to reduce solar gain in combination with insulated window frame, there are other options to help increase shading:

1. Use of permanent installed exterior shade screens
2. Louvers on the outside of the window are typically used on windows facing south. See Table 3-3 for different types of exterior shades and SHGC's.
3. Properly sized overhang - Discussed later in Section 3.5.8.4.

B. Dynamic Glazing

Dynamic glazing products are either integrated shading systems or electro-chromatic-type devices and are considered a fenestration product. Integrated shading systems include blinds positioned between glass panes that can be opened and closed using automatic controls. The labels for integral shading systems will reflect the endpoints of the product's performance for U-factor and SHGC (See Figure 3-6).

Figure 3-5: Example of Dynamic Glazing Type - Integrated Shading System



Source: NFRC Dynamic Glazing Products Fact Sheet

The unique rating “variable arrow” identifier helps consumers understand the “dynamics” of the product and allows comparison with other similar dynamic fenestration products. The following is a label reference:

- A. The variable arrow – If the fenestration product can operate at intermediate states, a dual directional arrow (\leftrightarrow) with the word “Variable” 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 or darker position), and the high value rating is displayed to the right (in the open or lighter position). This lets the consumer know at a glance the best and worst case performance of the product and the default or de-energized performance level.

Figure 3-6: Example of Dynamic Glazing Type - Integrated Shading System

 National Fenestration Rating Council® CERTIFIED		World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Dynamic Glazing • Argon Fill • Low E Product Type: Vertical Slider	
ENERGY PERFORMANCE RATINGS			
U-Factor (U.S./I-P) 0.30 <small>Variable</small> \leftrightarrow 0.40 <small>Off/Closed</small> <small>On/Open</small>		Solar Heat Gain Coefficient 0.10 <small>Variable</small> \leftrightarrow 0.50 <small>Off/Closed</small> <small>On/Open</small>	
ADDITIONAL PERFORMANCE RATINGS			
—		Air Leakage (U.S./I-P) 0.2	
<small>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</small>			

 National Fenestration Rating Council® CERTIFIED		World's Best Window Co. Millennium 2000+ Vinyl-Clad Wood Frame Double Glazing • Dynamic Glazing • Argon Fill • Low E Product Type: Vertical Slider	
ENERGY PERFORMANCE RATINGS			
U-Factor (U.S./I-P) 0.30 <small>Variable</small> \leftrightarrow 0.40 <small>Off/Closed</small> <small>On/Open</small>		Solar Heat Gain Coefficient 0.10 <small>Variable</small> \leftrightarrow 0.50 <small>Off/Closed</small> <small>On/Open</small>	
ADDITIONAL PERFORMANCE RATINGS			
Visible Transmittance 0.03 <small>Variable</small> \leftrightarrow 0.65 <small>Off/Closed</small> <small>On/Open</small>		Air Leakage (U.S./I-P) 0.2	
<small>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</small>			

Source: NFRC Dynamic Glazing Products Fact Sheet

C. Chromatic Glazing

One type of dynamic glazing product uses a chromatic type of glass that has the ability to change the performance properties, allowing occupants to control their environment manually or automatically by tinting or darkening a glass with the flip of a switch. Some fenestration products can change performance automatically with the use of an automatic control or environmental signals. These high-performance windows provide a variety of benefits, including reduced energy costs due to controlled daylighting and unwanted heat gain or heat loss. While still a relatively new technology, they are expected to grow substantially in the coming years. A view of chromatic glazing in the open (off) and closed (on) position is shown in Figure 3-7 below.

Figure 3-7: Chromatic Glazing



Source: Sage Electrochromics

3.5.7 Dynamic Glazing Device

A. Integral Shading Device

To use the high-performance values, one of the following must be met:

1. Must have an NFRC Certified Label sticker.
2. When no NFRC is available, then the default values from Tables 110.6-A and 110.6-B must be used.

B. Chromogenic Glazing

1. Must have an NFRC Certified Label sticker; and
2. Automatic controls must be installed to receive best rated performance value.
3. If there is no NFRC label but with automatic controls, then default to Table 150.1-A maximum U-factor of 0.32 and maximum SHGC of 0.25; or
4. If there is a NFRC label, but no automatic controls, then default to Table 150.1-A maximum U-factor of 0.32 and maximum SHGC of 0.25; or
5. If there is no NFRC and no automatic controls, then the default values from Tables 110.6-A and 110.6-B of the Energy Standards must be used.

C. Window Films

Window films are polyester film that offer high-clarity and can be pretreated to accept different types of coatings. There are three basic categories of window films:

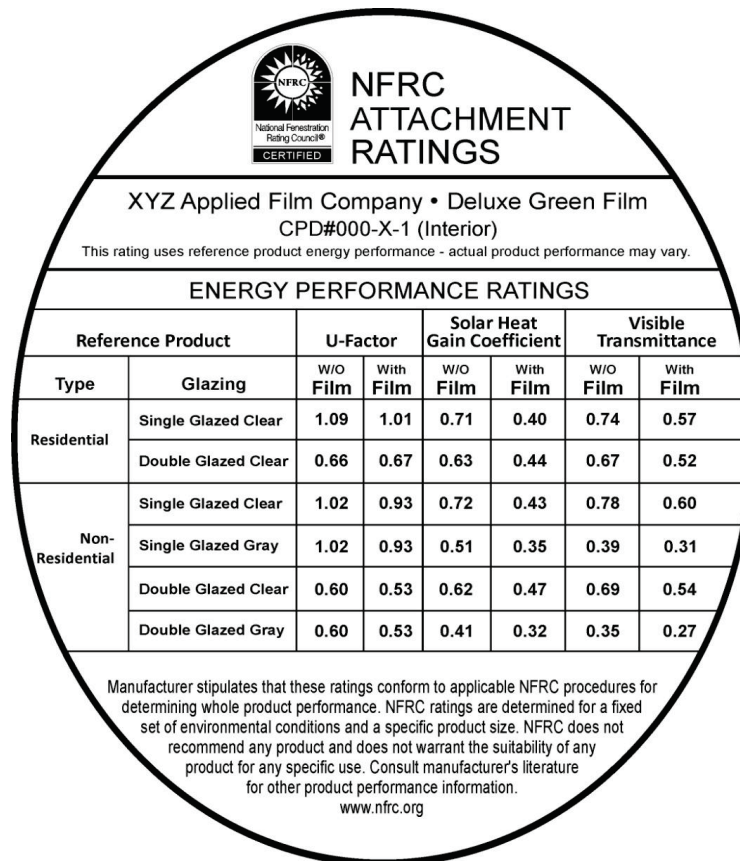
1. Clear (nonreflective) films are used as safety or security film to reduce ultraviolet (UV) light, which contributes greatly to fading; however, they are not normally used for solar control or energy savings.
2. Tinted or dyed (nonreflective) films reduce both heat and light transmission, mostly through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

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

- The performance approach must be used to meet energy compliance.
- NFRC Window Film Energy Performance Label is required for each different film applied; otherwise, the default values from Tables 110.6-A and 110.6-B of the Energy Standards must be used.
- Window films must have at least a 10-year warranty.

See Figure 3-8 below. The NFRC Attachment Ratings Label helps identify the energy performance of window films.

Figure 3-8: Window Film Energy Performance Label



Source: NFRC Applied Film Products Fact Sheet

D. Glazed Doors

§110.6

Any door that is more than one-half glass is considered a glazed door and must comply with the mandatory measures and other requirements applicable to a fenestration product. Up to 3 ft² of glass in a door is exempt from the U-factor and SHGC requirements (or can be considered equivalent to the Package A values). The U-factor and SHGC shall be based on either the NFRC values for the entire door, including glass area, or use default values in Table 110.6-A for the U-factor and Table 110.6-B for the SGHC of the Energy Standards. If the door has less than 50 percent glazing, the opaque part of the door is ignored in the prescriptive approach, but in the performance method it is assumed to have a default U-factor of 0.50. The glass area of the door is calculated as the sum of all glass surfaces plus 2 inches on all sides of the glass to account for a frame.

3.5.8 Compliance Alternatives

While the prescriptive requirements and mandatory measures establish a minimum level of building energy performance, opportunities to exceed the requirements of the Energy Standards are considerable. Some of these *compliance options* are discussed in this section, while others are included in the Performance Compliance section (Chapter 8). Options that are recognized for credit through the performance method are called *compliance options*. Most require using the performance approach, but a few exterior shading devices and south facing overhangs may be used to comply when using the prescriptive approach.

3.5.8.1 Fenestration Area

Beginning with the 2005 update to the standards, no credit is offered through the performance approach for reducing fenestration area below the maximum allowed 20percent of the conditioned floor area (CFA).

Data shows that the average window area in single-family homes is about 17.3 percent of the CFA. In multifamily buildings, the average window area is about 14.5 percent of the CFA.

The Energy Commission made fenestration area less than or equal to 20 percent a neutral variable in the *performance approach* with the 2005 update, and there is no change in this regard in the 2016 update. The Energy Commission recognizes that area and orientation can have a big effect on energy use, but because these are so variable in buildings, the Energy Commission does not want the energy efficiency of other building components to be eroded in buildings that have relatively small fenestration areas. While there is no credit for fenestration area less than 20 percent of CFA, there is a penalty for buildings that have a window area that exceeds 20 percent of CFA. Such buildings are permitted only with the performance approach, where the standard design has a fenestration area equal to the proposed design, up to 20 percent of CFA, and the glass area in the standard design is uniformly distributed among cardinal orientations. The proposed design has the exact proposed glass area and orientation.

3.5.8.2 Orientation

Window and skylight orientation has a huge impact on both energy use and peak electric demand. Orientation is a compliance option that is recognized in the performance approach, since the standard design has windows uniformly distributed on the north, south, east, and west sides of the building.

3.5.8.3 Improved Fenestration Performance

With the 2016 update, the weighted average U-factor remains at 0.32 in all climate zones, as indicated in Package A. This means there is only a minor credit available for installing high-performance fenestration that could be traded off or be used to avoid other measures, such as duct sealing and verification. However, choosing high-performance fenestration that performs better than the prescriptive requirements level can still earn significant credit through the performance method. For example, in air conditioning climates, choosing a window with an SHGC lower than 0.25 will reduce the cooling loads compared to the standard design.

The magnitude of the impact will vary by climate zone. In mild coastal climates, the benefit from reducing fenestration U-factor will be smaller than in cold, mountain climates. Several factors affect window performance. For fenestration with NFRC ratings, the following performance features are accounted for in the U-factor and SHGC ratings:

1. Frame materials, design, and configuration (including cross-sectional characteristics). Fenestration is usually framed in wood, aluminum, vinyl, or composites of these. Frame materials such as wood and vinyl are better insulators than metal. Some aluminum-framed units have thermal breaks that reduce the conductive heat transfer through the framing element as compared with similar units having no such conductive thermal barriers.
2. Number of panes of glazing, coatings, and fill gases. Double-glazing with coatings or dynamic glazing with controls offers opportunities for improving performance beyond the dimension of the air space between panes. For example, special materials that reduce emissivity of the surfaces facing the air space, including low-e or other coatings and chromogenic glazing, improve the thermal performance of fenestration products. Fill gases other than dry air, such as, carbon dioxide, argon, or krypton and chromogenic glazing, also improve thermal performance.

3.5.8.4 Fixed Permanent Shading Devices

Shading of windows is also an important compliance option. Overhangs or sidefins that are attached to the building or shading from the building itself are compliance options for which credit is offered through the performance approach. However, no credit is offered for shading from trees, adjacent buildings, or terrain.

Windows that face south can be effectively shaded by overhangs positioned above the window. The ideal overhang is one that provides shade during the months when the building is likely to be in an air conditioning mode and allows direct solar gains in the heating months. This can be achieved because during the summer the sun is high as it passes over the south side, while in the winter it is low, enabling solar radiation to pass beneath the overhang. Due to the potential effectiveness of south-facing overhangs, a prescriptive compliance option is offered. See Section 3.5.8.6 for details.

Shading is much more difficult on the east and west sides of the house. When the sun strikes these façades, it is fairly low in the sky, making overhangs ineffective. Vertical fins can be effective, but they degrade the quality of the view from the window and limit the natural light that can enter. In cooling climates, the best approach is to minimize windows that face east and west. Landscaping features can be considered to increase comfort but cannot be used for compliance credit.

3.5.8.5 **Reserved**

3.5.8.6 **Exterior Shading Devices**

The prescriptive requirements require fenestration products with an SHGC of 0.25 or lower in Climate Zones 2, 4, and 6 through 16. However, a fenestration product with an SHGC greater than 0.25 may be used with the prescriptive requirements if a qualifying exterior shading device is used. Exterior shading devices and associated SHGC values are shown in Table 3-3. These include woven sunscreens as well as perforated metal sunscreens. As shown in the table, these devices transmit between 13 percent and 30 percent of the sun that strikes them.

When exterior overhangs are used, the SHGC requirements of prescriptive Package A may be met if the calculated combination of the overhang and fenestration SHGC efficiency is equal or lower than 0.25.

For compliance credit, exterior shading devices must be permanently attached as opposed to being attached using clips, hooks, latches, snaps, or ties. Exterior shading devices on windows or skylights that are prohibited by life-safety codes from being permanently attached for emergency egress reasons are exempt from this requirement. Compliance form CF1R-ENV-03 is used to calculate the combined SHGC of windows and exterior shading devices. When exterior shades are required for compliance, they must also be listed on the CF1R form and documented on the plans.

The SHGC of the window in combination with an exterior device is given by the following:

Equation 3-1:

$$\text{SHGC}_{\text{combined}} = (0.2875 \times \text{SHGC}_{\text{max}} + 0.75) \times \text{SHGC}_{\text{min}}$$

All operable windows and skylights are assumed to have an insect screen, and this is the default condition against which other window/exterior shading device combinations are compared. The standard case is a window with an SHGC of 0.25 and an insect screen with an SHGC of 0.76. For this default case, the SHGC of the window is the SHGC_{min} , and the SHGC of the exterior sunscreen is SHGC_{max} . Working through the math on the CF1R-ENV-03 form, $\text{SHGC}_{\text{combined}}$ is 0.25. This means that any combination of window SHGC and exterior SHGC that results in a $\text{SHGC}_{\text{combined}}$ of 0.25 or less complies with the prescriptive requirements.

Most of the shading devices (other than the default insect screen) have an SHGC of 0.30 or lower. Combining this with the SHGC of any window may result in a combined SHGC that is equal to or lower than the prescriptive criterion of 0.25. This method of combining the SHGC of the window with the SHGC of the exterior shading device is also used with the whole-building performance approach.

Compliance form CF1R-ENV-03 is used to calculate the combined SHGC of windows and exterior sunscreen type shading devices. When exterior shades are required for compliance, they must be listed on the CF1R form and be documented on the plans.

¹ The equation can be found in the *2016 Residential Compliance Manual*, and it is included in WS-3R in Appendix A.

Table 3-3: Exterior Shades and Solar Heat Gain Coefficients

Exterior Shading Device	SHGC*
Standard Bug (insect) Screen (default for windows)	0.76
Exterior Sunscreens with Weave 53 x 16/inch	0.30
Louvered Sunscreens w/Louvers as wide as Window Openings	0.27
Low Sun Angle Louvered Sunscreen	0.13
Vertical Roller Shades or retractable/Drop Arm/Combination/Marquisolette and Operable Awnings	0.13
Roll Down Blinds or Slats	0.13
None (for skylights only)	1.00
* Reference glass values assume single pane clear glass and metal framing 1/8 th inch double strength (DSS) glass. Use WS-3R Worksheet for calculation.	

3.5.8.7 Interior Shading

There is no credit for interior aftermarket shading devices, although they can be effective in reducing solar gains and should be considered by homeowners. The Energy Commission considers these added interior shades in the category of home furnishings and not a feature of the house that is provided by the builder or fenestration manufacturer. Draperies, interior blinds, interior shades, and other interior devices are not credited toward energy compliance; however, a default standard shade is still considered in performance calculations so that estimates of energy use are more realistic, and tradeoffs against other measures are more equitable.

3.5.8.8 Bay Windows

Bay windows are a special compliance case. Bay windows may either have a unit NFRC rating (that is, the rating covers both the window and all opaque areas of the bay window), an NFRC rating for the window only, or no NRFC rating. Nonrated bay windows may or may not have factory-installed insulation.

For bay windows that come with an NFRC rating for the entire unit, compliance is determined based on the rough opening area of the entire unit, applying the NFRC U-factor and SHGC. If the unit U-factor and SHGC do not meet the package requirements or area-weighted average, the project must show compliance using the performance approach.

Bay windows with no rating for the entire unit (where there are multiple windows that make up the bay) and with factory-installed or field-installed insulation must comply accounting for the performance characteristics of each component separately. Opaque portions of bay windows including roofs and floors must be insulated to meet the wall insulation requirements of Package A for prescriptive compliance. The opaque portion must either meet the minimum insulation requirements of Package A for the applicable climate zone or be included in a weighted average U-factor calculation of an overall opaque assembly that does meet the Package A requirements. For the windows, the U-factor and SHGC values may be determined either from an NFRC rating or by using default values in Tables 110.6-A and 110.6-B of the Energy Standards. If the window U-factor and SHGC meet the package requirements, the bay window complies prescriptively (if overall building fenestration area meets prescriptive compliance requirements). If the bay window does not meet package requirements, the project must show compliance under the performance approach.

3.5.8.9 Natural Ventilation Through Fenestration

Operable fenestration can be a source of ventilation air useful for improving indoor air quality by dilution of indoor air contaminants and moisture and by “free” cooling. During periods when the outdoor temperature is lower than the desired indoor temperature and the indoor temperature is uncomfortably warm from solar gains through fenestration or from heat generated inside the house, windows may be opened for some or all of the cooling. Natural ventilation can reduce the need to run the air conditioner. Not only does natural ventilation save energy, but it can also provide better air quality inside the home.

Energy Commission-sponsored research in California homes has shown that a significant number of home occupants do not regularly open their windows and skylight for ventilation. When building envelopes are sealed to reduce infiltration, air exchange with the outside air is reduced, which increases the need for a mechanical means of bringing in outside air.

Starting with the 2008 update, it is mandatory to meet the requirements of ASHRAE Standard 62.2, which include mechanical ventilation and minimum openable window area requirements.

This mandatory measure is discussed in greater detail in Section 3.6.1.17 and 3.6.1.18.

3.5.8.10 Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the fenestration efficiency values, areas, orientation, and so forth be indicated on the CF1R form and also specified on the building plans. In addition, the area-weighted efficiency values of the actual installed fenestration products shall meet or exceed the efficiency values on the CF1R form. For more information, see Compliance and Enforcement on fenestration in Chapter 2 of this manual.

3.6 Envelope Features

This section of the building envelope chapter addresses the requirements for the building shell, excluding fenestration. Components of the building shell include walls, floors, and roofs and/or ceilings. Fenestration, windows, and doors are addressed in Section 3.5.

3.6.1 Mandatory Measures

§110.7, §110.8, §150.0

3.6.1.1 Joints and Other Openings

§110.7

Air leakage through joints, penetrations, cracks, holes, and openings around windows, doors, walls, roofs, and floors can result in higher energy use for home heating and cooling than necessary. The following openings in the building envelope shall be caulked, gasketed, weatherstripped, or otherwise sealed:

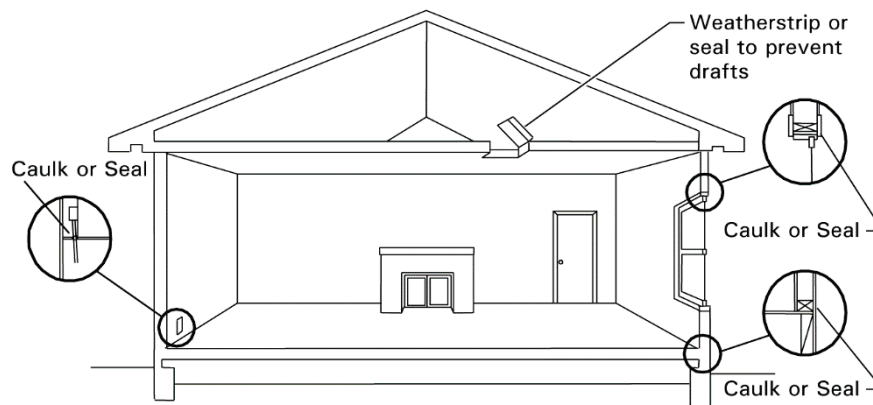
1. Exterior joints around window and door frames, including doors between the house and garage, between interior HVAC closets and conditioned space, between attic access and conditioned space, between wall sole plates and the floor, exterior panels and all siding materials
2. Openings for plumbing, electricity, and gas lines in exterior and interior walls, ceilings, and floors

3. Openings in the attic floor (such as where ceiling panels meet interior walls, exterior walls, and masonry fireplaces)
4. Openings around exhaust ducts such as those for clothes dryers
5. Weatherstripping is required for all field-fabricated operable windows and doors (other windows and doors must meet infiltration requirements and be laboratory tested). This includes doors between the garage and the house, between interior HVAC closets and conditioned space, and between the attic access and conditioned space (§110.6(b))
6. All other such openings in the building envelope.

Alternative techniques may be used to meet the mandatory caulking and sealing requirements for exterior walls. These include, but are not limited to:

1. Stucco
2. Caulking and taping all joints between wall components (for example, between slats in wood slat walls)
3. Building wraps
4. Rigid wall insulation installed continuously on the exterior of the building

Figure 3-9: Caulking and Weatherstripping



Source: California Energy Commission

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that all potential sources of infiltration and exfiltration in the building envelope, joints, and openings are caulked, gasketed, or otherwise sealed. For more information on Compliance and Enforcement for joints and openings, see Chapter 2.

3.6.1.2 Certification of Insulation Materials

§110.8(a)

Manufacturers must certify that insulating materials comply with *California Quality Standards for Insulating Materials* (CCR, 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. Builders and enforcement agencies shall use the Department of Consumer Affairs *Directory of Certified Insulation Material* to verify the certification of the insulating material. If an insulating product is not listed in the current edition of the directory, contact the Department of Consumer Affairs, Bureau of Home

Furnishing and Thermal Insulation Program, at (916) 999-2041 or by E-mail:
HomeProducts@dca.ca.gov.

3.6.1.3 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, a volatile and harmful organic chemical.

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 vapor retarder must be placed in the wall construction to isolate the insulation from the interior of the space. The vapor retarder must be 4-mil (0.1 mm) thick polyethylene or equivalent.

3.6.1.4 Flame Spread Rating of Insulation

§110.8(c)

The *California Quality Standards for Insulating Materials* requires that exposed facings on insulation material be fire resistant and be tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings must be in contact with the finished assembly surface, or they are considered exposed applications and cannot be installed.

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

3.6.1.5 Insulation Requirements for Heated Slab Floors

§110.8(g)

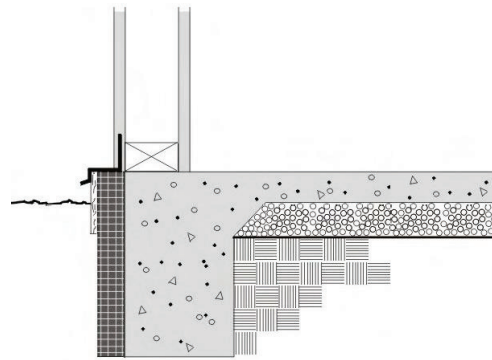
Heated slab-on-grade floors must be insulated according to the requirements in Table 110.8-A and Table 3.4 below. The top of the insulation must be protected with a rigid material to prevent intrusion of insects into the building foundation.

A common location for the slab insulation is on the foundation perimeter. (See Figure 3-10.) 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 between the heated slab and foundation wall. In this case, insulation must extend downward to the top of the footing and then extend horizontally inward 4 ft toward the center of the slab. R-5 vertical insulation is required in all climates except climate zone 16, which requires R-10 of vertical insulation and R-7 horizontal insulation.

Figure 3-10: Perimeter Slab Insulation



Source: California Energy Commission

Table 3-4: 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 plan view.	1 – 15	5
			16	10 vertical and 7 horizontal

3.6.1.6 Wet Insulation Systems

§110.8(h)

Wet insulation systems are roofing systems where the insulation is installed above the waterproof membrane of the roof. 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 and using the result value in choosing the table column in Reference Joint Appendix JA4, for determining assembly U-factor (when using the Joint Appendix JA4 table to comply). See the footnotes for Tables 4.2.1 through 4.2.7 in the Reference Joint Appendix JA4.

3.6.1.7 Roofing Products Solar Reflectance and Thermal Emittance

§110.8(i)

Roofing products shall be rated by the Cool Roof Rating Council (CRRC) and labeled appropriately by the roofing manufacturer for both solar reflectance and thermal emittance. The CRRC certification includes solar reflectance and thermal emittance. There are three kinds 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 reflectance. However, if the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the aged value shall be derived from the CRRC aged value equation (using the initial value for solar reflectance) or an accelerated process. Until the appropriate aged rated value for the reflectance is posted in the directory, the equation below can be used to calculate the aged rated solar reflectance or a new method of testing is used to find the accelerated solar reflectance.

Equation 3-2:

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

Where:

ρ_{initial} = Initial Reflectance listed in the CRRC Rated Product Directory

β = soiling resistance which is listed in Table 3-5


Table 3-5: Values of Soiling Resistance β by Product Type

PRODUCT TYPE	β
Field-applied coating	0.65
Other	0.70

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

1. For asphalt shingles, 0.08/0.75
2. For all other roofing products, 0.10/0.75

Figure 3-11: Sample CRRC Product Label and Information

	<u>Initial</u>	<u>Weathered</u>	
	Solar Reflectance	0.00	Pending
	Thermal Emittance	0.00	Pending
Rated Product ID Number		-----	
Licensed Seller ID Number		-----	
Classification	Production Line		
<p>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.</p> <p>Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.</p>			

Source: Cool Roof Rating Council

A. Field-Applied Liquid Coatings

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. These requirements do not apply to industrial coatings that are factory-applied, such as metal roof panels. The requirements address elongation, tensile strength, permeance, and accelerated weathering. The requirements depend on the type of coating and are described in greater detail below. Liquid roof coatings applied to low-sloped roofs in the field as the top surface of a roof covering shall comply with the following mandatory requirements and descriptions.

a. Aluminum-Pigmented Asphalt Roof Coatings

Aluminum-pigmented coatings are silver-colored coatings that are commonly applied to modified bitumen and other roofing products. The coating has aluminum pigments that float to the top surface of the coating while it is setting, providing a shiny and reflective 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.

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, considering the substrate on which the coating will be applied. Also, the aluminum-pigmented asphalt roof coatings shall be manufactured in accordance with ASTM D2824. Standard specification is also required for aluminum-pigmented asphalt roof coatings, nonfibered, asbestos-fibered, and fibered without asbestos that are suitable for application to roofing or masonry surfaces by brush or spray; and installed in accordance with ASTM D3805, *Standard Guide for Application of Aluminum-Pigmented Asphalt Roof Coatings*.

b. Cement-Based Roof Coatings

This class of coatings consists of a layer of cement and has been used for a number of years in California’s Central Valley and other regions. These coatings may be applied to almost any type of roofing product.

Cement-based coatings shall be applied across the entire roof surface to meet the dry mil thickness or coverage recommended by the manufacturer. Also, cement-based

coatings shall be manufactured to contain no less than 20 percent Portland cement and meet the requirements of ASTM D822, ASTM C1583, and ASTM D5870.

c. Other Field-Applied Liquid Coatings

Other field-applied liquid coatings include elastomeric and acrylic-based coatings. These coatings must be applied across the entire roof surface 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 several performance and durability requirements as specified in Table 110.8-C of the Energy Standards or the minimum performance requirements of ASTM C836, D3468, or D6694, whichever are appropriate to the coating material.

3.6.1.8 Radiant Barriers

§110.8(j)

The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain in the roof. Radiant barriers are installed below the roof deck in the attic and reduce radiant heat to air distribution ducts and insulation located below the radiant barrier. To qualify, a radiant barrier must have an emittance of 0.05 or less. The product must be tested according to ASTM C-1371-10 or ASTM E408-13(2013) and must be certified by the California Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation and listed in its Consumer Guide and Directory of Certified Insulation material, at <http://www.bhfti.ca.gov/industry/tinsulation.shtml>.

3.6.1.9 Ceiling and Attic Roof Insulation

§110.8(d), §150.0(a).

Wood-framed roof/ceiling construction assemblies must have at least R-22 insulation or a maximum U-factor of 0.043 based on 16 inch on center wood-framed rafter roofs, as determined from JA4. Some areas of the roof/ceiling can be greater than the maximum U-factor as long as other areas have a U-factor lower than the requirement and the weighted average U-factor for the overall ceiling/roof is 0.043 or less.

Metal-framed and roof/ceiling constructions other than wood-framed must have a U-factor of 0.043 or less to comply with the mandatory measures. If the insulation is not penetrated by framing, such as rigid insulation laid over a structural deck, then the rigid insulation can actually have a rated R-value of less than R-22 so long as the total roof/ceiling assembly U-factor is not greater than U-0.043.

3.6.1.10 Loose Fill Insulation

§150.0(b)

Loose fill insulation must be blown in evenly, and insulation levels must be documented on the certificate of installation (CF2R). The insulation level can be verified by checking that the depth of insulation conforms to the manufacturer's coverage chart for achieving the required R-value. The insulation must also meet the manufacturer's specified minimum weight per ft² for the corresponding R-value. When installing loose fill insulation, the following guidelines should be followed:

1. For wood trusses that provide a flat ceiling and a sloped roof, the slope of the roof should be 4:12 or greater to provide adequate access for installing the insulation. Insulation thickness near the edge of the attic will be reduced with all standard trusses, but this is acceptable as long as the average thickness is adequate to meet the minimum insulation requirement.

2. If the ceiling is sloped (for instance, with scissor trusses), loose fill insulation can be used as long as the slope of the ceiling is no more than 4:12. If the ceiling slope is greater than 4:12, loose fill should be used only if the insulation manufacturer will certify the installation for the slope of the ceiling.
3. At the apex of the truss, a clearance of at least 30 inch should be provided to simplify installation and inspection.

3.6.1.11 Wall Insulation

§150.0(c)

The mandatory measures have two requirements depending on frame size:

1. 2x4 inch wood-framed walls above grade shall have at least R-13 insulation installed in the cavities between framing members, or a U-factor that cannot exceed U-0.102. Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the area-weighted U-factor does not exceed 0.102 to show equivalence to an R-13 wall.
2. 2x6 inch or greater wood-framed walls above grade shall have at least R-19 insulation installed in the cavities between framing members or a U-factor not exceeding 0.074. Insulation may be of greater insulating value in certain areas of the wall and of lesser insulating value in other areas of the wall provided that the area-weighted U-factor does not exceed 0.074 to show equivalence to an R-19 wall.

There are several cases where the mandatory measures for wall insulation do not apply or apply in a special way. For best practice, the following should be implemented:

1. The mandatory measures apply to framed foundation walls of heated basements or heated crawl spaces that are located above grade, but not to the portion that is located below grade.
2. For additions to existing buildings, existing wood-framed walls that are already insulated with R-11 insulation need not comply with the mandatory R-13 wall insulation.
3. Rim joists between floors of a multistory building are deemed to comply with these mandatory measures if they have R-13 insulation installed on the inside of the rim joist and are properly installed between intersecting joist members.

Demising partitions and knee walls are not required to meet the prescriptive requirements of §150.1(c)1B. Demising partitions and knee walls are required to meet the mandatory minimum insulation requirement as set in §150.0(c)1 and §150.0(c)1, requiring that insulation not less than R-13 be installed between 2x4 framing, or a U-factor that shall not exceed U-0.102. §150.0(c)2 requires insulation not less than R-19 be installed in framing of 2x6 inch or greater, or a U-factor equal to or less than 0.074.

3.6.1.12 Raised-Floor Insulation

§150.0(d)

Wood-framed floors must have at least R-19 insulation installed between framing members, or the construction must have a U-factor of 0.049 or less. The equivalent U-factor is based on R-19 insulation in a 2x6, 16 inch on center wood-framed floor without a crawl space. The R-19 insulation value and U-factor of U-0.049 are for the floor assembly alone and do not assume the effects of a crawlspace or buffer zone beneath the floor. If comparing to a crawlspace assembly, the equivalent U-factor is 0.037, which includes the effect of the crawlspace.

Other types of raised floors, except for concrete raised floors (concrete raised floors do not have a mandatory requirement, but do have a prescriptive requirement) must also meet the maximum U-factor. In all cases, some areas of the floor can have a U-factor greater than the requirement as long as other areas have a U-factor that is lower than the requirement and the area-weighted average U-factor is less than that described above.

Raised slab floors with radiant heat (heated slab floors) must meet special insulation requirements that are described in Chapter 4 of this manual.

When a controlled ventilated or an unvented crawlspace is used, raised-floor insulation is not required, although vapor retarder is required over the ground, and the foundation walls must be insulated.

3.6.1.13 Fireplaces, Decorative Gas Appliances, and Gas Logs

§150.0(e)

The Energy Standards have mandatory requirements to limit infiltration associated with fireplaces, decorative gas appliances, and gas logs. Fireplace efficiency can be greatly improved through proper air control. Reduced infiltration is also a benefit when the fireplace is not operating (the majority of the time for most homes).

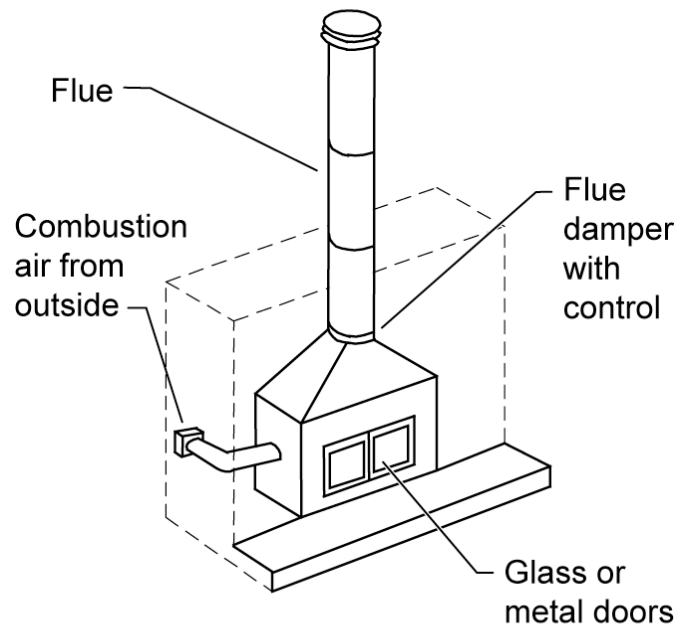
Installation of factory-built or masonry fireplaces (see Figure 3-12) must include:

1. Closable metal or glass doors covering the entire opening of the firebox that can be closed when the fire is burning.
2. A combustion air intake that is at least 6 square inches to draw air from outdoors and equipped with a readily accessible, operable, and tight-fitting damper or combustion air control device (*Exception: An outside combustion air intake is not required if the fireplace is installed over a concrete slab and the fireplace is not located on an exterior wall.*)
3. A flue damper with a readily accessible control. (*Exception: When a gas log, log lighter, or decorative gas appliance is installed in a fireplace, the flue damper shall be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.*)

Continuously burning pilot lights are prohibited for fireplaces as well as for decorative gas appliances and gas logs. In addition, indoor air may not be used for cooling a firebox jacket when that indoor air is vented to the outside of the building.

When a gas log, log lighter or decorative gas appliance is installed in a fireplace, the flue damper must be blocked open if required by the manufacturer's installation instructions or the California Mechanical Code.

Equipment certified to the Energy Commission as a gas space heater may have a continuously burning pilot light.

Figure 3-12: Fireplace Installation

Source: California Energy Commission

Example 3-15**Question:**

If I want to have a gas log or some other device in the fireplace of my home, can I have a standing pilot light? Can I block open the damper?

Answer:

The Energy Standards disallow standing pilot lights. The flue damper may be blocked open if required by either the manufacturer's installation instructions or the California Mechanical Code.

Example 3-16**Question:**

§150.0(e)2 states that no fireplace, decorative gas appliance, or gas log can be installed if it has a continuously burning pilot light. The California Mechanical Code requires all gas appliances installed in California to have a manually operated shut-off valve, accessible to the inhabited space. Does this shut-off valve meet the intent of this section?

Answer:

Not if the pilot light must be manually extinguished when the appliance is off. A unit that meets the intent of this section will have a pilot light that cannot stay on when the unit is off.

Example 3-17**Question:**

A building plan specifies a freestanding gas heater that is decorative; however, the equipment is vented and is rated as a room heater. Is it acceptable that this appliance have a pilot light?

Answer:

Yes. Since this equipment is rated as a room heater, it can have a continuous burning pilot light.

Example 3-18**Question:**

Do decorative gas appliances need glass or metal doors?

Answer:

Yes, the door requirement applies to masonry or factory-built fireplaces only. If a decorative gas appliance is installed inside a fireplace, the fireplace needs doors. Consult with the manufacturer of the decorative gas appliance regarding combustion air requirements.

3.6.1.14 Slab Insulation

§150.0(f) §118(g)

The mandatory requirements state that the insulation material must be suitable for the application, with a water absorption rate no greater than 0.3 percent when tested in accordance with ASTM C272 Test Method A, 24-Hour immersion, and a vapor permeance no greater than 2.0 perm/inch when tested in accordance with ASTM E96. An example of an insulating material that meets these specifications is smooth-skin extruded polystyrene.

The insulation must also be protected from physical and UV degradation by either installing a water-resistant protection board, extending sheet metal flashing below grade, choosing an insulation product that has a hard durable surface on one side, or by other suitable means.

3.6.1.15 Vapor Retarder

§150.0(g) and RA4.5.1

Vapor retarder class is a measure of the ability of a material or assembly to limit the amount of moisture that passes through the material or assembly. Vapor retarder classes are defined in Section 202 of the CBC. Testing for vapor retarder class is defined using the desiccant method of ASTM E96.

1. Class I: 0.1 perm or less
2. Class II: $0.1 < \text{perm} \leq 1.0$ perm
3. Class III: $1.0 < \text{perm} \leq 10$ perm

In Climate Zones 14 and 16, a continuous Class I or Class II vapor retarder, lapped or joint sealed, must be installed on the conditioned space side of all insulation in all exterior walls, on the roof decks of vented attics with above-or below-deck air-permeable insulation, and in unvented attics with air-permeable insulation.

Buildings with unvented crawl spaces in Climates Zones 1-16 must have a Class I or Class II vapor retarder covering the earth floor to protect against moisture condensation.

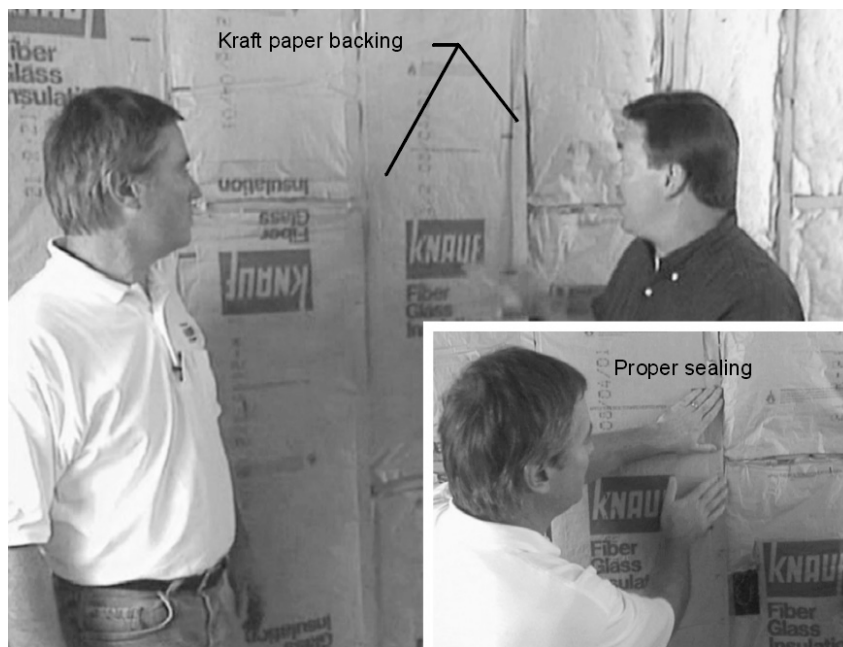
If a building has a controlled-ventilation crawl space, a Class I or Class II vapor retarder must be placed over the earth floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with RA4.5.1.

There are many product types having tested vapor retarder performance. Some common examples are the following:

1. Foil and other facings on gypsum board can provide moisture resistance, and product literature should always be checked to ensure conformance to ASTM E96.
2. The kraft paper used as facing on thermal batt insulation material is typically a Class II vapor retarder. Faced batts may have flanges for fastening to assembly framing. Fastening flanges may be face- or inset-stapled or not stapled at all, as the flanges provide no moisture control. Face stapling of flanged thermal batts helps ensure the insulation material is installed fully and properly within the framed cavity. Flangeless batts are also common and require no fastening as these materials maintain installation integrity through friction-fitting within the cavity of framed assemblies. In all cases, the insulation must be installed properly.
3. Many interior painted surfaces may also qualify for meeting the vapor retarder requirement if the paint product has been tested to show compliance as a vapor retarder. The effectiveness of vapor retarder paint depends upon the installed thickness (in mils). These products often require more than one layer to achieve the tested perm rating, and care must be shown by the installer of the paint and for inspection by the building official.
4. Closed-cell spray polyurethane foam (ccSPF) products can provide Class I or Class II vapor retarder performance, depending on thickness.

For all types of vapor retarders, care should be taken to seal penetrations, such as electric outlets on exterior walls.

Figure 3-13: Typical Kraft Faced Vapor Retarder Facing



Source: California Energy Commission

3.6.1.16 Recessed Luminaires in Ceilings

§150.0(k)1C

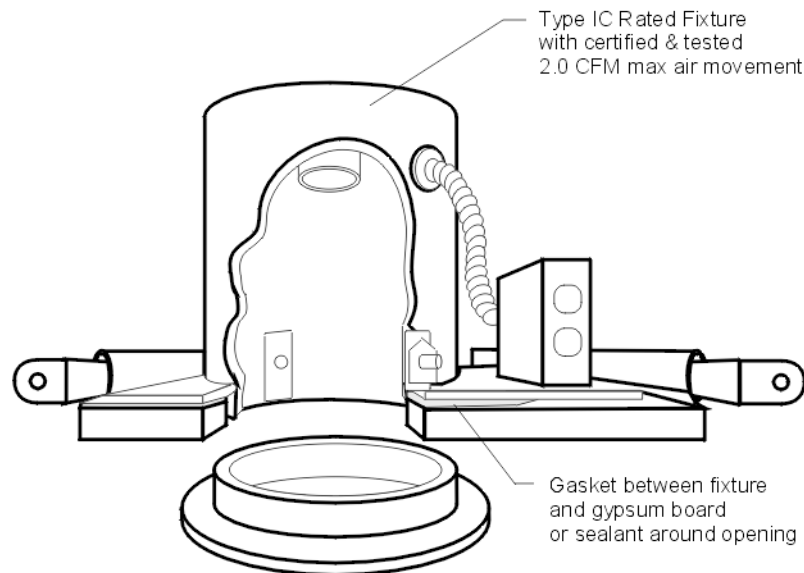
Luminaires recessed in insulated ceilings can create thermal bridging through the insulation. Not only does this degrade the performance of the ceiling assembly, but it can permit condensation on a cold surface of the luminaire if exposed to moist air, as in a bathroom.

For these reasons, luminaires recessed in insulated ceilings must meet three requirements:

1. They must be listed as defined in the Article 100 of the California Electric Code for zero clearance insulation contact (IC) by Underwriters Laboratories or other testing/rating laboratories recognized by the International Code Council (ICC). This enables insulation to be in direct contact with the luminaire.
2. The luminaire must have a label certified as per §150.0(k)1Cii for airtight (AT) construction. Airtight construction means that leakage through the luminaire will not exceed 2.0 cfm when exposed to a 75 Pa pressure difference, when tested in accordance with ASTM E283.
3. The luminaire must be sealed with a gasket or caulk between the housing and ceiling.

Refer to the Lighting chapter (Chapter 6) of this compliance manual for more information regarding the applicable requirements for recessed luminaires.

Figure 3-14: IC-Rated Luminaire (Light Fixture)



Source: California Energy Commission

3.6.1.17 Ventilation for Indoor Air Quality

§150.0(o)

All buildings shall meet the requirements of ASHRAE Standard 62.2, *Ventilation and Acceptable Indoor Air Quality in Low-Residential Buildings*. The whole-building ventilation airflow shall be provided to meet the requirements of ASHRAE 62.2. Window operations are not a permissible method for providing whole-house ventilation. Use of a continuously operating central fan integrated with a forced-air system air handler cannot be used to meet the whole-building ventilation airflow requirement.

3.6.1.18 Ventilation Openings

ASHRAE Standard 62.2 requires ventilation openings in habitable spaces, toilets, and utility rooms. Spaces that meet the exhaust requirements are exempted from meeting the whole-building ventilation air flow requirement; therefore, an exhaust system can be substituted for a ventilation opening. (See Section 4.6.6.6.)

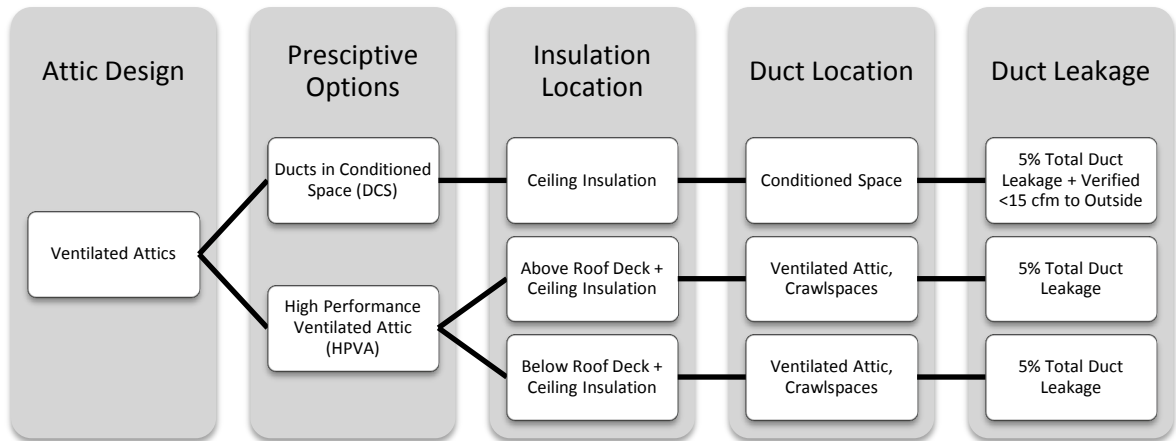
Field verification and diagnostic testing is required to confirm proper ventilation airflow, following the procedures specified in the RA3.7.

3.6.2 Prescriptive Approach

3.6.2.1 Roof/Attic

The 2016 Energy Standards are designed to offer flexibility to the builders and designers of residential new construction in terms of achieving the intended energy efficiency targets. As such, the Energy Standards offer several options for achieving one of two design objectives related to improving energy performance of homes built with ventilated attics in Climate Zones 4, 8-16 as shown in Figure 3-15.

Figure 3-15: Ventiladed Attic Prescriptive Compliance Choices



High-Performance Ventiladed Attic (HPVA) implements measures that minimize temperature difference between the attic space and the conditioned air being transported through ductwork in the attic. The package consists of insulation either below the roof deck or insulation above the roof deck in addition to insulation at the ceiling, R-8 ducts, and 5 percent total duct leakage of the nominal air handler airflow.

Ducts in Conditioned Space (DCS) locates ducts and air handlers in the thermal and air barrier envelope of the building. The Ducts in Conditioned Space option requires field verification to meet the prescriptive requirement.

Note: All the prescriptive requirements for HPVA or DCS are based on the assumption that the home is built with the following construction practices:

1. The attic is ventilated with appropriate free vent area as described in Section 3.6.2.1(E).
2. The roof is constructed with standard wood rafters and trusses.
3. The outermost layer of the roof construction is either tiles or shingles.
4. The air handler and ducts are in the ventilated attic for HPVA and are in conditioned space for DCS.
5. The air barrier is located at the ceiling (excludes “cathedral” roof/ceiling systems).

If a building design does not meet all of these specifications, it must comply through the performance approach.

Example 3-19

Question:

If 5 percent of a roof will be a cathedral ceiling, can it still comply under the prescriptive requirements?

Answer:

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard wood rafter trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

Example 3-20

Question:

Does a sealed (unventilated) attic with insulation at the roof deck comply under the prescriptive requirements?

Answer:

No. The entire attic must be a ventilated space with the building air barrier located at the ceiling with standard wood rafter trusses to comply with the prescriptive requirements. This project must comply through the performance approach.

A. Roof/Ceiling Insulation

This section describes the requirements and approaches necessary to meet the requirements for the HPVA as they relate to roof/ceiling insulation. HVAC aspects of the HPVA including duct insulation and duct leakage are described in Section 4. Requirements and approaches to meet the Ducts in Conditioned Space (DCS) are also described in Section 4 of this manual.

§150.1(c).1 requires different values of roof/ceiling insulation, depending on whether the HPVA (option A or B) or DCS (option C) is chosen as described in Figure 3-16.

The standard design in the performance approach is based on Option B, as detailed in ¹ of Figure 3-17, installed with a tile roof.

Figure 3-16: Prescriptive Requirements for Roof/Ceiling Insulation (§150.1(c).1)

Strategy		How to Comply
High-Performance Ventilated Attics		
Option A	Vented attic with continuous insulation applied above the roof deck. (Figure 3-18). Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option A
Option B	Vented attic with batt, spray in cellulose/fiberglass secured with netting, or SPF. (Figure 3-18). Ceiling insulation required separately above finished attic ceiling.	Table 150.1-A of the Energy Standards Roof Assembly Option B
Ducts in Conditioned Space		
Option C	Vented attic with no insulation at roof deck. Ceiling insulation required separately above finished attic ceiling. Ducts and air handler equipment in conditioned space that is NOT a sealed attic.	Table 150.1-A of the Energy Standards Roof Assembly Option C Form: CF2R-MCH-20b

Figure 3-17: Checklists for Prescriptive Requirements for HPVA/DCS for the related climate zones

Option A (CZ 4, 8-16)	Option B ¹ (CZ 4, 8-16)	Option C (CZ 4, 8-16)
<input type="checkbox"/> Vented attic <input type="checkbox"/> R6 (air space) or R8 (no air space) continuous above deck rigid foam board insulation <input type="checkbox"/> R38 ceiling insulation <input type="checkbox"/> Radiant Barrier <input type="checkbox"/> R8 duct insulation <input type="checkbox"/> 5% total duct leakage	<input type="checkbox"/> Vented attic <input type="checkbox"/> R13 (air space) or R15 (no air space) batt, spray in cellulose/fiberglass below roof deck secured with netting, or SPF <input type="checkbox"/> R38 ceiling insulation <input type="checkbox"/> R8 duct insulation <input type="checkbox"/> 5% total duct leakage	<input type="checkbox"/> Vented attic <input type="checkbox"/> R30 or R38 ceiling insulation (climate zone specific) <input type="checkbox"/> R6 or R8 ducts (climate zone specific) <input type="checkbox"/> Radiant Barrier <input type="checkbox"/> Verified ducts in conditioned space
¹ Standard Design used to set the energy budget for the Performance Approach.		

Figure 3-18: Option A (left) and Option B (right)

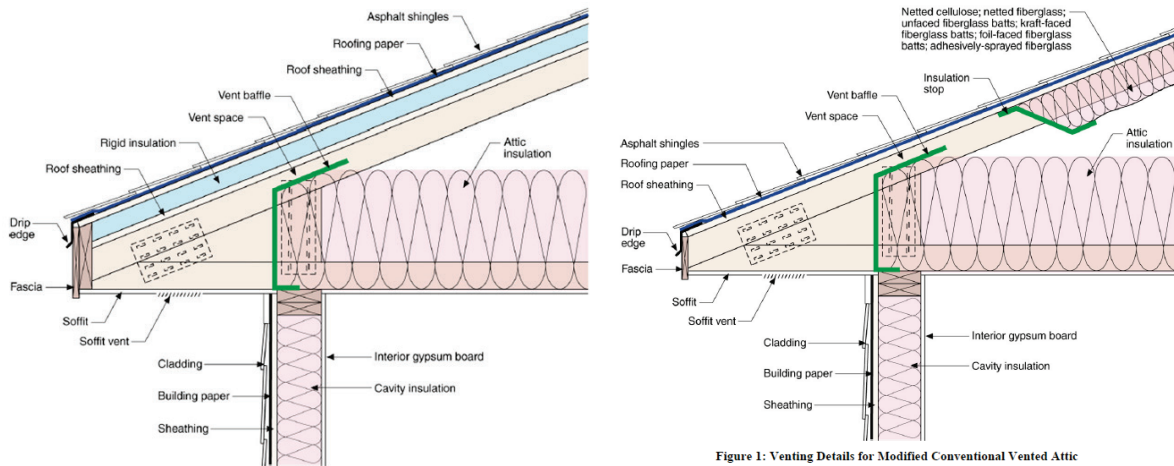


Figure 1: Venting Details for Modified Conventional Vented Attic

Source: Building Science Corporation

Option A requires insulation above the roof rafters, directly in contact with the roof deck, while Option B requires insulation installed between the roof rafters. The insulation values are different depending on whether there is an air gap present between the roofing materials and the roof deck. For roof constructions with an air gap present, which is standard for concrete or clay tile, R6 insulation is required above the roof rafters or R13 below the roof deck placed between the rafters. If there is no air gap present between the roofing and roof deck, R8 insulation is required above the roof rafter or R18 below the roof deck placed between the rafters.

The R-values for insulation installed above the roof rafters are lower than the R-values for insulation installed below the roof deck due to the added benefit of reduced thermal bridging when continuous insulation is applied to the roof deck. Further, when an air space is present between the roofing and the roof deck, the effect of insulation is greater than when there is no air space.

Standard residential roof construction practice in California for concrete/clay tiles is to have an air gap between the tiles and roof deck. For asphalt shingles, the practice is to place the roofing material directly on top of the roof deck without an air gap. It is, however, possible for builders to construct different construction assemblies than these standard assemblies such as providing air gaps between the asphalt shingles and roof deck through construction techniques explained later in this document.

The prescriptive requirement for roof deck insulation can also be met by placing ducts in conditioned space and getting HERS verification (Option C). The requirements to comply with Option C are explained in Chapter 4 of this manual.

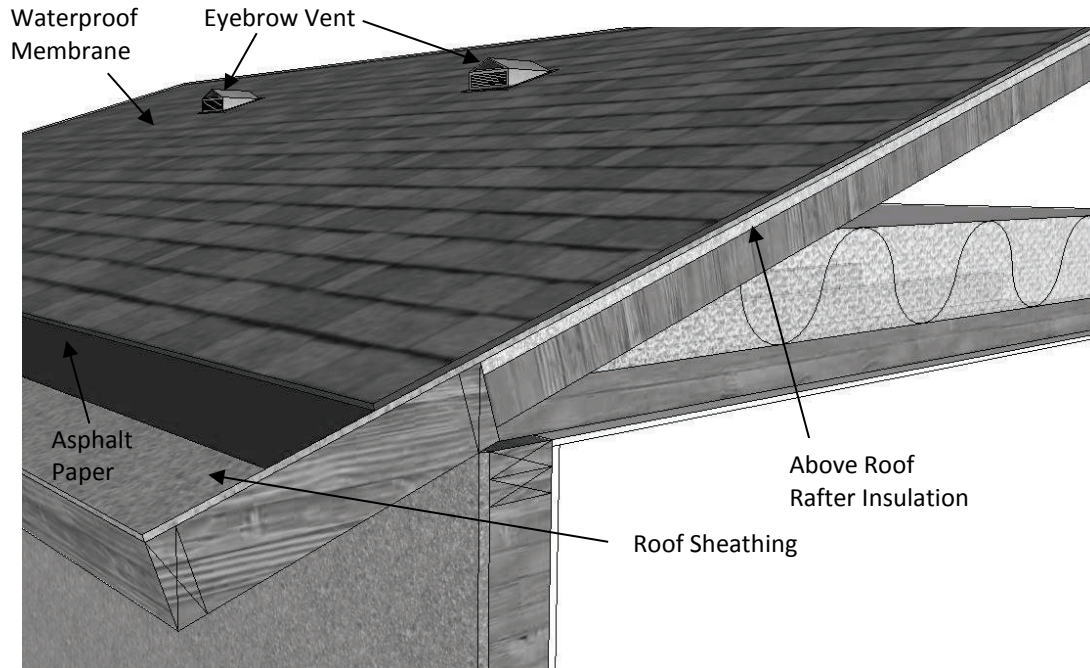
*Construction Practice/Compliance and Enforcement***Is this strategy new for you?**

Design Considerations and Best Practices:

- Commit to a compliance strategy early in the building design process.
- Have a kick-off meeting with builder, subcontractor, designer, energy consultant, and HERS Rater to set expectations and express the value of the design.
- Communicate strategy and schedule to subcontractors and other team members early.
- May require coordinating an additional building inspection for above-deck insulation prior to installation of final roofing materials.
- Include insulation specifications according to the CF1R on the building plans.
- Roofer will install above-roof deck insulation, whereas insulation contractor will install insulation below roof deck (ideally at the same time as ceiling insulation).
- All relevant subcontractors must be aware of where air barrier is located and be conscious of where they make penetrations, especially if designing for verified ducts in conditioned space.

1. Above-Roof Rafter Insulation (Option A):

In a vented attic, rigid board insulation can be installed above the roof rafters to add value to the thermal integrity of the roof system. As described above, the prescriptive insulation value depends on whether an air gap is present above the rigid insulation. Above-rafter insulation can be implemented with either asphalt shingles or clay/concrete tiles. Check manufacturer's specifications for proper nail schedules (fastening patterns); this will change depending on the roof pitch, truss spacing, and roofing material. When above-rafter insulation is installed, a radiant barrier must also be installed in the required climate zones.

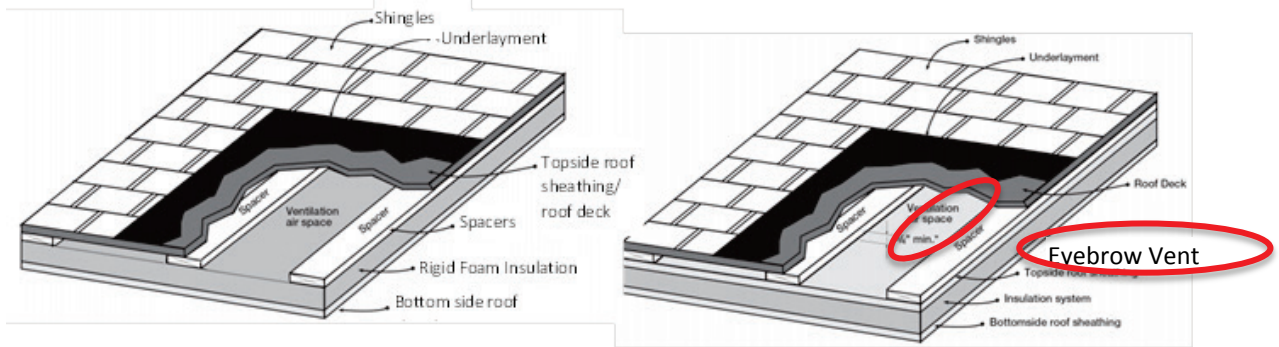
Figure 3-19: Above-Roof Rafter Insulation

Source: California Energy Commission

Roofing With Asphalt Shingles – Best Practices:

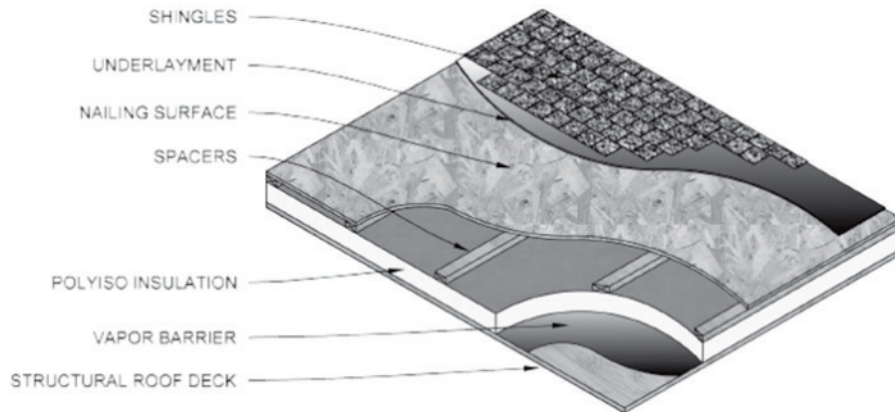
When installing asphalt shingles with roof deck insulation, it is best to implement a ventilation method between the roofing product and the top sheathing or insulation, as shown in Figure 3-20, to prevent the roofing material from experiencing high temperatures and reducing effective product life. Spacers can be inserted either above or below a second roof sheathing to provide both roof deck ventilation and a nailable base for asphalt shingles, as seen in Figure 3-21. Manufacturers offer prefabricated insulation products with spacers and top sheathing. Check manufacturers' and trade association websites for a list of products available that provide an air space and nailable base.

Figure 3-20: Above Deck Insulation With Spacers Installed With and Without Top Sheathing



Source: ARMA technical bulletin No. 211-RR-94

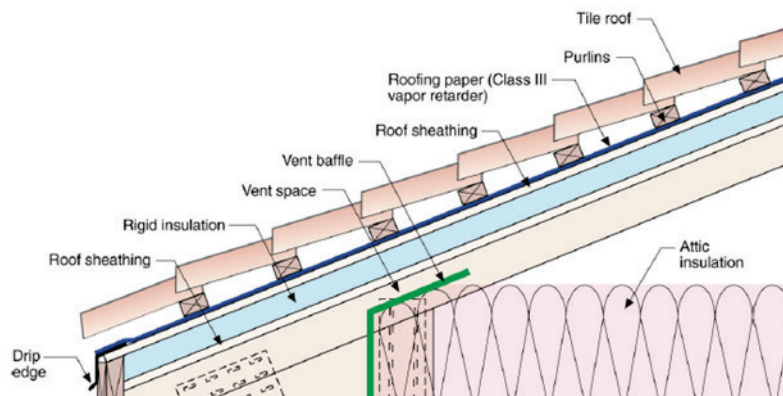
Figure 3-21: Asphalt Shingles and Spacers Installed With Above-Deck Insulation



Source: PIMA Tech Bulletin #106

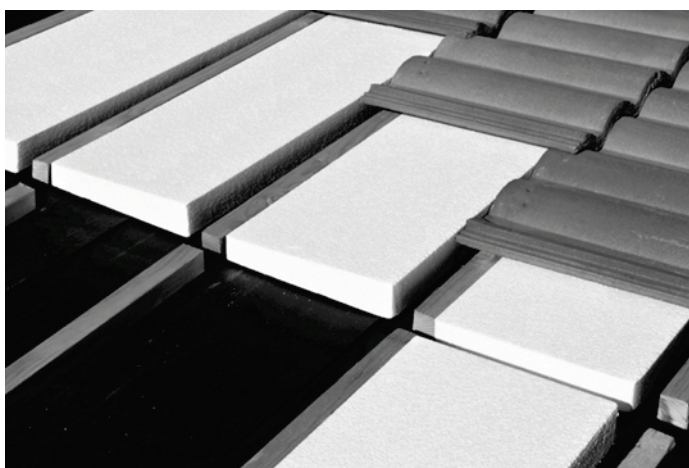
Roofing With Concrete/Clay Tiles – Best Practices:

With tile roofs, there is traditionally an air gap between the tile and the roof deck due to the shape of the tiles and the way tiles are installed over battens. When adding insulation above roof deck, there are two options to addressing the air gap. If the air gap is desired, one option is to install rigid insulation over the roof deck and a second roof sheathing layer added above the rigid insulation, along with a vapor retarder above that to host the purlins above with the tiles rest. This is shown in Figure 3-22.

Figure 3-22: Battens (Purlins) Installed With Above-Deck Insulation

Source: Building Science Corporation

If the air gap is not desired, there are insulation products available that can fit directly under concrete/clay or steel tile, as shown in the figure below.

Figure 3-23: Wedged Insulation Formed to Be Placed Directly Below Tile Without an Air Gap

Source: Wedge-It

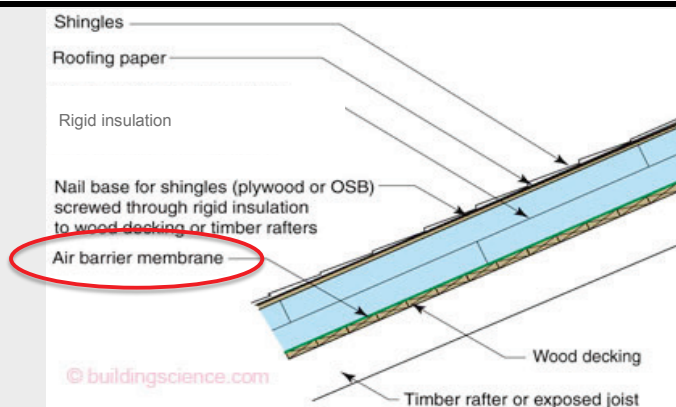
Example 3-21

Question:

A project plans to install R8 rigid foam insulation above the roof deck using two R4 foam boards. Can this method be used to meet the prescriptive requirements? If so, are there best practices for installing the two layers of insulation?

Answer:

Yes, installing two R4 rigid foam board layers meets the R8 prescriptive requirement. (Remember that R8 is required when there is no air gap between insulation and roofing materials, but R6 is required if there is air gap.) To prevent water infiltration, it is best to stagger the horizontal and vertical joints of the two layers and take care to seal each joint properly.



Source: Building Science Corporation

Example 3-22

Question:

A project plans to install R6 rigid foam insulation above the roof deck with roofing material placed *directly* over the insulation; does this meet the prescriptive requirements? Are there best practices for installing the insulation?

Answer:

No, this construction does not comply with the prescriptive requirements. R6 insulation can be used only above the roof deck when there is an air gap between the insulation and the finishing roofing material. Using spacers or battens (purlins) are two strategies to create this air gap. Products exist that combine insulation, spacers, and an additional sheathing for nailing asphalt shingles, check with insulation manufacturers for available products. Refer to the best practices above in the Above Roof Deck Insulation section. Alternatively, R8 insulation can be installed if no air gap is desired.

Addressing Attic Ventilation With Above-Deck Insulation

Proper attic ventilation occurs at two points at the roof: the soffit (or eave) vents and the ridge (or eyebrow) vents. Ridge or eyebrow venting must be maintained when installing above-deck insulation, as shown in Figure 3-26.

Example 3-23

Question:

Does a roof assembly using above deck insulation meet Class A/B/C fire rating specifications, as determined by California Building Code, Chapter 15?

Answer:

Application of above-deck insulation affects the fire rating classification of roof covering products. Roof covering products are currently rated to class A/B/C based on the ASTM E108 (NFPA 256, UL790) test. Class A/B/C ratings are done with specific roof assemblies, and ratings are valid only when the installation is the same as the assembly as rated. Under current building code requirement, tile roof products installed directly over the roof deck or over purlins are automatically rated Class A. Chapter 15 in the California Building Code (and International Building Code section 1505 for Fire Classification) specify that certain roofing materials are Class A without having to test to ASTM E108. These materials include slate, clay, concrete roof tile, an exposed concrete roof deck, and ferrous and copper shingles; however, asphalt shingles are not covered under this category.

Insulation products, on the other hand, are subject to a different fire test from roof-covering products. California Building Code and International Building Code (Section 2603 for Foam Plastic Insulation) require foam plastic insulation to be tested to demonstrate a flame-spread index of not more than 75 and a smoke-developed index of not more than 450 according to ASTM E84 [UL723]. The requirements are applicable to roof insulation products, including XPS/polyiso/polyurethane above-deck insulation and SPF below-deck insulation products.

To ensure that roof assemblies with insulation meet the proper fire rating classification, roof product manufacturers and insulation manufacturers must test and develop assemblies that meet the CBC testing specifications.

2. Below-Deck Insulation (Option B):

In a vented attic, air-permeable or air-impermeable insulation (that is, batt, spray foam, loose-fill cellulose, or fiberglass) should be placed **directly** below the roof deck between the truss members and secured in place to provide a thermal barrier for the attic space. This is especially useful when ducts and equipment are present. Insulation must be in direct contact with the roof deck and secured by the insulation adhesion, facing, mechanical fasteners, wire systems, a membrane material, or netting.

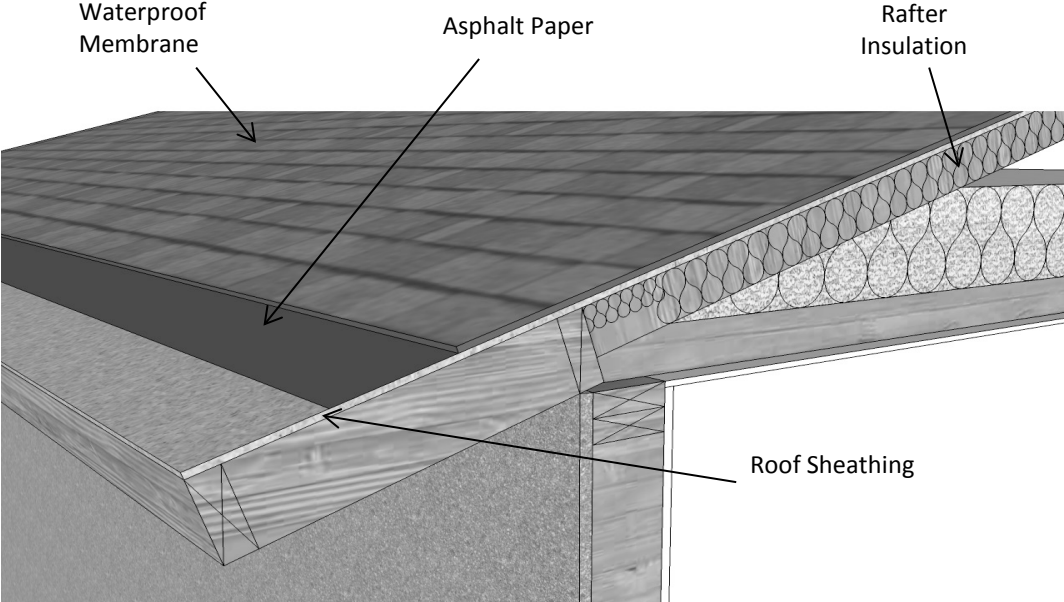
Proper attic ventilation must always be maintained to prevent the potential for moisture to condense. In Climate Zones 14 and 16, a Class I or Class II vapor retarder must also be used to manage moisture², as stated in California Residential Code Section R806.2. See Figure 3-24 through Figure 3-27 for depictions of insulation options and maintaining proper ventilation. More information on best practices to maintain proper attic ventilation is discussed below.

Best Practice:

Attic vapor retarders are not required in most climates when using spray foam, blown-in insulation or unfaced batts when sufficient attic ventilation is maintained. Even when not required, the use of vapor retarders can provide additional security against possible moisture buildup in attic and framed assemblies.

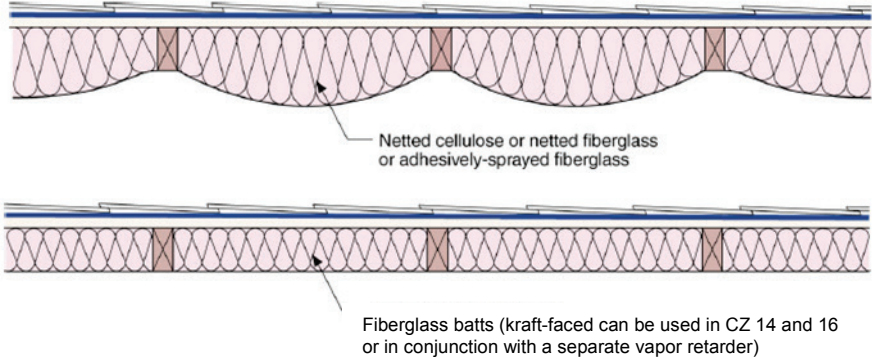
² Insulation Contractors Association of America. (2004). Technical Bulletin No. 6 Use of Vapor Retarders.

Figure 3-24: Below-Roof Deck Insulation



Source: California Energy Commission

Figure 3-25: Placement of Insulation Below the Roof Deck



Source: Building Science Corporation

When insulation is installed below the roof deck to meet the prescriptive requirements, a radiant barrier is not required. However, a draped radiant barrier may be installed to receive performance credit.

Addressing Attic Ventilation With Below-Deck Insulation

When installing insulation below the roof deck, vent baffles and insulation stoppers can be used to maintain proper ventilation space, as shown in Figure 3-27. Proper flow of air through the space helps remove moisture and prevents any associated issues.

Figure 3-26: Insulation Air Baffles

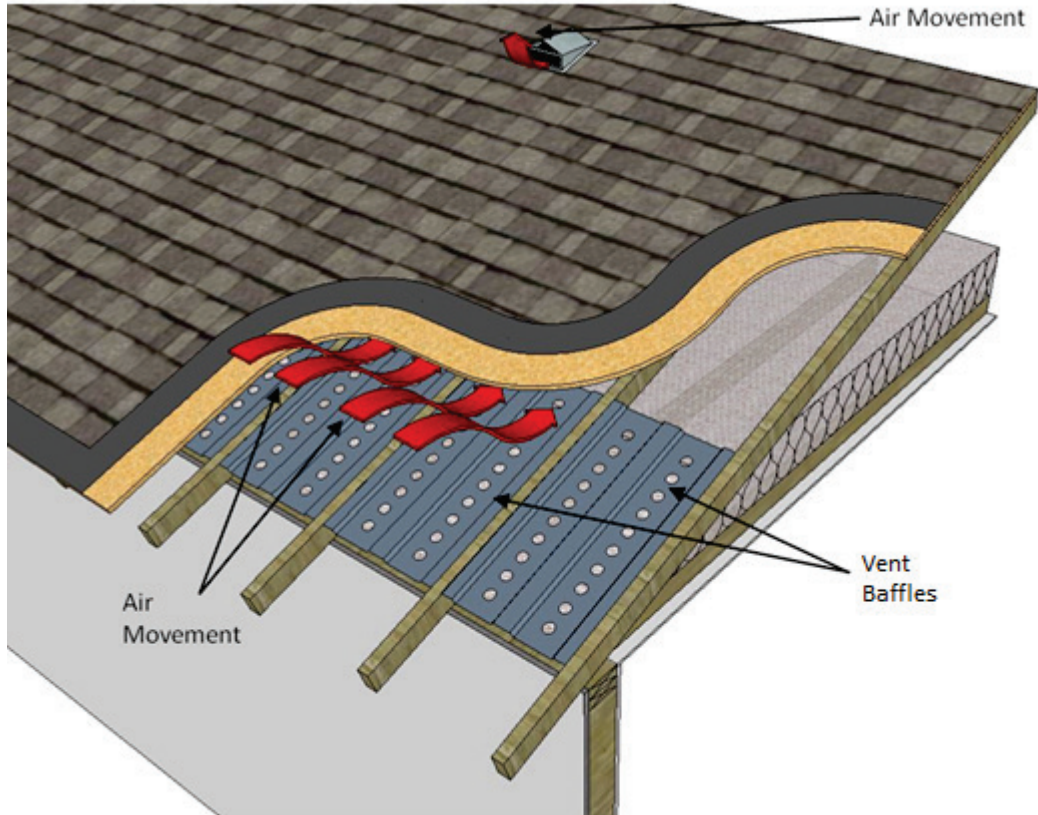


Figure 3-27: Vented Attic – Below-Deck Insulation With Insulation Stopper

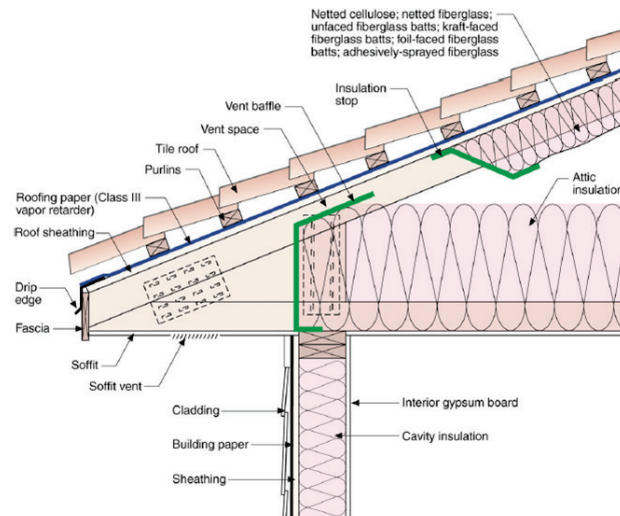


Figure 31: Vented Attic – Tile Roof – Air Permeable Insulation On Underside of Roof Deck - Can be

Source: Building Science Corporation

Example 3-24**Question:**

A new construction project in Climate Zone 12 with HVAC ducts in the attic was designed to meet the prescriptive requirements for roof deck and ceiling insulation. Due to miscommunication amongst the team, however, the roof deck insulation was not installed, and R-49 ceiling insulation was installed instead. Does this project still comply?

Answer:

This project no longer meets the prescriptive requirements and must follow the performance approach. For future projects, clearly communicating the project expectations to all team members early in the construction process is key to succeeding at this design strategy. Having a project initiation meeting with all subcontractors and team members is a best practice, at least for the first few projects, until the entire team is aware of the design needs.

Note: If the design was changed so that the roof deck has a radiant barrier and the HVAC equipment and ducts are verified to be in conditioned space, the altered design will meet the prescriptive requirements under Option C.

3. Duct and Air Handlers Located in Conditioned Space (Option C):

Option C allows a project to place and verify that ducts are located in conditioned space instead of installing insulation at the roof deck. If complying with this path, ceiling and duct insulation must be installed at the values specified in Table 150.1-A for Option C, and a radiant barrier is also required in some climate zones. Simply locating ducts in conditioned space does not qualify for this requirement; a HERS Rater must test and verify the system and that the ducts are insulated to a level required in Table 150.1-A of the Energy Standards.

Design strategies that can be used to prescriptively comply with Option C include dropped ceilings (dropped soffit), plenum or scissor truss to create a conditioned plenum box, and open-web floor truss. The key is that the ducts and equipment are placed within the air barrier of the building. See Section 4.4.2 for detailed information on DCS strategies.

B. Ceiling Insulation

Insulation coverage should extend far enough to the outside walls to cover the bottom chord of the truss. However, insulation should not block eave vents in attics because the flow of air through the attic space helps remove moisture that can build up in the attic and condense on the underside of the roof. (See Figure 3-27.) This can cause structural damage and reduce the effectiveness of the insulation.

Based on area-weighted averaging, ceiling insulation may be tapered near the eave, but it must be applied at a rate to cover the entire ceiling at the specified level. An elevated truss is not required but may be desirable. See Section 3.6.3.1(C) for details.

C. Radiant Barriers

§150.1(c)2

The prescriptive requirements call for a radiant barrier in Climate Zones 2 through 15, except when below-deck insulation is installed. The radiant barrier is a reflective material that reduces radiant heat transfer caused by solar heat gain in the roof. Radiant barriers reduce the radiant gain to air distribution ducts and insulation located below the radiant barrier, typically within the attic space. In the performance approach, radiant barriers are modeled as separate adjustments to the heating U-factor and the cooling U-factor. The duct

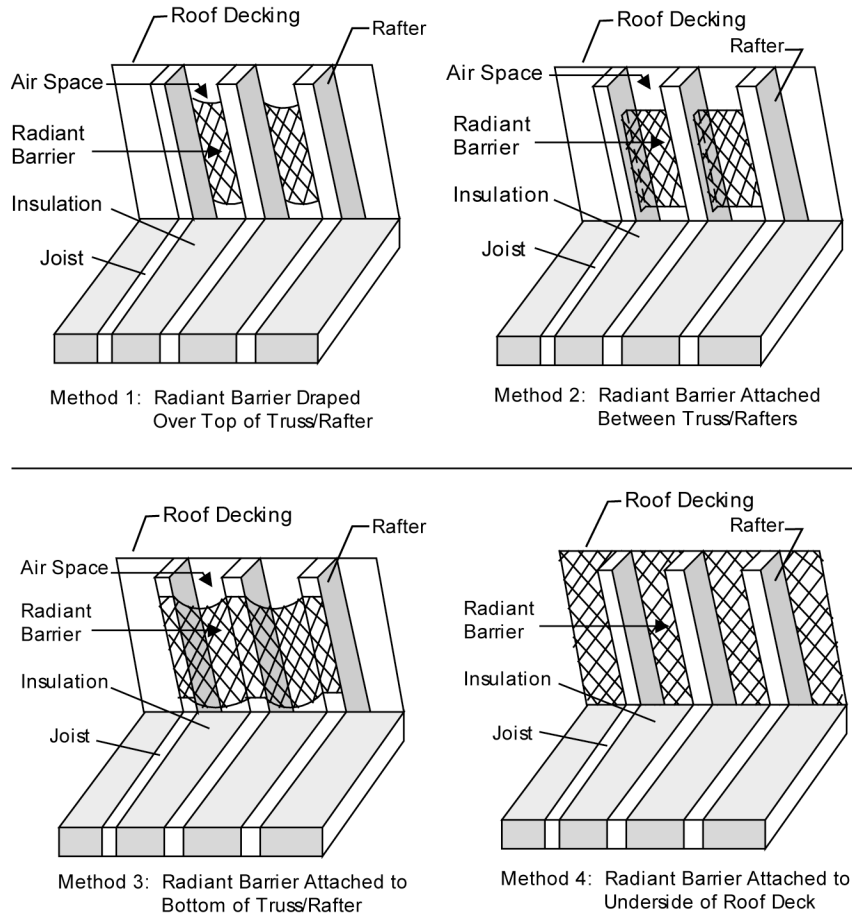
efficiency is also affected by the presence of a radiant barrier when using the performance approach.

Construction Practice

A radiant barrier must have a tested emissivity of 0.05 or less. The most common way of meeting the radiant barrier requirement is to use roof sheathing that has a radiant barrier bonded to it by the manufacturer. Some oriented strand board (OSB) products have a factory-applied radiant barrier. The sheathing is installed with the radiant barrier (shiny side) facing down toward the attic space. Alternatively, a radiant barrier material that meets the same ASTM test and moisture perforation requirements that apply to factory-laminated foil can be field-laminated. Field lamination must use a secure mechanical means of holding the foil type material to the bottom of the roof decking such as staples or nails that do not penetrate all the way through the roof deck material. Roofs with gable ends must have a radiant barrier installed on them to meet the radiant barrier requirement.

Other acceptable methods are to drape a foil type radiant barrier over the top of the top chords before the sheathing is installed, stapling the radiant barrier between the top chords after the sheathing is installed, and stapling the radiant barrier to the underside of the truss/rafters (top chord). For these installation methods, the foil must be installed with spacing requirements as described in Residential Reference Appendices RA4.2.1. Installation of radiant barriers is somewhat more challenging in the case of closed rafter spaces, particularly when roof sheathing is installed that does not include a laminated foil type radiant barrier. Radiant barrier foil material may be field-laminated after the sheathing has been installed by “laminating” the foil as described above to the roof sheathing between framing members. This construction type is described in the Residential Reference Appendices RA4.2.1.1. See below for drawings of radiant barrier installation methods.

Figure 3-28: Methods of Installation for Radiant Barriers



Source: California Energy Commission

D. Roofing Products (Cool Roof)

§150.1(c)11

Cool roofs of steep and low-sloped roofs are required in some climate zones. A low-slope roof is defined as a surface with a pitch less than or equal to 2:12 (9.5 degrees from the horizontal or less) while a steep-slope roof is a surface with a pitch greater than 2:12 (more than 9.5 degrees from the horizontal). The prescriptive requirement is based on an aged solar reflectance and thermal emittance tested value from the Cool Roof Rating Council (CRRC).

For projects using the prescriptive compliance path, an alternative to the aged solar reflectance and thermal emittance is to use the Solar Reflectance Index (SRI) to show compliance. A calculator has been produced to calculate the SRI by designating the solar reflectance and thermal emittance of the desired roofing material. The calculator can be found at <http://www.energy.ca.gov/title24/2016standards>. To calculate the SRI, the 3-year aged value of the roofing product must be used. By using the SRI calculator a cool roof may comply with an emittance lower than 0.85, as long as the aged reflectance is higher and vice versa.

The residential roofing product requirement in the prescriptive package is as follows:

1. For steep-sloped applications in Climate Zones 10-15, the three year aged solar reflectance minimum is 0.20 and the (three-year aged or initial) thermal emittance minimum is 0.75, or a minimum solar reflectance index (SRI) of 16.
2. For low-sloped roofing applications in Climate Zones 13 and 15, there is a minimum aged solar reflectance of 0.63 and thermal emittance of 0.75, or a minimum SRI of 75.

There are two exceptions to meeting the roofing products requirements in the prescriptive package:

1. The roof area with building-integrated photovoltaic panels and building-integrated solar thermal panels are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI Exception 1 to §150.1(c)11B.
2. Roof constructions that have thermal mass over the roof membrane with a weight of at least 25 lb/ft² are exempt from the minimum requirements for aged solar reflectance and thermal emittance or SRI under Exception 2 to §150.1(c)11B.

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the cool roof efficiency values (solar reflectance and thermal emittance values) modeled on the CF1R form are specified on the building plans, and that those same values of the actual installed cool roof product meet or exceed the efficiency values on the CF1R form. For more information on compliance and enforcement for cool roofs, see Chapter 2 of this manual.

Example 3-25

Question:

A computer method analysis shows that a new house requires R-19 ceiling insulation to comply using the performance approach, but the minimum mandatory insulation level for ceiling insulation is R-22. Which insulation level should be used?

Answer:

The mandatory insulation requirement is an area-weighted average. Therefore, some areas can have lower insulation, such as R-19, but other areas will need to have higher levels of insulation so that the area-weighted average is at least R-22.

Example 3-26

Question:

A small addition to an existing house appears to comply using only R-15 ceiling insulation with the performance approach. Does this insulation level comply with the standards?

Answer:

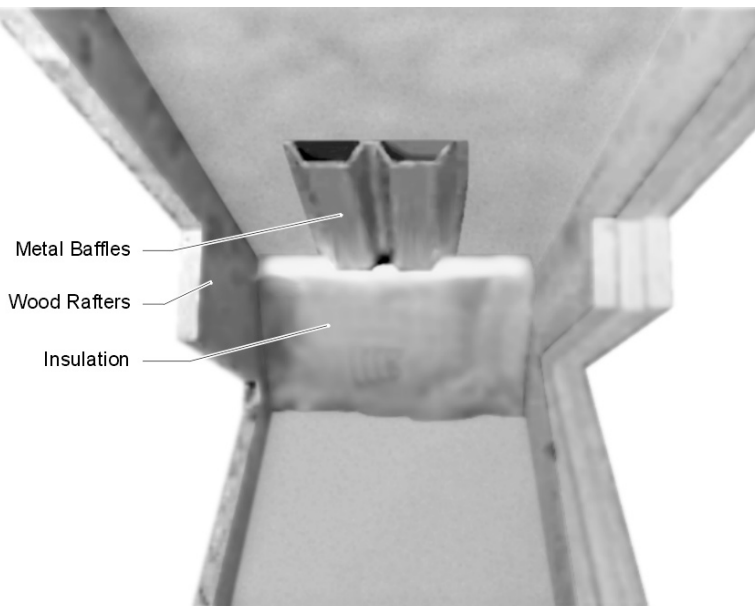
No. R-15 would not be sufficient because the required minimum ceiling insulation level established by the mandatory measures is R-22. However, R-15 could be used in limited areas, as follows:

1. 16 inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.032.
 2. 24 inches on center framing with attic with the weighted average U-factor for the entire ceiling/roof less than 0.031
 3. 16 inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.051.
 4. 24 inches on center rafter without attic with the weighted average U-factor for the entire ceiling/roof less than 0.049.
-

E. Attic Ventilation

Where ceiling insulation is installed next to eave or soffit vents, a rigid baffle should be installed at the top plate to direct ventilation air up and over the ceiling insulation. (See Figure 3-29.) The baffle should extend beyond the height of the ceiling insulation and should have sufficient clearance between the baffle and roof deck at the top. There are several acceptable methods for maintaining ventilation air, including preformed baffles made of either cardboard or plastic. In some cases, plywood baffles are used.

Figure 3-29: Baffles at the Eave in Attics



Source: California Energy Commission

Source: California Energy Commission

The California Building Code (CBC) requires a minimum vent area to be provided in roofs with attics, including enclosed rafter roofs creating cathedral or vaulted ceilings. Check with the local building jurisdiction to determine which of the two CBC ventilation requirements are to be followed:

1. CBC, Title 24, Part 2, Vol. 1, Section 1203.2 requires that the net free ventilating area shall not be less than 1/300 of the area of the space ventilated.
2. CBC, Title 24, Part 2, Vol. 2.5, Section R806.2 requires that the net free ventilating area shall not be less than 1/150 of the area of the space ventilated. This ratio may be reduced to 1/300 if a ceiling vapor retarder is installed.

In either situation, a minimum of 50 percent of the vents must be located in the upper portion of the space being ventilated at least 3 feet above eave or cornice vents.

Ventilated openings are covered with corrosion-resistant wire cloth screening or similar mesh material. When part of the vent area is blocked by meshes or louvers, the resulting “net-free area” of the vent must be considered when meeting ventilation requirements.

Many jurisdictions in California are covered by Wildland Urban Interface (WUI) regulations where specific measures for construction materials must be used to improve fire resistance for the building. These regulations require special vents that are expressly tested to resist the intrusion of flame and burning embers. Check with the building department to ensure compliance with local codes.

3.6.2.2 Walls

A. Wall Insulation

1. Framed Walls

§150.1(c)1B

The Package A prescriptive requirements (Table 150.1-A) call for a U-factor of 0.051 in Climate Zones 1-5 and 8-16, and a U-factor of 0.065 in Climate Zones 6 and 7.

The designer may choose any wall construction from Reference Joint Appendix JA4 (Tables 4.3.1 and 4.3.4) that has a U-factor equal to or less than 0.051 or 0.065, depending on the climate zone. U-factors can also be calculated by building the construction assembly in Commission-approved compliance software, including the inside finish, sheathing, cavity insulation, and exterior finish. JA4 Table 4.3.4 shows that a 2x6 wood-framed wall at 16" on center can achieve a U-factor of 0.051 with R-19 batt insulation in the cavity and R-5 exterior insulation. Some examples of various wood-framed wall assemblies, associated construction, and U-values are provided in Figure 3-30.

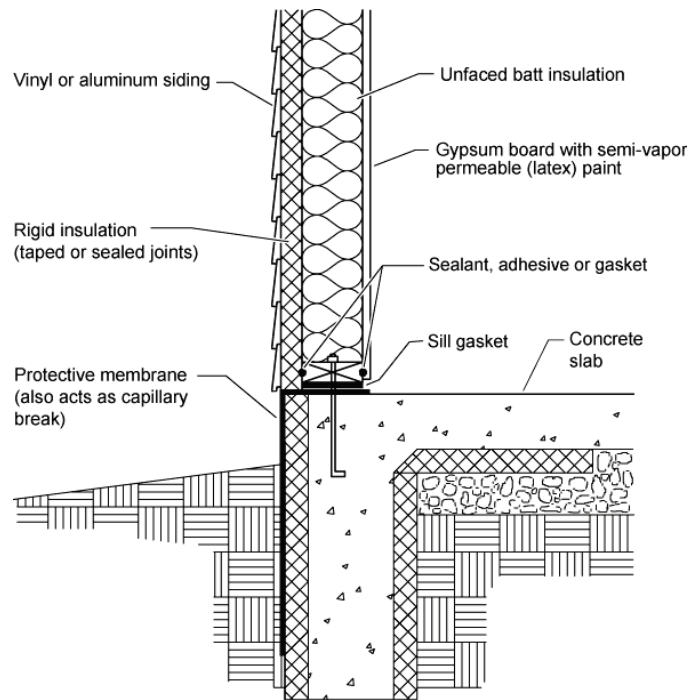
Figure 3-30: Examples of Wood-Framed Wall Assemblies and U-Factors, Assuming Gypsum Board Interior

Stud	Cavity Insulation	Cavity Insulation Type	Exterior Insulation	U-Factor
2x4	R15	High density batt	R4	0.065
2x6	R21	Loose-fill cellulose or high density batt	R4	0.051
2x6	R19	Low density batt	R5	0.051
2x4	R15	High density batt	R8	0.050
2x6	R31	Closed-cell spray foam (ccSPF)	R2	0.050
2x6	R23	High density batt or mineral wool	R4	0.049

Metal-framed assemblies will also require rigid insulation to meet the maximum U-factor criteria. U-factors for metal-framed walls are given in Reference Joint Appendix JA4 Table 4.3.4 and can also be calculated in compliance software.

Demising partitions and knee walls are not required to meet the prescriptive Package A requirements. Demising partitions and knee walls shall meet the mandatory minimum wall insulation requirements from §150.0(c)1 and §150.0(c)1 requires a minimum of R-13 cavity insulation in 2x4 wood framing, or a U-factor less than or equal to U-0.102. §150.0(c)2 requires a minimum of R-19 cavity insulation for 2x6 inch or greater wood framing, or a U-factor less than or equal to 0.074.

Figure 3-31: Example of Wood-Framed Wall With Protective Membrane on Slab-Edge Insulation Detail



Source: California Energy Commission

2. Mass Walls

§150.1(c) These sections are also shown in Appendix B of this document.

The prescriptive requirements have separate criteria for mass walls with interior insulation and mass walls with exterior insulation. “Interior” denotes that insulation is installed on the interior surface of the mass wall, and “exterior” denotes insulation is installed on the exterior surface of the mass wall. Placement of insulation on mass walls does affect the thermal mass properties of a building. The effect of thermal mass helps temper the fluctuation of heating and cooling loads throughout the year in the building.

a. Concrete Mass and Furred Walls

To determine the total R-value of a mass wall, the U-factor from Reference Joint Appendix JA4 Table 4.3.5, 4.3.6 or other masonry tables is added to an insulation layer selected from Reference Joint Appendix JA4 Table 4.3.14. When the prescriptive compliance approach is used, the insulation must be installed integral with or on the exterior or interior of the mass wall.

Figure 3-32: Masonry Wall With Furring Details

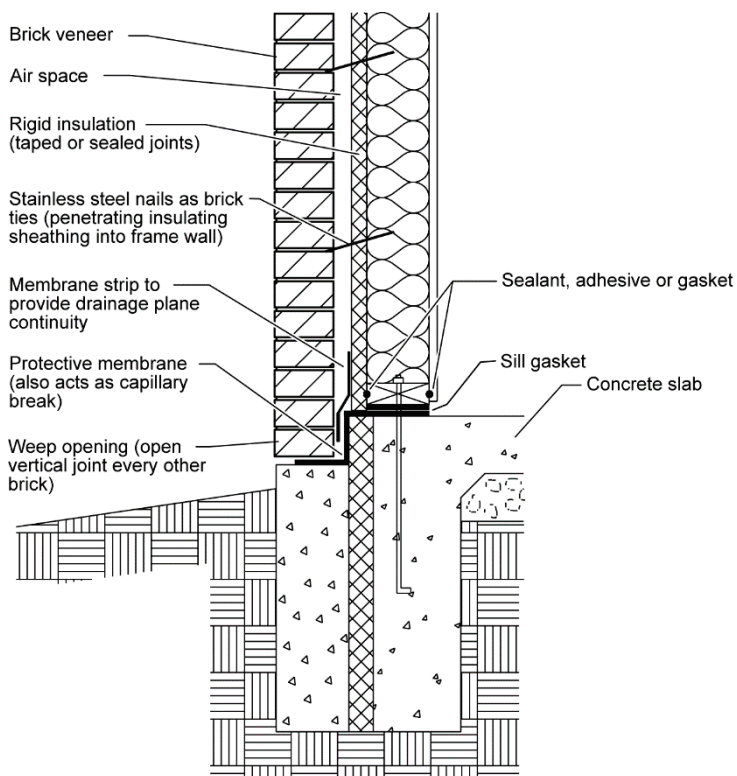
Source: California Energy Commission

The walls addressed in the Properties of Solid Unit Masonry and Solid Concrete Walls tables in the Reference Joint Appendix JA4 tables are rarely used in residential construction but are common in some types of nonresidential construction. For residential construction, the Prescriptive CF1R, CF1R-ADD and CF1R-ALT can calculate complex wall systems to include furred walls.

A four-step process is required to calculate the effective U-factor of a furred wall:

1. Select one of the concrete or masonry walls tables and select a U-factor.
2. Select the appropriate effective R-value for interior or exterior insulation layers in Table 4.3.14.
3. Fill out the CF1R Insulation Values for Opaque Surface table columns. To achieve the proposed assembly U-factor or R-value column, first the Furring Strips Construction Table for Mass Walls Only table needs to be completed.
4. Calculate the final assembly R-value and carry the value back to the Insulation Values for Opaque Surface Details table. Compare the R-value; it must be equal to or greater than the mass standard R-value from Energy Standards Prescriptive Table 150.1-A of the Energy Standards.

The U-factor of furred concrete or masonry walls could also be determined by building the construction assembly in Commission-approved compliance software.

Figure 3-33: Wood-Framed Wall With Brick Veneer

Source: California Energy Commission

Construction Practice/Compliance and Enforcement

The compliance and enforcement process should ensure that the insulation R-value for walls (cavity and/or continuous) on the CF1R form is specified on the building plans and that the same value for the actual installed wall insulation meets or exceeds the R-value on the CF1R form. For more information on compliance and enforcement on wall insulation, see Chapter 2 of this manual.

Because it is difficult to inspect wall insulation behind tub/shower enclosures after the enclosures are installed, insulation of these wall sections should be inspected during the framing inspection.

Batt and loose fill insulation should fill the wall cavity evenly. If kraft or foil-faced insulation is used, it should be installed per manufacturer recommendations to minimize air leakage and avoid sagging of the insulation.

Wall insulation should extend into the perimeter floor joist (rim joist) cavities along the same plane as the wall. If a vapor retarder is required, it must be installed on the conditioned space side of the framing.

Example 3-27

Question:

Do new residential buildings or additions consisting of block walls (for example, converting a garage into living space) have to comply with the R-13 minimum wall insulation requirement? If not, what insulation R-value do they need?

Answer:

Block walls are considered opaque nonframed assemblies and according to §150.0(c)3, the wall has to have a U-factor not exceeding U-0.102, which is equivalent to R-13 insulation in a wood framed wall.

Example 3-28

Question:

For a new wall, if 2-inches of medium–density, closed-cell spray polyurethane foam (ccSPF) is used in combination with R-13 batt insulation in the cavity of a 2x6 wood framed wall with 16” on center spacing, without continuous insulation added, what is the total U-factor for the wall assembly? Does this assembly meet prescriptive compliance Package A requirements in Climate Zones 6 and 7? How about other climate zones?

Answer:

The assembly does meet Package A requirements in Climate Zones 6 and 7. Medium-density ccSPF is given a default value of R-5.8 per inch, as per JA Table 4.1.7. When 2 inches of ccSPF is added to R-13 batt insulation, the total cavity insulation is rounded to R-25. The assembly U-factor was calculated to be 0.065 using Commission-approved compliance software:

Construction Data		
Currently Active Construction:	Exterior Wall Cons	
Construction Name:	Exterior Wall Cons	
Can Assign To:	Exterior Walls	
Construction Type:	Wood Framed Wall	
Construction Layers (inside to outside)		
	Cavity Path	Frame Path
Inside Finish:	Gypsum Board	Gypsum Board
Sheathing / Insulation:	- no sheathing/insul. -	- no sheathing/insul. -
Cavity / Frame:	R 25	2x6 @ 16 in. O.C.
Sheathing / Insulation:	- no sheathing/insul. -	- no sheathing/insul. -
Exterior Finish:	- select finish -	- select finish -
<input type="checkbox"/> Non-Standard Spray Foam in Cavity		
<input type="checkbox"/> Specify Non-std Framing Factor		
Winter Design U-value:	0.065 Btu/h-ft ² -°F (meets max code 0.065 U-value (0.065))	

CBECC-Res Software Wall Assembly Construction showing U-0.065 Assembly

The assembly does meet the minimum mandatory wall insulation U-factor requirement of 0.074, as well as the prescriptive Package A U-factor requirement of 0.065 in Climate Zones 6 and 7.

However, the assembly does not meet the prescriptive compliance Package A U-factor requirement of 0.051 in Climate Zones 1-5 and 8-16. To meet the Package A requirement for those climate zones, other wall assemblies may be used, such as those in Figure 3-30, and/or advanced wall system (AWS) techniques may be used to reduce the framing factor. Alternatively, the project could be shown to comply with Title 24 using the performance approach, which allows energy efficiency trade-offs with other building components.

Example 3-29

Question:

A new single-family house will have six inches of framed walls with R-19 cavity insulation and R-5 continuous rigid insulation on the outside. Can this building comply with Title 24 using either the prescriptive or performance approach?

Answer:

If the house has wood framing, the assembly U-factor would be U-0.051 as per JA4 Table 4.3.1. This U-factor prescriptively complies with the Package A U-factor requirements in all climate zones, and the building would not need to use the performance approach. If the house has metal framing, the assembly U-factor would be U-0.084 as per JA4 Table 4.3.4. This U-factor exceeds the maximum U-factor allowed in the prescriptive Package A and exceeds the mandatory maximum (U-0.074). Thus, the building would not be able to comply even by using the performance method.

3.6.2.3 Floor/Slab

A. Floor Insulation

1. Raised-Floor

§150.1(c)1C

Package A prescriptive requirements call for R-19 or maximum U-factor of 0.037 insulation in raised floors in all climates.

The requirement may be satisfied by installing the specified amount of insulation in a wood-framed floor or by meeting an equivalent U-factor. U-factors for raised floors are listed in Reference Joint Appendix JA4. Concrete floors separating multifamily habitable space from a parking garage are also considered a raised floor. For this class of construction, R-4 insulation is required for Climate Zones 12 and 15, and R-8 is required for Climate Zones 1, 2, 11, 13, 14, and 16. No insulation is required in other climate zones with a concrete raised floor.

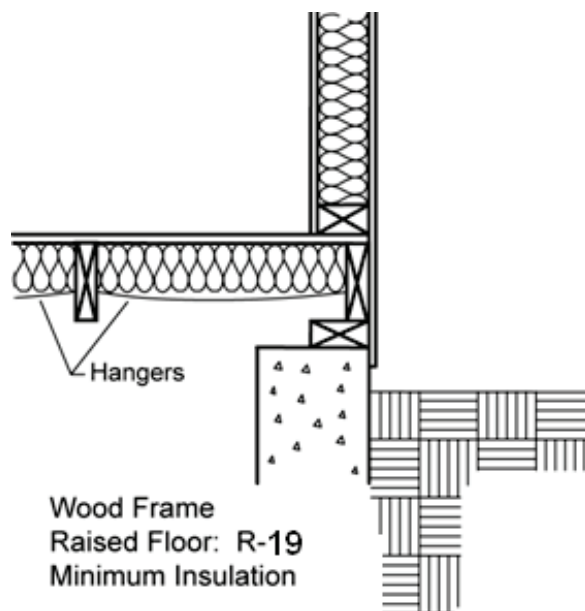
Table 3-6: Raised Floor Constructions Used as Basis for Equivalent U-Factor Compliance

Insulation R-value	Crawlspace?	Reference Joint Appendix JA4 Construction and Table Cell Entry	Equivalent U-factor
R-19	No	4.4.2 A4	0.049
R-19	Yes	4.4.1 A4	0.037

Construction Practice/Compliance and Enforcement

Floor insulation should be installed in direct contact with the subfloor so that there is no air space between the insulation and the floor. Support is needed to prevent the insulation from falling, sagging, or deteriorating.

Options for support include netting stapled to the underside of floor joists, insulation hangers running perpendicular to the joists, or other suitable means. Insulation hangers should be spaced at 18 inch or less before rolling out the insulation. (See Figure 3-34.) Insulation hangers are heavy wires up to 48 inch long with pointed ends, which provide positive wood penetration. Netting or mesh should be nailed or stapled to the underside of the joists. Floor insulation should not cover foundation vents.

Figure 3-34: Raised Floor Insulation

Source: California Energy Commission

B. Slab Insulation

§150.1(c)1D

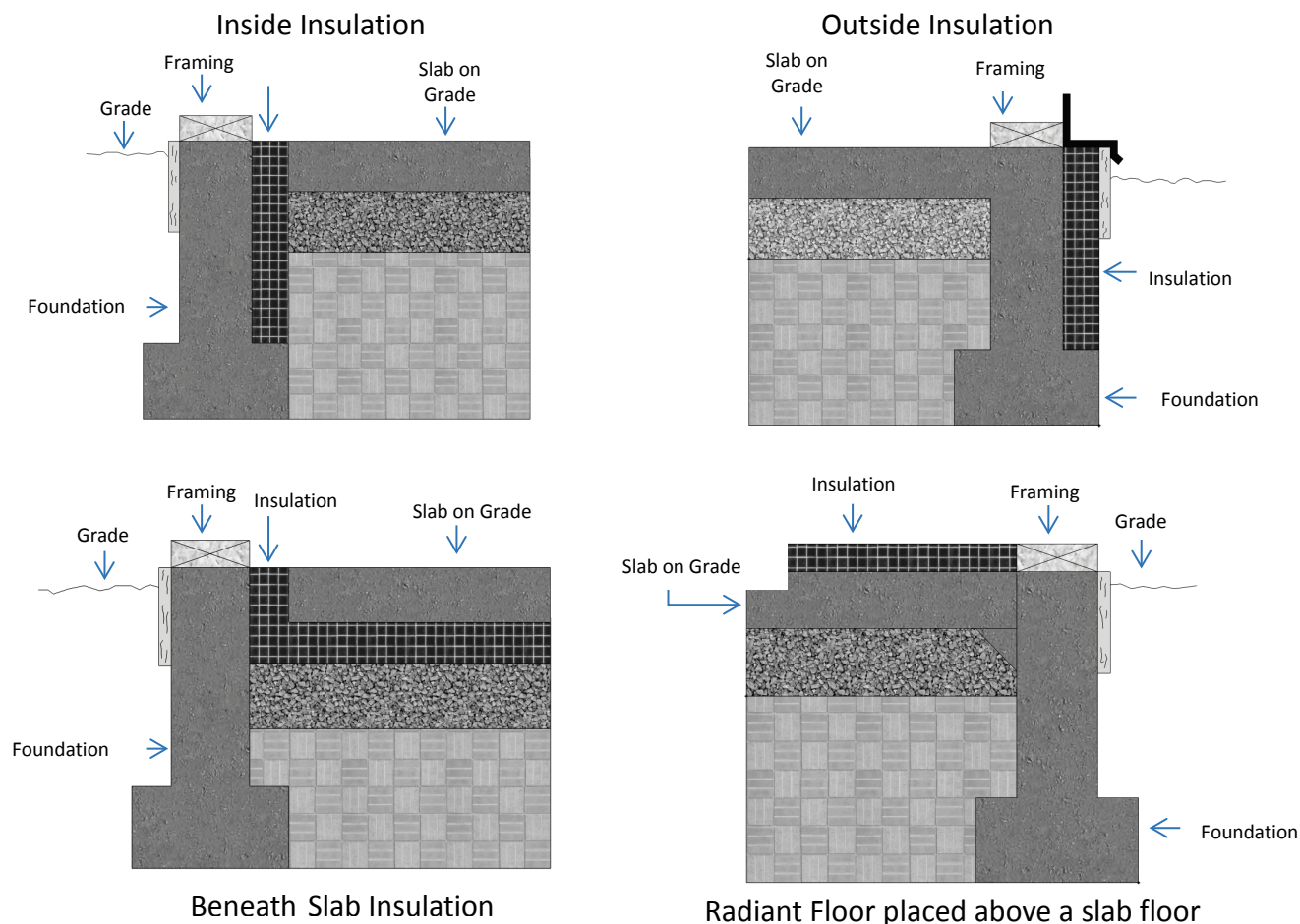
§150.1-A of the Energy Standards, Package A, requires slab insulation only in Climate Zone 16. In this case, a minimum of R-7 must be installed. The insulation must be installed to a minimum depth of 16 in. or to the bottom of the footing, whichever is less. The depth is measured from the top of the insulation, as near the top of slab as practical, to the bottom edge of the insulation. (See Figure 3-35.)

Perimeter insulation is not required along the slab edge between conditioned space and the concrete slab of an attached unconditioned enclosed space such as a garage, covered porch, or covered patio. Neither would it be practical or necessary to insulate concrete steps attached to the outside slab edge.

In situations where the slab is below grade and slab edge insulation is being applied to a basement or retaining wall, the top of the slab edge insulation should be placed as close to ground level as possible and extended down at least 16 inches. In situations where the slab is above grade and slab edge insulation is being applied, the top of the slab edge insulation should be placed at the top of the slab.

Construction Practice/Compliance and Enforcement

Slab-edge insulation should be protected from physical damage and ultraviolet light exposure because deterioration from moisture, pest infestation, ultraviolet light, and other factors can significantly reduce the effectiveness of the insulation. (See Figure 3-31.)

Figure 3-35: Allowed Slab Edge Insulation Placement

Source: California Energy Commission

When slab-edge insulation is required by the prescriptive or performance requirements, then minimum depth is 16 inch or to the top of the footing, whichever is less.

Example 3-30

Question:

What are the slab edge insulation requirements for a hydronic-heating system with the hot water pipes in the slab?

Answer:

The requirements for insulation of heated slabs can be found in §110.8(g) of the Energy Standards and are described in Chapter 4 of this manual. The material and installation specifications are as follows:

- Insulation values as shown in Table 110.8-A of the Energy Standards
- Protection from physical damage and ultraviolet light deterioration
- Water absorption rate no greater than 0.3 percent (ASTM-C272)
- Water vapor permeance no greater than 2.0 perm/inch (ASTM-E96)

3.6.3 Performance Approach

Some residential designs may not wish to use or do not meet the requirements for prescriptive options A, B, and C described above in Section 3.6.2. The performance approach offers increased flexibility as well as compliance credits for certain assemblies, usually requiring HERS verification. The designs described below are examples of residential envelope strategies that can be implemented under the performance approach. The proposed design used under the performance approach is compared to the standard design, which is determined by the prescriptive requirements.

3.6.3.1 Roof Assembly

The construction techniques described below are assemblies that can be used in residential construction to help meet or perform better than minimum prescriptive requirements when using the performance compliance approach. This section describes typical constructions for unvented attics, attic ventilation, insulated tiles, and raised heel trusses (also called “energy trusses”).

A. Unvented Attics

Attic ventilation is the traditional way of controlling temperature and moisture in an attic. In an unvented attic assembly, insulation is applied directly at the roofline of the building, either above or below the structural roof rafter. The roof system becomes part of the insulated building enclosure. For this case, the thermal boundary of the building results in an unvented attic space between the ceiling gypboard and the insulated roof above (See Figure 3-36).

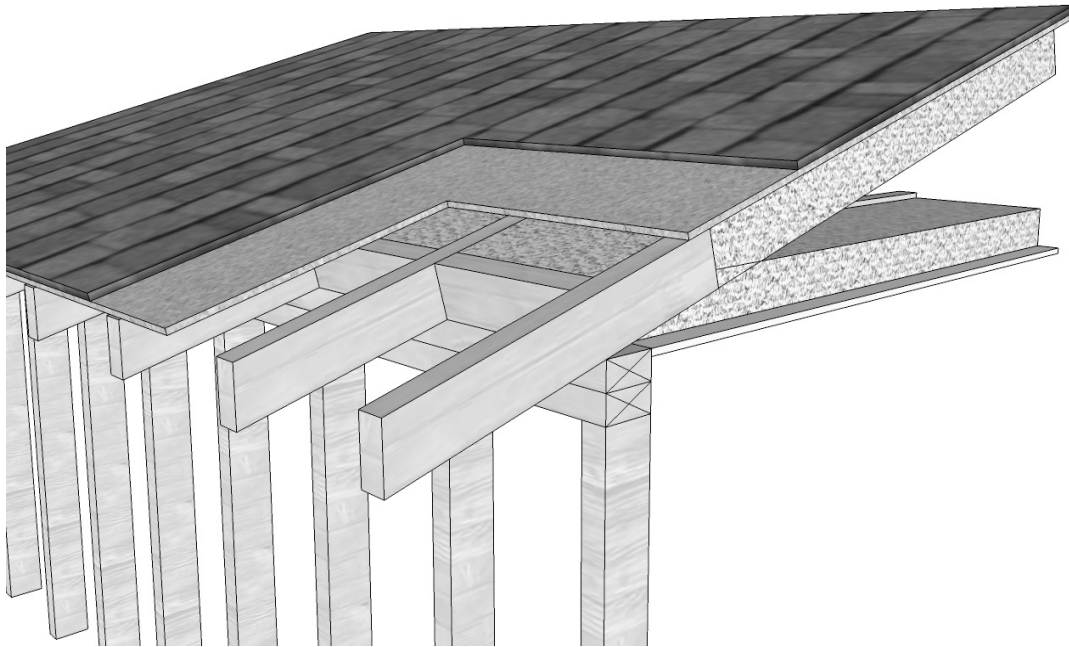
The provisions of CBC, Title 24, Part 2, Vol. 2.5, Section R806.4 describes conditions for insulation placed at the roof of the building as opposed to on top of the horizontal ceiling. Unvented attic assemblies are allowed provided that:

1. **Air-impermeable** insulation is used below and in direct contact with the underside of the roof sheathing.
2. **Air-permeable** insulation is used below and in direct contact with the underside of the roof sheathing and rigid board or sheet insulation of at least R-4 is used above the roof sheathing.
3. **Air-impermeable** insulation is used below and in direct contact with the underside of the roof sheathing, and an additional layer of air-permeable insulation is installed directly under the air-impermeable insulation.

Check with the local building jurisdiction to determine its specific requirements for unvented attic conditions.

Combining this strategy with the additional design improvement of low air leakage for the rest of the building would achieve energy savings and compliance energy credit. Furthermore, this design eliminates the need to seal or limit penetrations at the ceiling level, such as recessed cans, because the air and thermal boundary is now located at the roof deck.

Figure 3-36: Unvented Attic Assembly With Insulation at the Ceiling and Between the Roof Rafters

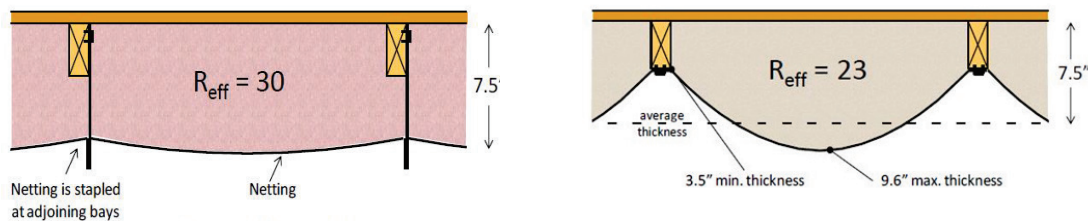


Source: California Energy Commission

B. Below-Deck Netted Insulation

Alternative types of insulation can provide high R-value insulation below the roof deck in an unvented attic. One approach is a boxed netted system that is suspended from the top member of the truss, or top chord, to provide a fill depth that completely encloses the top chord, creating a uniform insulation layer of loose-fill fiberglass across the entire underside of the roof deck. This method can be done with common loose-fill insulation tools and equipment. See Figure 3-37A for details of this type of below-deck netted insulation. Draped netted insulation, another approach to below deck insulation, results in a non-uniform insulation layer, created by leaving the truss chords exposed and leading to increased thermal bridging (see Figure 3-37B).

Figure 3-37A (left): Box Netted Insulation and Figure 3-37B (right): Draped Netted Insulation



Source: Owens Corning

C. Insulated Roof Tiles

Insulating roof tile (IRT) is another option for improving the thermal performance of the roof assembly and lowering attic temperatures. IRT combines concrete/clay tiles with insulation as a packaged product. Most of the increase in R-value is due to the integration of insulation into the roofing product itself; however, additional thermal performance can be gained by combining IRT with rigid foam insulation inserts (Figure 3-39). These tiles are lighter than typical roof tiles and have better thermal performance than traditional tiles due to the insulation core.

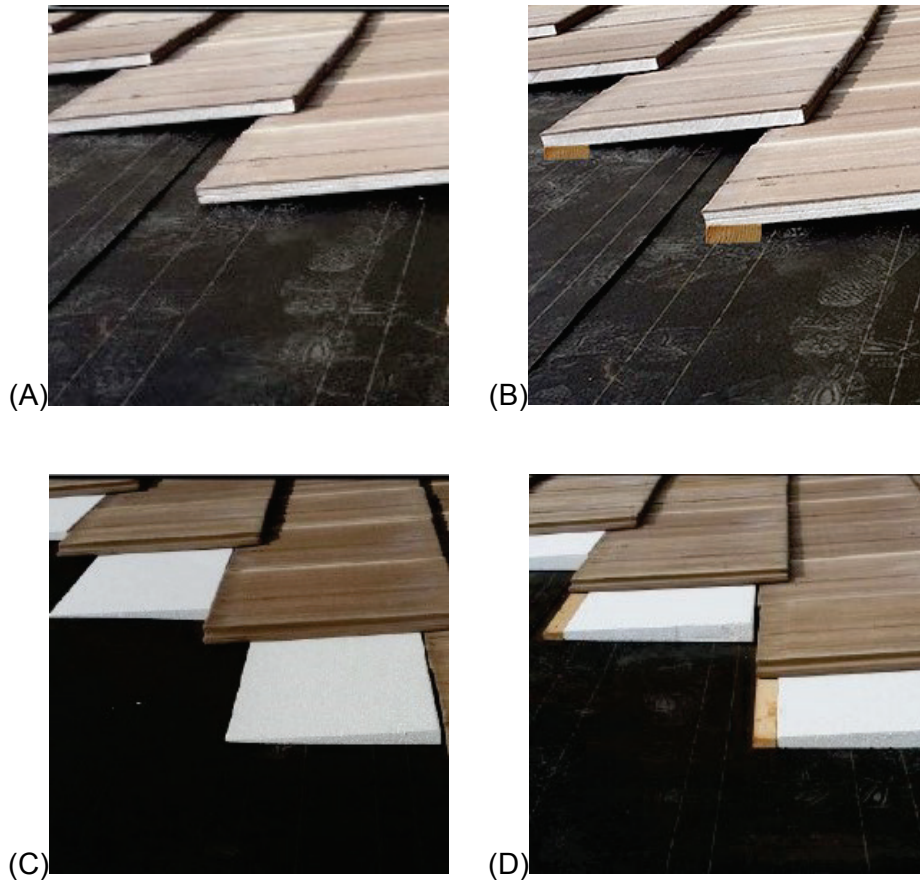
Furthermore, IRT can reduce radiant losses and maintain warmer roof deck temperatures, thereby reducing the potential for condensation. Using one of the options below provides additional R-value when conventional (ceiling) insulation is also installed. All four configurations (A-D) can be installed without any significant changes to conventional roof or attic design (such as changes to fascia dimensions, and so forth), and IRT can be used in both vented and unvented attic configurations.

Figure 3-38: Insulated Concrete Tile



Source: Green Hybrid Roofing

Figure 3-39: Insulated Roof Tile (IRT) (A) attached directly to roof deck, (B) attached to batten, (C) attached directly to roof deck with wedged foam filling air space, and (D) attached to battens with wedged foam filling air space



Source: Green Hybrid Roofing

Some IRTs are ASTM rated for Class A fire rating (ASTM E108) and have CRRC certification for cool roof tiles in several colors. Depending on the configuration selected from the four options (A-D) in Figure 3-39, a U-factor between 0.18 and 0.10 can be achieved, with option D performing the best. It is best practice to check with manufacturers about the ratings and certifications for each tile. Product manufacturers cite several advantages of the product due to its lightweight construction and increased insulation properties – ease of installation, ability to install similar to traditional roof tiles but at a much faster pace, less weight on the roof structure, increased thermal resistance, and improved thermal performance.

D. Raised Heel or Extension Truss (Energy Truss)

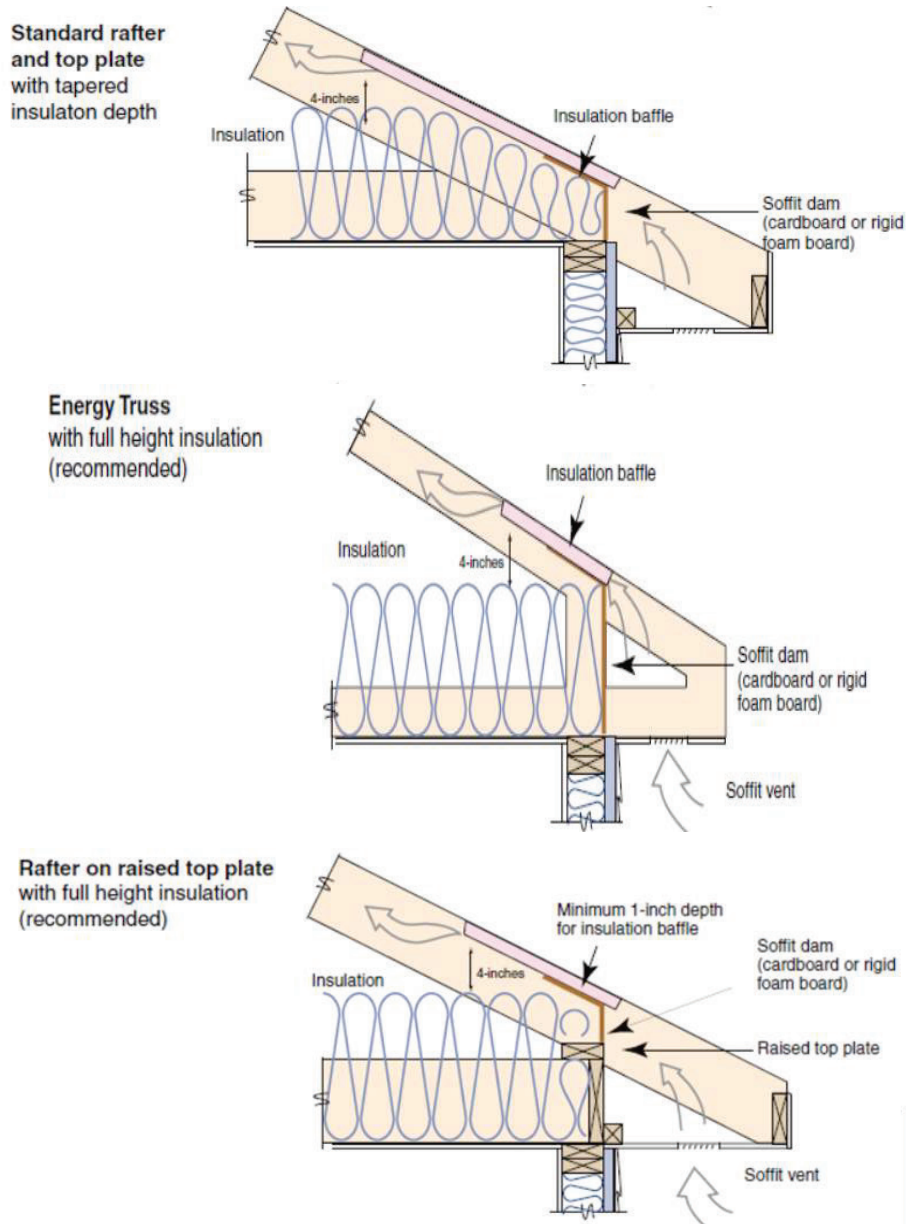
The use of an energy truss, usually referred to as a raised heel or extension truss, allows full depth, uncompressed insulation at the ceiling to continue to the ceiling edge where the roof and ceiling meet. For this strategy, the roof truss is assembled with an additional vertical wood framed section at the point where the top and bottom truss chords meet. The vertical section raises the top chord and provides increased space that can be filled with insulation. See Figure 3-40 for details of a raised heel truss. Benefits of this strategy include:

- Realizing the full benefit of ceiling insulation.
- Providing more space for air handler and duct systems if located in the attic.

The 2016 CBECC-Res compliance software allows for the modeling of raised heel trusses and provides credit for the additional insulation at the edges.

Other methods to achieve the similar outcome include framing with a rafter on raised top plate or using spray foam or rigid foam at the edge.

Figure 3-40: Raised Heel Truss (Energy Truss)

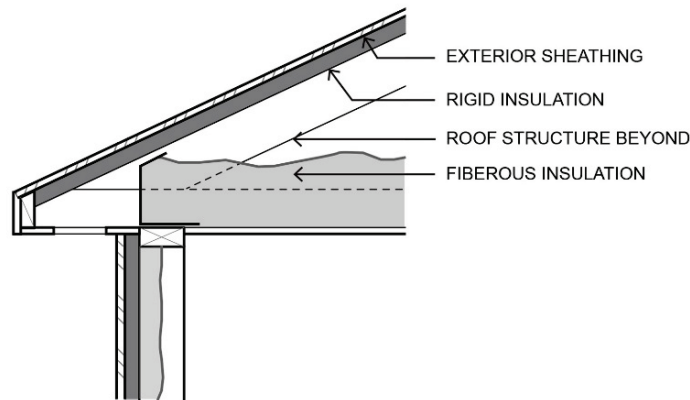


Source: Georgia Department of Community Affairs

E. Nail Base Insulation Panel

The nail base insulation panel is an above-roof rafter insulation strategy that consists of exterior-facing OSB or other structural sheathing laminated to continuous rigid insulation, which is fastened directly to roof framing (See Figure 3-40A). This saves the time and expense of installing a structural sheathing layer above and below the rigid insulation. The nail base insulation panel creates a nailing surface for the attachment of roof cladding. Suitable for both vented and unvented attic assemblies, the exposed underside of the rigid insulation has a facer that provides a radiant barrier as well as ignition/thermal barrier protection as required by code.

Figure 3-40A: Nail base insulation panel with radiant barrier (one-sided SIP) affixed to trusses in a prescriptive, vented attic configuration



3.6.3.2 Wall Assembly

See Energy Commission videos

A. Advanced Wall System (AWS)

Advanced wall systems (AWS), also known as *optimum value engineering (OVE)*, refers to a set of framing techniques and practices that minimize the amount of wood and labor necessary to build a structurally sound, safe, durable, and energy-efficient building. AWS improves energy and resource efficiency while reducing first costs.

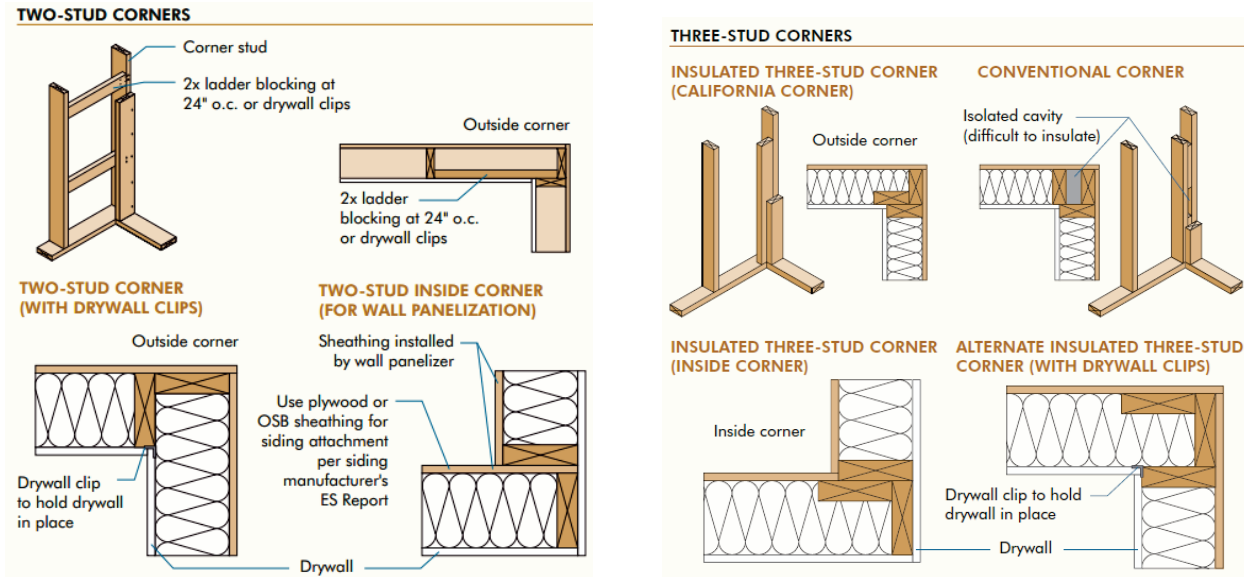
Reducing the amount of wood in wood-framed exterior walls improves energy efficiency, allowing more insulation to be installed, and has greater resource efficiency for the materials being used. In addition, using fewer framing studs reduces the effects of “thermal bridging” and increases the amount of insulation in the wall, resulting in a more energy-efficient building envelope. The framing factor assumed for calculating the energy performance of a wood framed 2x4 wall at 16” oc is 25 percent. When AWS is used, the framing factor is reduced to 17 percent, reflecting the improved energy performance of the wall system.

While AWS represents a range of practices, it must be adequately inspected to ensure framing contractors have adhered to all best practice construction throughout the exterior envelope. Examples of construction practices for AWS that can be used as a general guide for enforcement are provided below:

1. Use a minimum 2x6 at 24" on-center wall framing.
 2. Use precise engineering of headers on load-bearing walls.
 3. Install 2x4, 2x6, or I-joist headers on exterior nonload-bearing walls.
 4. Eliminate cripple studs at window and door openings less than 4 feet wide.
 5. Align window/door openings with standard stud spacing.
 6. The king stud, on at least one side of the window/door opening, must take the place of an on-layout AWS stud.
 7. Use an insulated corner, either a two-stud corner or a California (3-stud) corners, as in the examples provided in Figure 3-41.
 8. Nailing for interior gypsum board can be accomplished with drywall clips, 1x nailer strip, recycled plastic nailing strip. Drywall clips reduce the potential for drywall cracking.
 9. Use ladder block where interior partitions intersect exterior walls, instead of 3-stud channels.
 10. Eliminate unnecessary double-floor joists underneath nonbearing walls.
 11. Use metal let-in T-bracing or other methods on non-shear walls to allow full insulation.
 12. Include detailed framing plans and elevations on the construction permit plan set.
 13. Optimize house design for efficient material use (for example, reducing header spans, designing exterior surfaces in two-foot modules, designing clear spans to eliminate interior bearing walls).
 14. Build with "insulated headers" (a "sandwich" of two solid or engineered lumber components with a layer of foam insulation in the middle or on one or both sides of the header). An example of a single-ply insulated header is provided in Figure 3-42. Insulated headers may also earn QII compliance credits by installing R-2 insulation in one of three ways:
 - a. Two-member header with insulation in between. The header and insulation must fill the wall cavity. There are prefabricated products available that meet this assembly. Example: a 2x4 wall with two 2x nominal headers, or a 2x6 wall with a 4x nominal header and a 2x nominal header. Insulation is required to fill the wall cavity and must be installed between the headers.
 - b. Single-member header, less than the wall width, with insulation on the interior face. The header and insulation must fill the wall cavity. Example: a 2x4 wall with a 3-1/8-inch-wide header, or 2x6 wall with a 4x nominal header. Insulation is required to fill the wall cavity and must be installed to the interior face of the wall.
 - c. Single-member header, same width as wall. The header must fill the wall cavity. Example: a 2x4 wall with a 4x nominal header or a 2x6 wall with a 6x nominal header. No additional insulation is required because the header fills the cavity.
- Wood structural panel box headers may also be used as load-bearing headers in exterior wall construction, when built in accordance with 2015 CRC Figure R602.7.3 and Table R602.7.3.
15. Use engineered lumber. Examples include: "I"-joists, open web floor trusses, 2x "raised heel" roof trusses, glulam beams, laminated veneer lumber (LVL), laminated strand lumber (LSL), parallel strand lumber (PSL), oriented strand board (OSB).

16. Eliminate trimmers at window and door opening headers less than 4 ft wide, only when rated hangers are used and noted on the plans.
17. Use 2x4 or 2x3 interior nonload-bearing walls.
18. Integrate framing design with HVAC system.
19. Use “inset” shear wall panels.

Figure 3-41: Advanced Framing Corners



Source: APA Advanced Framing Guide

Figure 3-42: Headers Designs with Cavity Insulation Space

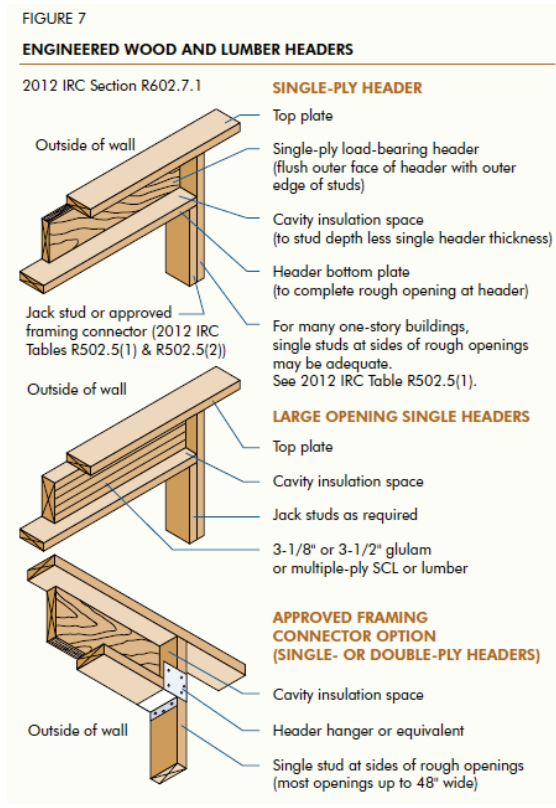
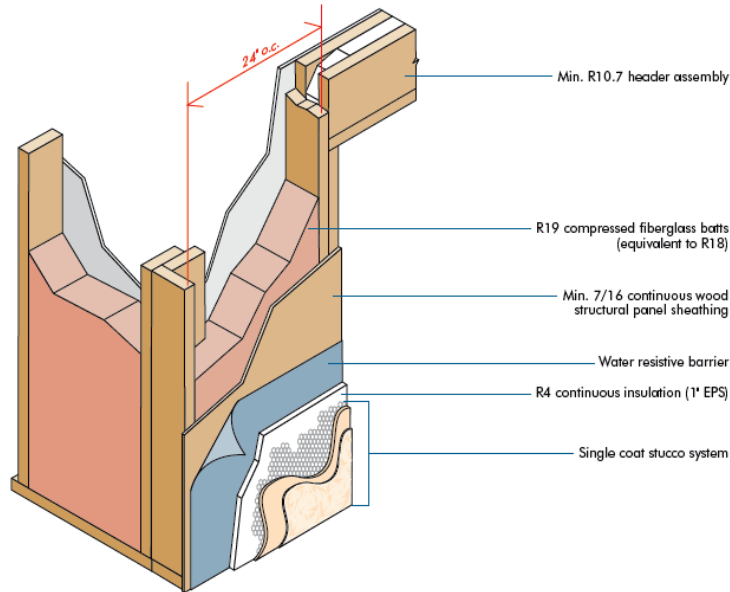


Figure 3-43 below is a description of one AWS and the assembly characteristics that are used in the prescriptive and performance compliance approaches. This assembly meets a U-factor of 0.051 with an exterior insulation of R-4, due to 24” stud spacing and R-7 header assemblies. The building official must ensure during planning, to check the accuracy of the parallel heat flow calculation and, during framing, inspect that all elements of AWS have been met.

Figure 3-43: Wood-Framed Wall, 2x6 @ 24” oc, AWF with 3-stud corners



Source: APA, The Engineered Wood Association

Table 3-7: Assumptions

Layer	Assembly Type: Wall 2x6 @ 24” oc AWS	R-Value		
	Framing Material: Wood			
	Assembly Components	Cavity (R_c)	Frame (R_f)	Header (R_h)
0	Frame Factor	78%	18%	4%
1	Outside air film	0.17	0.17	0.17
2	Building paper	0.06	0.06	0.06
3	3/8 inch single coat stucco	0.08	0.08	0.08
4	R4 continuous insulation (1” EPS)	4	4	4
5	7/16 inch continuous oriented strand board sheathing (OSB)	0.44	0.44	0.44
6	R-18 compressed fiberglass batts	18.0	--	--
7	Header assembly – 3.5” wood			3.46
8	Header assembly – 1 inch of R4 foam			4
9	2x6 douglass fir framing @ R-1.086/inch	--	5.973	--
10	½ inch gypboard	0.45	0.45	0.45

11	Inside air film	0.68	0.68	0.68
	Subtotal R-Values	23.875	11.848	13.335
	U-Factors (Frame % x 1/R)	0.0327	0.0152	0.0030
	[Assembly U-factor	Assembly U-factor	0.051	

Assumptions: Values in Table 3-7 were calculated using the parallel heat flow calculation method, documented in the *2009 ASHRAE Handbook of Fundamentals* and outlined in Joint Appendices JA4.1.2 and JA4.6. The construction assembly in Table 4.6.1 in JA4.6 assumes an exterior air film of R-0.17, a 3/8-inch layer of stucco of R-0.08 (SC01), building paper of R-0.06 (BP01), sheathing or continuous insulation layer, if present, the cavity insulation/framing layer, 1/2-inch gypsum board of R-0.45 (GP01), and an interior air film 0.68. The framing factor is assumed to be 25 percent for 16-inch stud spacing, 22 percent for 24-inch spacing, and 17 percent for advanced wall system (AWS). Actual cavity depth is 3.5 inch for 2x4, 5.5 inch for 2x6.

B. Double and Staggered Wall Assemblies

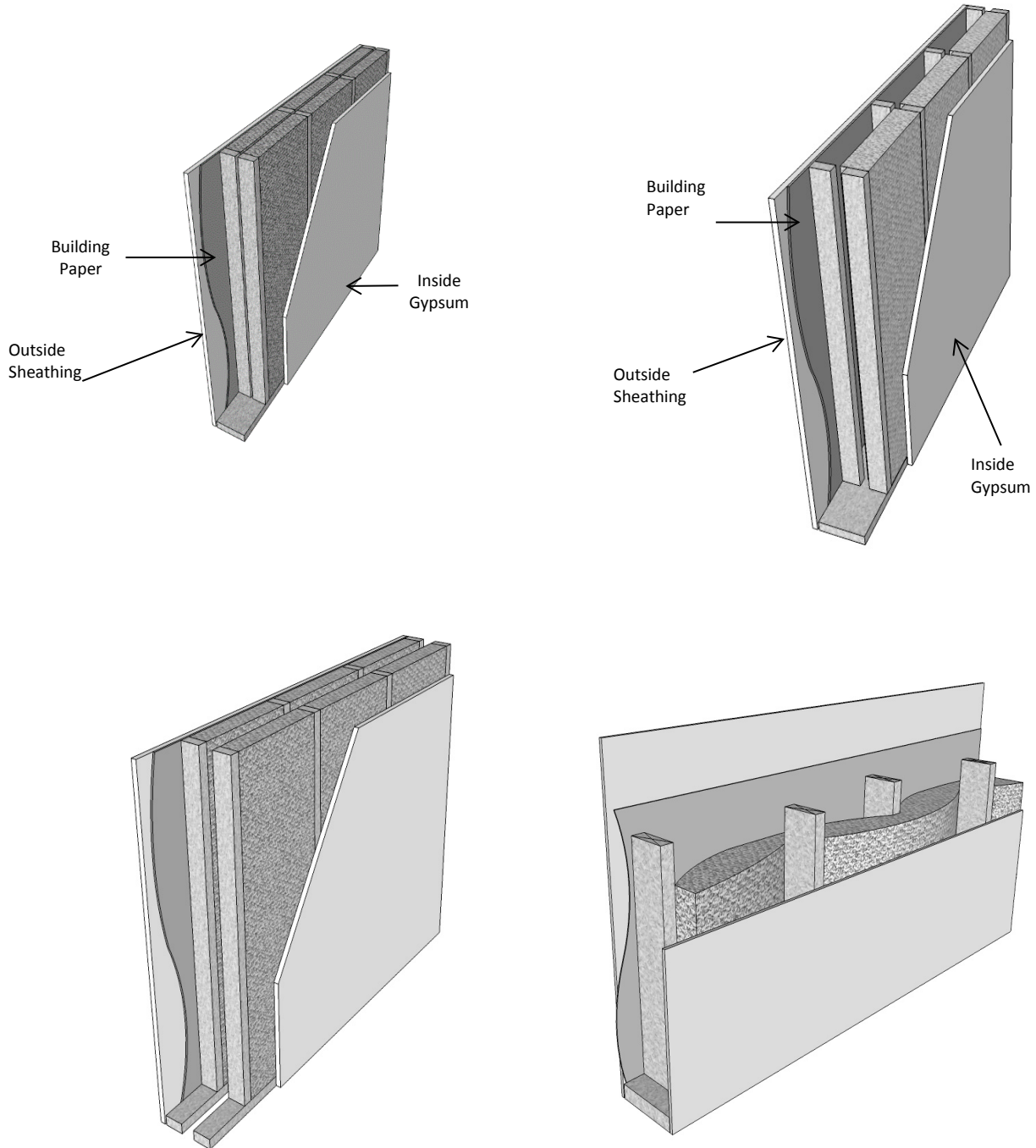
Double-wall and staggered-wall systems were developed to better accommodate electrical and plumbing systems, allow higher levels of insulation, and provide greater sound attenuation. The advantages of these types of wall systems are:

1. Smaller dimensional lumber can be used.
2. It is easier to install installation properly.
3. It eliminates thermal bridging through the framing.
4. It reduces sound transmission through the wall.

With double walls, insulation may be on one side of the wall or on both (higher R-values). It is not uncommon to find double walls with insulation installed within the outside wall cavities, leaving the inside wall sections open for wiring and plumbing. (See Figure 3-44.)

With staggered walls, thermal batt insulation may be installed horizontally or vertically, butting the sides of the insulation until the cavity across the entire wall section is completely filled.

Figure 3-44: Typical Double and Staggered Wall Systems



Source: California Energy Commission

C. Metal Framing

A change from wood framing to metal framing can significantly affect compliance. Metal-framed assemblies are often chosen where greater structural integrity is necessary, or in climate conditions where greater durability is desired from the effects of excessive moisture exposure. Metal-framed wall construction generally requires a continuous layer of rigid insulation to meet the mandatory minimum wall insulation levels and/or the

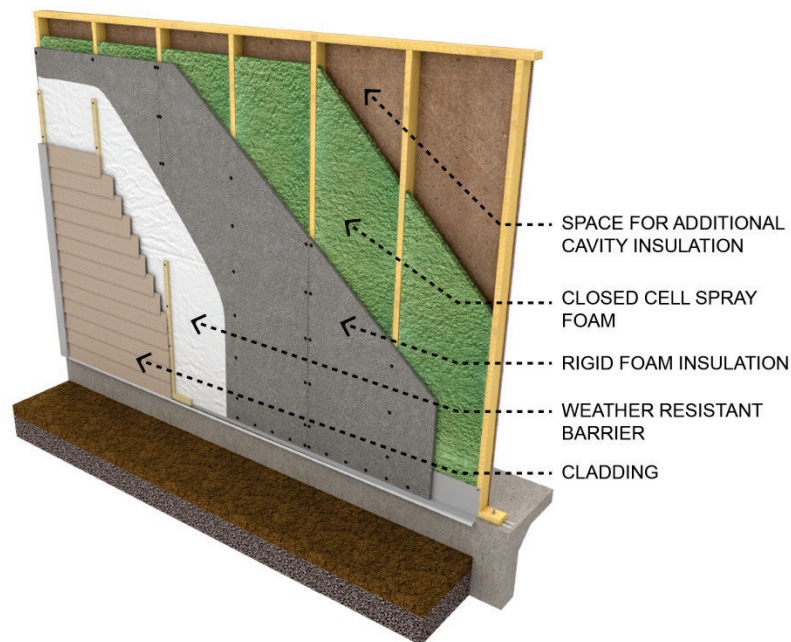
prescriptive requirements since metal is more conductive than wood. In JA4, Tables 4.2.4 and 4.2.5 have U-factors for metal-framed ceiling/roof constructions. Table 4.3.4 has U-factors for metal-framed walls. Tables 4.4.4 and 4.4.5 have U-factors for metal-framed floors.

To comply prescriptively, a non-wood-framed assembly, such as a metal-framed assembly, must have an assembly U-factor that is equal to or less than the U-factor of the wood-framed assembly for that climate zone. Compliance credit is available through the performance approach for metal-framed assemblies that exceed the prescriptive requirements of the equivalent wood-framed assemblies.

D. High-Performance Structural Foam Wall System

The high-performance structural foam wall assembly is an Advanced Assembly System that consists of ccSPF placed in the cavity bonded to wood framing and continuous rigid board insulation on the exterior of the frame. The bond that occurs between the ccSPF, the framing, and the continuous rigid insulation can provide code-compliant wind and seismic structural load resistance without the use of OSB sheathing (See Figure 3-44A).

Figure 3-44A: High Performance Structural Foam Wall Systems use ccSPF to insulate, air seal, and structurally bond together exterior foam sheathing with wall framing to allow builders to construct 2x4 at 24” O.C. while improving structural and thermal performance.



Source: BASF Corporation

A builder can configure the thicknesses of the cavity ccSPF, rigid insulation, and alternative cavity insulation to attain U-factors of 0.050 or better in 2x4 at 24” OC assembly. The structural foam wall assembly can be combined with advanced framing or OVE techniques to increase energy and resource efficiency while reducing both material cost and labor.

3.6.3.3 Floor Assembly

A. Controlled Ventilation Crawl Space (CVC)

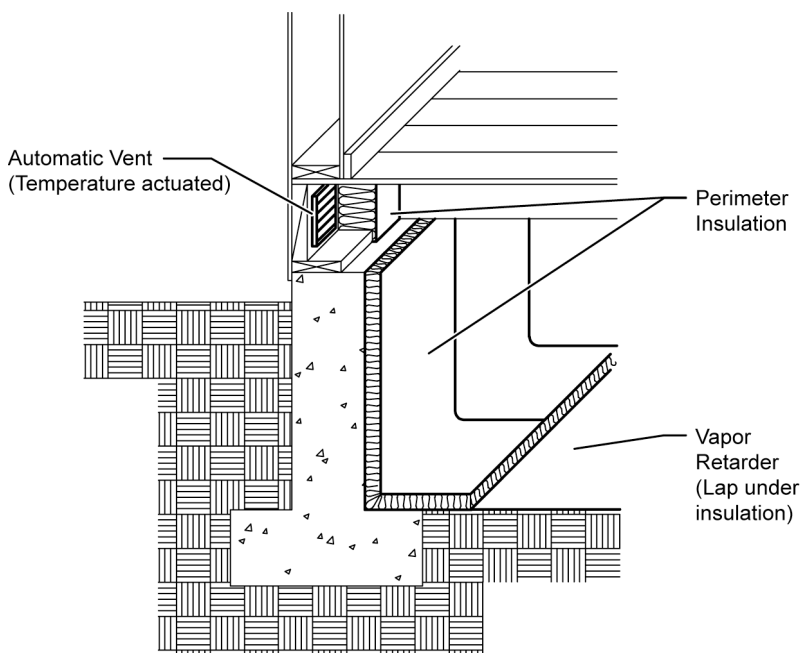
CVC Eligibility Criteria in 2016 RA4.5.1

Buildings that have crawl space foundations must meet mandatory and prescriptive requirements for insulation of a raised floor separating the unconditioned crawl space from conditioned space above (§150.0(d) and §150.1(c)1C). An alternative to underfloor insulation is insulating the stem wall of the foundation crawl space. Insulating the crawl space foundation can improve the thermal efficiency of the floor system by:

1. Reducing heat transfer into the unconditioned crawl space.
2. Reducing moisture buildup in the crawl space.
3. Minimizing insulation exposure to adverse weather prior to enclosure of the building shell.

An energy credit can be taken in compliance software for controlled ventilation crawl space (CVC). This credit requires insulating the foundation stem wall, using automatically controlled crawl space vents, and vapor retarder covering the entire ground soil area for moisture control on the crawl space floor.

Figure 3-45: Controlled Ventilation Crawl Space



Source: California Energy Commission

All building designs should ensure that proper site engineering and drainage away from the building is maintained. This includes landscaping techniques that emphasize sound water management strategies:

1. **Drainage:** Crawl space buildings in particular are susceptible to moisture ponding when good drainage and/or moisture removal designs are not employed.
2. **Ground water and soils:** Local groundwater tables at maximum winter recharge elevation should be below the lowest excavated elevation of the site foundation.

Sites that are well-drained and that do not have surface water problems are generally good candidates for this stem wall insulation strategy. However, allowance for this alternative insulating technique is entirely at the enforcement agency's discretion. The building permit applicant should be prepared to provide supporting information that site drainage strategies (for example, perimeter drainage techniques) will prevent potential moisture concerns.

The following eligibility criteria in RA4.5.1 are required in order to use the CVC energy credit:

1. **Ventilation:** All crawl space vents must have automatic vent dampers. Automatic vent dampers must be shown on the building plans and installed. Dampers shall be temperature actuated to be fully closed at about 40°F and fully open at about 70°F. Cross-ventilation consisting of the required vent area shall be distributed between opposing foundation walls.
2. **Insulation:** The R-value of insulation placed on the foundation stem wall shall be equal to or greater than the wall insulation above the raised floor. Stem wall insulation shall run vertically along the stem wall and horizontally across the crawl space floor for a distance of 2 ft (24 inches).
3. **Direct Earth Contact:** Foam plastic insulation used for crawl space insulation having direct earth contact shall be a closed-cell, water-resistant material and meet the slab edge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory requirements (§110.8(g)1).

A Class I or Class II vapor retarder rated as 1.0 perm or less must be placed over the earthen floor of the crawl space to reduce moisture entry and protect insulation from condensation in accordance with RA4.5.1. This requires essentially a polyethylene-type ground cover having a minimum 6 mil thickness (0.006 inch) or approved equal. The vapor retarder must be overlapped a minimum of 6 inches at joints and shall extend over the top of footings and piers. All overlapping of joints shall be sealed with tape, caulk, or mastic.

- Penetrations, tears, and holes in the vapor barrier shall be sealed with tape, caulk, or mastic.
- Edges of the vapor retarder shall be turned up a minimum of 4 inches at the stem wall and securely fastened and before insulation is installed.
- In sloping crawl space ground soil areas, the vapor retarder shall be securely held in place, such as spiked with 5-inch gutter nails, then have proper sealing of penetration holes.
- The vapor retarder shall be shown on the plans.

3.6.3.4 Quality Insulation Installation (QII)

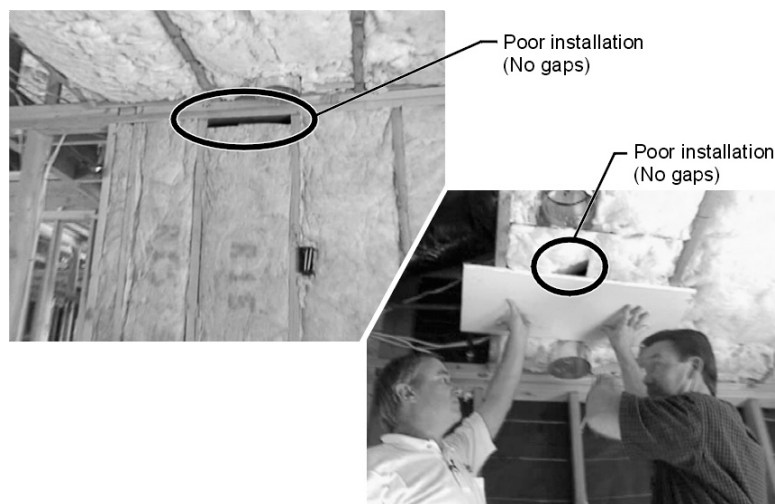
Energy Commission videos
RA3.5

All insulation shall be installed properly throughout the building. When compliance credit is taken for QII, a third-party HERS Rater is required to verify the integrity of the installed insulation. The installer shall provide evidence with compliance documentation that all insulation specified is installed to meet specified R-values and assembly U-factors.

Many residential insulation installations have flaws that degrade thermal performance. Four problems are generally responsible for this degradation:

1. There is an inadequate air barrier in the building envelope, or holes and gaps within the air barrier system inhibit the ability to limit air leakage.
2. Insulation is not in contact with the air barrier, creating air spaces that short-circuits the thermal barrier of the insulation when the air barrier is not limiting air leakage properly.
3. The insulation has voids or gaps, resulting in portions of the construction assembly that are not insulated and, therefore, has less thermal resistance than other portions of the assembly.
4. The insulation is compressed, creating a gap near the air barrier and/or reducing the thickness of the insulation.

Figure 3-46: Examples of Poor Quality Insulation Installation



Source: California Energy Commission

An energy credit for correctly installing an air barrier and insulation to eliminate or reduce common problems associated with poor installation is provided in the RA3.5. This compliance credit applies to framed and nonframed assemblies. Residential construction may incorporate multiple frame types, for example, using a combination of nonframed walls with a framed roof/ceiling. Likewise, multiple insulation materials are often used. Framed assemblies include wood and steel construction insulated with batts of mineral fiber, mineral and natural wool, and cellulose; loose-fill insulation of mineral fiber, mineral and natural wool, cellulose, and SPF; and rigid board insulation used on the exterior or interior of framed or nonframed assemblies. Nonframed assemblies include structural insulated panels, insulated concrete forms, and mass walls of masonry, concrete and concrete sandwich panels, log walls, and straw bale.

This compliance credit can only be taken for the whole building—roof/ceilings, walls, and floors – and requires field verification by a third-party HERS Rater. Further explanation is provided below:

1. Compliance credit is not allowed for walls alone, or credit is allowed for roofs/ceilings but not walls also.
2. Compliance credit is allowed for a building built on a slab floor, where the slab has no requirement for insulation. However, if insulation is installed (that is, slab edge insulation for radiant floor heating), then the integrity of the slab edge insulation must

also be field-verified in addition to the air barrier and insulation system for walls and the roof/ceiling.

3. Combinations of insulation types (hybrid systems) are allowed.
4. An air barrier shall be installed for the entire envelope.
5. Compliance credit is allowed for additions to existing buildings where energy compliance has been demonstrated for the “addition alone” (§150.2(a)2A).
6. Compliance credit is not allowed for additions to existing buildings where the “existing plus alteration plus addition” approach is used (§150.2(a)2B).
7. Compliance credit is not allowed when using the PV trade-off package.

Approved computer compliance modeling software automatically reduces the effectiveness of insulation for compliance. This reduction is accounted for in developing the Energy Standards and prescribing the required prescriptive measures for each climate zone to establish the standard design energy budget in performance compliance calculations. The effect of a poorly installed air barrier system and envelope insulation results in higher wall heat loss and heat gain than standard R-value and U-factor calculations would indicate. Similar increases in heat loss and heat gain are experienced for roof/ceilings where construction and installation flaws are present.

To take advantage of the QII energy credit, two primary installation criteria must be adhered to and they both must be field verified by a HERS Rater.

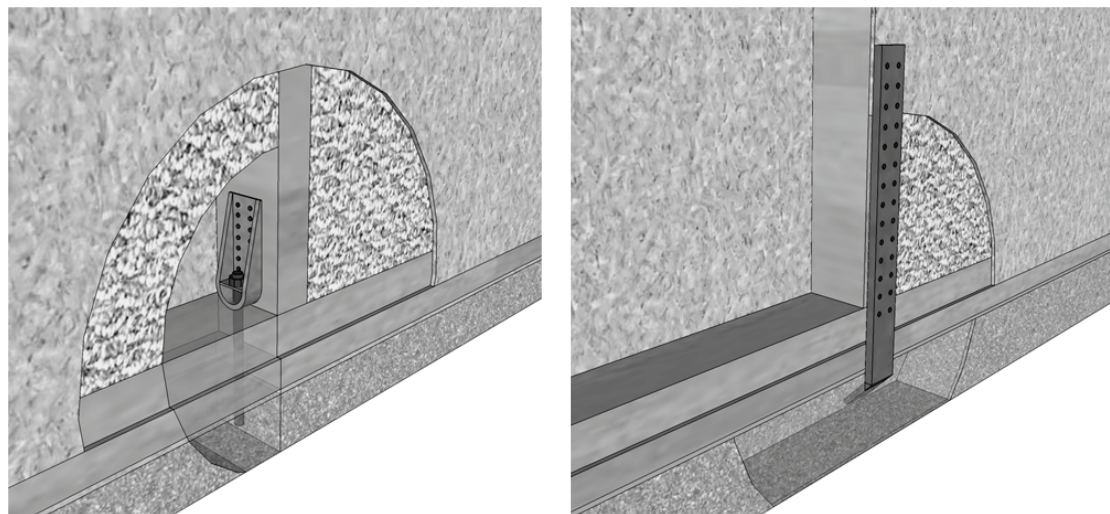
A. Structural Bracing, Tie-Downs, Steel Structural Framing

RA3.5.5.2.8

When metal bracing, tie-downs, or steel structural framing is used to connect to wood framing for structural or seismic purposes, the QII energy credit still can be taken if:

1. Metal bracing, tie-downs or steel structural framing is identified on the structural plans.
2. Insulation is installed in a manner that restricts the thermal bridging through the structural framing assembly.
3. Insulation fills the entire cavity and/or adheres to all sides and ends of structural assembly that separates conditioned from unconditioned space.

Figure 3-47: Structural Bracing, Tie-downs



Source: California Energy Commission

B. Air Barrier

RA3.5.2

An air barrier shall be installed enclosing the entire building. When this credit is shown to be taken on compliance documentation a third-party HERS Rater is required to verify the integrity of the air barrier system. The air barrier must be installed in a continuous manner across all components of framed and nonframed envelope assemblies. The installer shall provide evidence with compliance documentation that the air barrier system meets one or more of the air barrier specifications shown in Table 3-8 below. More detailed explanation is provided in RA3.5. Documentation for the air barrier includes product data sheets and manufacturer specifications and installation guidelines. The third-party HERS Rater shall verify that the air barrier has been installed properly and is integral with the insulation being used throughout the building.

Table 3-8: Continuous Air Barrier

Continuous Air Barrier	<p>A combination of interconnected materials and assemblies are joined and sealed together to provide a continuous barrier to air leakage through the building envelope separating conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses. An air barrier is required in all thermal envelope assemblies to limit air movement between unconditioned/outside spaces and conditioned/inside spaces and must meet one of the following:</p> <ol style="list-style-type: none"> 1. Using materials that have an air permeance not exceeding 0.004cfm/ft² under a pressure differential of 0.3in. w.g. (1.57psf) (0.02 L/s.m² at 75 pa) when tested in accordance with ASTM E2178. 2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft² under a pressure differential of 0.3 in. w.g (1.57psf) (0.2 L/s.m² at 75 pa) when tested in accordance with ASTM E2357, ASTM E1677, ASTM E1680 or ASTM E283. 3. Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft² at a pressure differential of 0.3 in w.g. (1.57 psf) (2.0 L/s.m² at 75 pa) in accordance with ASTM E779 or an equivalent approved method. <p>Materials and assemblies of materials that can demonstrate compliance with the air barrier testing requirements must be installed according to the manufacturer's instructions, and a HERS Rater shall verify the integrity of the installation. Below are example materials meeting the air permeance testing performance levels of 1 above. Manufacturers of these and other product types must provide a specification or product data sheet showing compliance to the ASTM testing requirements to be considered as an air barrier.</p> <ul style="list-style-type: none"> • Plywood – minimum 3/8 inch • Oriented strand board – minimum. 3/8 inches • Extruded polystyrene insulation board – minimum. ½ inch • Foil-back polyisocyanurate insulation board – minimum. ½ inch • Foil backed urethane foam insulation (1 inch) <p>-- Closed-cell spray polyurethane foam (ccSPF) with a minimum density of 2.0 pcf and a minimum thickness of 2.0 inches. Alternatively, ccSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m² at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.</p> <p>-- Open cell spray polyurethane (ocSPF) foam with a minimum density of 0.4 to1.5 pcf and a minimum thickness of 5½ inches. Alternatively, ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m² at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.</p> <ul style="list-style-type: none"> • Exterior or interior gypsum board - minimum 1/2 inch • Cement board - minimum 1/2 inch • Built-up roofing membrane • Modified bituminous roof membrane • Particleboard-minimum 1/2 inch • Fully adhered single-ply roof membrane • Portland cement/sand parge ,or gypsum plaster minimum 5/8 inch • Cast-in-place and precast concrete. • Fully grouted uninsulated and insulated concrete block masonry • Sheet steel or aluminum
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C. Reduced Building Air Leakage

RA3.8

An energy credit is allowed through the performance approach when the rate of envelope air leakage of the building is less than the air leakage rate assumed for the standard design building. A third-party HERS Rater shall verify the air leakage rate shown on compliance documentation through diagnostic testing of the air leakage of the building.

The air leakage testing (blower door) involves closing all the windows and doors; pressurizing the house with a special fan, usually positioned in a doorway (see Figure 3-48); and measuring the leakage rate, measured in cubic feet per minute at a 50 Pa pressure difference (CFM50). This measurement procedure is described in the RA3.8. It is derived from the Residential Energy Services Network's (RESNET) Mortgage Industry National Home Energy Rating Standards, Standard 800, which is based on ASTM E779 air-tightness measurement protocols. This procedure requires the use of software consistent with ASTM E779. This test method is intended to produce a measure of the air tightness of a building envelope for determining the energy credit allowance for reduced building air leakage. Further explanations are described below:

1. This procedure shall be used only to verify the building air leakage rate before the building construction permit is finalized when an energy credit for reduced air leakage is being claimed on compliance documentation.
2. The Home Energy Rating System (HERS) Rater shall measure the building air leakage rate to ensure measured air leakage is less than or equal to the building air leakage rate stated on the certificate of compliance and all other required compliance documentation. HERS-verified building air leakage shall be documented on compliance forms.
3. This is a whole-building credit; therefore, no credit is allowed for the installation of individual envelope measures that may help in reducing the air leakage rate of the building's, such as for an exterior air retarding wrap, or for an air barrier material or assembly meeting the requirements describe in Table 3-8 above.

Figure 3-48: Blower Door Testing

Source: California Energy Commission

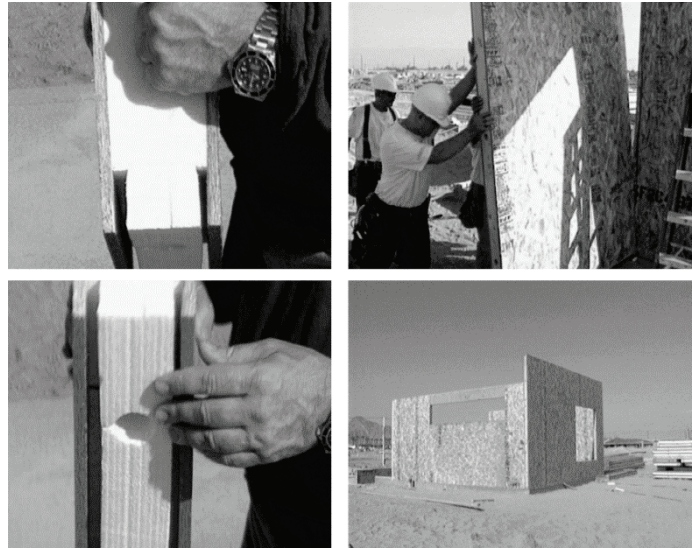
D. Structural Insulated Panels (SIPS)

RA3.5.7

Structural insulated panels (SIPS) are a nonframed advanced construction system that consists of rigid foam insulation sandwiched between two sheets of board. The board can be sheet metal, plywood, cement, or oriented strand board (OSB), and the foam can be expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane, or polyisocyanurate (polyiso) foam. SIPS combine several components of conventional building, such as studs and joists, insulation, vapor barrier, and air barrier. They can be used for many different applications, such as exterior walls, roofs, floors, and foundation systems. Little or no structural framing penetrates the insulation layer. Panels are typically manufactured at a factory and shipped to the job site in assemblies that can be as large as 8 ft by 24 ft.

In the field, the SIPS panels are joined in one of three ways: (1) single or double 2x splines, (2) I-joists, or (3) with OSB splines. The choice of these options affects thermal performance and structural capacity. The 2x and I-joist spline types fit in a recess of the foam core, between the two layers of plywood or OSB. JA4, Table 4.2.3 contains U-factors for roof/ceiling assemblies, JA4 Table 4.3.2 has U-factors for SIPS wall assemblies and JA4 Table 4.4.3 has U-factors for SIPS floor constructions. U-factors used for compliance must be taken from these tables or by using approved performance compliance software.

Figure 3-49: Methods of Joining SIPS Panels



Source: California Energy Commission

E. Insulating Concrete Forms (ICF)

RA3.5.8

Insulating concrete forms (ICFs) is a system of formwork for concrete that stays in place as permanent building insulation is used for cast-in-place, reinforced above- and below-grade concrete walls, floors, and roofs. ICFs are interlocking modular units that can be dry-stacked (without mortar) and filled with concrete as a single concrete masonry unit (CMU). ICFs lock together externally and have internal metal or plastic ties to hold the outer layer(s) of insulation to create a concrete form for the structural walls, roof/ceilings, or floors of a building. ICFs are manufactured from several materials, including expanded and extruded polystyrene foam, polyurethane foam, cement-bonded wood fiber, and cement-bonded polystyrene beads.

Three factors contribute to the energy efficiency of buildings using an ICF wall:

1. Continuous rigid insulation on both sides of a high-mass core,
2. Elimination of thermal bridging from wood framing components, and
3. A high degree of air-tightness inherent to this method of construction.

Climate zones with large daily temperature fluctuations have the greatest potential to benefit from the time lag and temperature dampening effects of these high-mass envelope systems. However, this combination of mass and insulation is beneficial in almost all climates, with the possible exception of mild coastal climate zones.

There are three basic types of ICFs: flat wall, waffle-grid and screen-grid. A flat wall ICF results in a wall with a consistent and continuous thickness of concrete. A waffle-grid ICF creates a concrete waffle pattern, an uninterrupted grid, with some concrete sections thicker than others. A screen-grid ICF consists of a discrete post-and-beam structure with the concrete completely encapsulated by the foam insulation, except at the intersection of posts and beams. The insulating panels for all three ICF types are most commonly made from expanded polystyrene (EPS) and extruded polystyrene (XPS) rigid insulation boards. Insulating panels are also made from polyurethane, composites of cement and EPS, and

composites of cement and shredded wood fiber, although these tend to be proprietary materials developed by the ICF manufacturer.

Plastic or metal cross-ties, consisting of two flanges and a web, separate the insulating panels and provide structural integrity during the pouring of concrete, resulting in a uniform wall thickness. A variety of wall thicknesses can be obtained by changing the length of the web. The area of attachment of the cross-ties to the insulating form provides a secure connection surface located at standard spacings for mechanical attachment of finished materials to the interior and exterior of the wall. ICFs can be used to construct load-bearing and nonload-bearing walls and above- and below-grade walls, and can be designed to structurally perform in any seismic zone.

The ICF system is modular and stackable with interlocking edges. The materials can be delivered as preassembled blocks or as planks that require the flanges and web to be assembled during construction. The forms vary in height from 12" - 24" and are either 4' or 8' long. Vertical panels come in similar modules but are stacked vertically. ICF panels are typically available with core thickness ranging from 4" to 12".

The thermal aspects of ICFs are represented in the JA4, Table 4.3.13.

3.7 More Information on Insulation and Assemblies

The Energy Commission encourages the use of energy-saving techniques and designs for showing compliance with the standards. Many standard products with traditional construction practices can be used in ways that improve building efficiency beyond requirements set by the standards. In addition, innovative construction techniques and building products are being used more often by designers and builders who recognize the value of energy-efficient, high-performance buildings. When the performance compliance method is used, an energy credit can be taken for design strategies that reduce building energy use below the standard design energy budget (compliance credit). Some strategies may require third-party verification by a HERS Rater, others do not.

3.7.1 Insulation Installation in Framed Assemblies

Insulation is one of the least expensive measures to improve building energy efficiency. Insulation requires no maintenance, helps improve indoor comfort, and provides excellent sound control. Adding extra insulation at a later time is much more expensive than maximizing insulation levels at the beginning of construction. General insulation types are discussed below.

Documentation of insulation R-values and assembly U-factors includes product data sheets, manufacturer specifications and installation guidelines, insulation product and assembly testing information, and U-factor calculations following the procedures specified in JA4 or from results of approved performance compliance computer software. The third-party HERS Rater shall verify that all insulation has been installed properly and is integral with the air barrier being used throughout the building.

There are four basic types of insulation, or insulation "systems," installed in residential buildings and the use varies based on the design and type of construction:

1. **Batt and Blanket:** Batt and blanket insulation is made of mineral fiber and mineral wool – either processed fiberglass, rock, or slag wool; natural wool products—animal wool or cotton-based products; or cellulose materials. These products are used to insulate below floors, above ceilings, below roofs, and within walls. They offer ease of installation with R-values set by the manufacturer based on size and thickness. They

are available with facings, some as vapor retarders, and have flanges to aid in installation to framed assemblies. They also are available as unfaced material and can be easily friction-fitted into framed cavities.

Batt and blanket insulation allow easy inspection, and installation errors can readily be identified and remedied, including breeches in the air barrier system that allow air leakage. Nevertheless, care should always be taken to install the insulation properly, filling the entire cavity, and butting ends or sides of the batt material to ensure uniformity of the installation. Batt and blanket insulation material must be split to allow for wiring, plumbing, and other penetrations within the framed cavity.

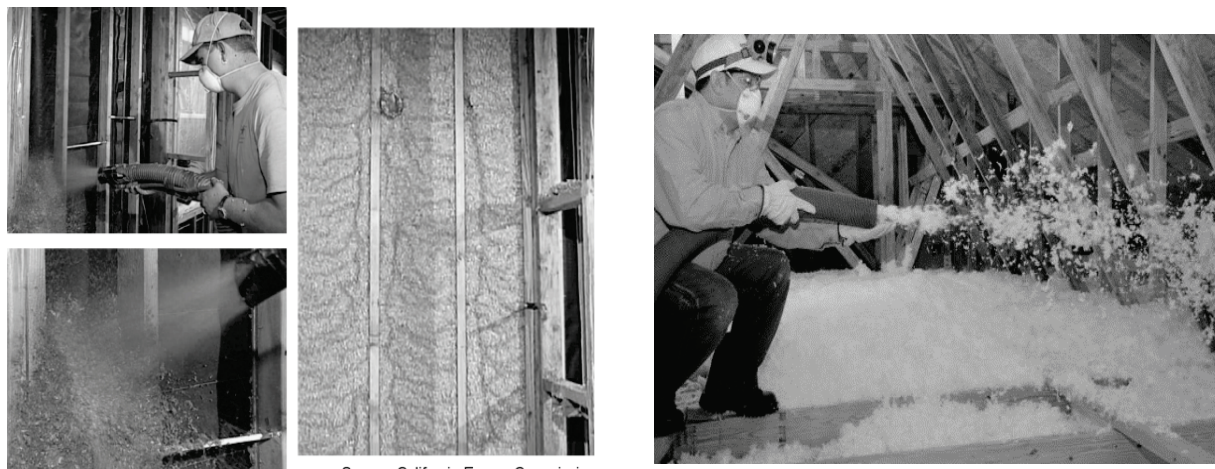
- 2. Loose-Fill Insulation:** There are several commonly used types of insulation that have a pneumatic or blown installation process, including cellulose, fiberglass, and natural wool (animal- or cotton-based products). Blown wall insulation can be an effective way to deal with the irregularities of wall cavities, especially the spaces around pipes, electric cables, junction boxes, and other equipment that is embedded in cavities. (See Figure 3-50A.) The R-value of blown wall insulation material installed in closed cavities is determined by the installed thickness. This differs from manufactured products such as fiberglass or mineral wool batts for which the R-value has been tested and arrives at the construction site in preformed lengths and thicknesses with set R-value thicknesses.

When installed in floors, walls, and other vertical assemblies, these fibrous insulations are held in place in one of three ways:

1. Pre-installed netting or fabric
2. Use of existing cavity walls
3. Use of integral adhesives

Blown wall insulation installed in closed cavities must be thoroughly checked for density (or coverage) to ensure the R-value is achieved. A line of sight down a wall section can deceptively hide imperfections in the installation, leading to underachieving stated R-values. Depressions and voids within the insulated cavity are areas lacking in R-value performance. Where netting is used, overspraying can result in a higher installed density (higher R-value) but can be troublesome for attaching gypsum board to wall framing. Where cavities have been underfilled, there may be voids or “soft” areas under the netting. These areas are often refilled, or the area is removed of insulation material, and a thermal batt is installed in its place.

When installed in open surfaces, such as an attic floor or open wall, no netting or preexisting wall cladding is needed. (See Figure 3-50B.) In open horizontal applications, such as attic floors, no adhesives are used, and the R-value is verified by thickness and rated coverage. In open vertical applications, integral adhesives are used to hold the fibers in place. Water-activated adhesives are used for moist-spray cellulose, and polymer adhesives are used for fiberglass loose-fill applications. The adhesive causes the insulation to adhere to itself and stick to surfaces of the wall cavity. Excess insulation that extends past the wall cavity is scraped off and recycled. R-value depends on the installed density of the material at the building site, and the building official should ensure that the installed density meets manufacturer specifications.

Figure 3-50A (left): Cellulose-Insulated Wall and Figure 3-50B (right): Attic Floor

Source: California Energy Commission

3. **Spray Polyurethane Foam (SPF):** SPF is a two-part, liquid-foamed thermoset plastic (such as polyurethane). Polyurethane is formed by the reaction of an isocyanate and a polyol. Blowing agents, catalysts, and surfactants are added to develop a cellular structure before the polyurethane mixtures cures. When this mixture is applied to substrate materials, the SPF material forms in place to provide insulation, an air seal, and, in the case of closed-cell SPF, an integral vapor retarder and water barrier.

SPF insulation is a two-component reactive system mixed at a spray gun or a single-component system that cures by exposure to humidity. The liquid is sprayed through a nozzle into the wall, roof/ceiling, and floor cavities. SPF insulation can be formulated to have specific physical properties (such as density, compressive strength, fire resistance, and R-value).

SPF insulation is spray-applied to adhere fully to the joist and other framing faces to form a complete air seal within the construction cavities. SPF must be separated from the interior of the building, even attic spaces, by an approved thermal barrier consisting of ½-inch (12.7 mm) gypsum wallboard or equivalent thermal barrier material (Section 316.4, CBC).

There are two types of SPF insulation:

- a. **Low-Density Open-Cell SPF (ocSPF) Insulation:** A spray-applied polyurethane foam insulation having an open cellular structure resulting in an installed nominal density of 0.4 to 1.5 pounds per cubic foot (pcf), ocSPF has been assigned a default R-value of 3.6 per inch for compliance purposes, but some products can achieve higher R-values. The ocSPF insulation is sprayed then expands to fill the framed cavity. (See Figure 3-51.) Excess insulation is removed with a special tool. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation surface shall not be greater than 1 inch of the required thickness, provided these depressions do not exceed 10 percent of the surface area being insulated. The ocSPF must fill the cavity of 2x4 framing to achieve R-13.

Figure 3-51: Open-Cell SPF Installed in Wall Cavity (may be trimmed to facilitate interior cladding installation)



Source: SPFA

b. Medium-Density Closed-Cell SPF (ccSPF) Insulation: A spray-applied polyurethane foam insulation having a closed cellular structure resulting in an installed nominal density of greater than 1.5 to less than 2.5 pounds per cubic foot (pcf), ccSPF has been assigned a default R-value of 5.8 per inch for compliance, but some products can achieve higher R-values. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the surface of the foam insulation shall not be greater than ½-inch of the required thickness at any given point of the surface area being insulated. CcSPF is not required to fill the cavity. (See Figure 3-52.)

SPF R-value depends on the installed thickness, and the building official should ensure the thickness and uniformity of the SPF material within each cavity of framed assemblies meets manufacturer specifications. Default R-values assigned to SPF are shown in Table 3-9.

Table 3-9: Required Thickness of SPF Insulation to Achieve Default R-values

Thickness of SPF Insulation	R11	R13	R15	R19	R21	R22	R25	R30	R38
Required thickness of ccSPF Insulation (inches)	2.00	2.25	2.75	3.50	3.75	4.00	4.50	5.25	6.75
Required thickness of ocSPF Insulation (inches)	3.00	3.50	4.20	5.30	5.80	6.10	6.90	8.30	10.6

Alternatively, the total R-value may be calculated based on the thickness of insulation multiplied by the "tested R-value per inch" as listed in the Table of R-values or R-value Chart from the manufacturer's current ICC Evaluation Service Report (ESR) that shows compliance with *Acceptance Criteria for Spray-Applied Foam Plastic Insulation--AC377*. Overall assembly U-factors are determined by selecting the assembly type, framing configuration, and cavity insulation rating from the appropriate JA4 table, other approved method specified in JA4, or using the Energy Commission-approved compliance simulation software.

Figure 3-52: Closed-Cell SPF Installation in a Wall Cavity (full-fill not needed; thickness installed to achieve R-value only)



Source: SPFA

4. **Rigid Insulation:** Rigid board insulation sheathing is made from fiberglass, expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate (ISO), or polyurethane. It varies in thickness, and some products can provide up to R-6 per inch of thickness.

This type of insulation is used for above-roof decks, exterior walls, cathedral ceilings, basement walls, as perimeter insulation at concrete slab edges, and to insulate special framing situations such as window and door headers, and around metal seismic bracing. Rigid board insulation may also be integral to exterior siding materials. Properly sealed rigid insulation can be used continuously across an envelope surface to reduce air infiltration and exfiltration, and thermal bridging at framing.

The Department of Energy Building America website contains regularly updated information on proper continuous rigid insulation installation, including recommendations for button cap nails, furring strips, flashing, and design of the drainage plane. An image showing proper rigid insulation installation is shown in Figure 3-53.

Figure 3-53: Properly Installed Rigid Insulation With Sealant Tape



Source: U.S. Environmental Protection Agency

The 2015 California Residential Code (CRC) provides guidance on fastener penetration depth, diameter, and spacing for exterior foam sheathing in Section R703.11.2. CRC Table 703.15.1 , reproduced below in Figure 3-54, shows the fastener spacing for cladding attachment over foam sheathing to wood framing.

Figure 3-54: Fastening Requirements Over Foam Sheathing

TABLE R703.15.1
CLADDING MINIMUM FASTENING REQUIREMENTS FOR DIRECT ATTACHMENT
OVER FOAM PLASTIC SHEATHING TO SUPPORT CLADDING WEIGHT^a

CLADDING FASTENER THROUGH FOAM SHEATHING	CLADDING FASTENER TYPE AND MINIMUM SIZE ^b	CLADDING FASTENER VERTICAL SPACING (inches)	MAXIMUM THICKNESS OF FOAM SHEATHING ^c (inches)					
			16" o.c. Fastener Horizontal Spacing			24" o.c. Fastener Horizontal Spacing		
			Cladding Weight:			Cladding Weight:		
			3 psf	11 psf	25 psf	3 psf	11 psf	25 psf
Wood Framing (minimum 1 1/4-inch penetration)	0.113" diameter nail	6	2	1	DR	2	0.75	DR
		8	2	1	DR	2	0.5	DR
		12	2	0.5	DR	2	DR	DR
	0.120" diameter nail	6	3	1.5	0.5	3	0.75	DR
		8	3	1	DR	3	0.5	DR
		12	3	0.5	DR	2	DR	DR
	0.131" diameter nail	6	4	2	0.75	4	1	DR
		8	4	1.5	0.5	4	0.75	DR
		12	4	0.75	DR	2	0.5	DR
	0.162" diameter nail	6	4	4	1.5	4	2	1
		8	4	3	1	4	1.5	0.75
		12	4	2	0.75	4	1	DR

For SI: 1 inch = 25.4 mm, 1 pound per square foot = 0.0479 kPa, 1 pound per square inch = 6.895 kPa.

DR = Design required.

o.c. = On center.

- a. Wood framing shall be Spruce-pine-fir or any wood species with a specific gravity of 0.42 or greater in accordance with AWC NDS.
- b. Nail fasteners shall comply with ASTM F 1667, except nail length shall be permitted to exceed ASTM F 1667 standard lengths.
- c. Foam sheathing shall have a minimum compressive strength of 15 psi in accordance with ASTM C 578 or ASTM C 1289.

Source: 2015 International Residential Code

3.7.2 Thermal Mass

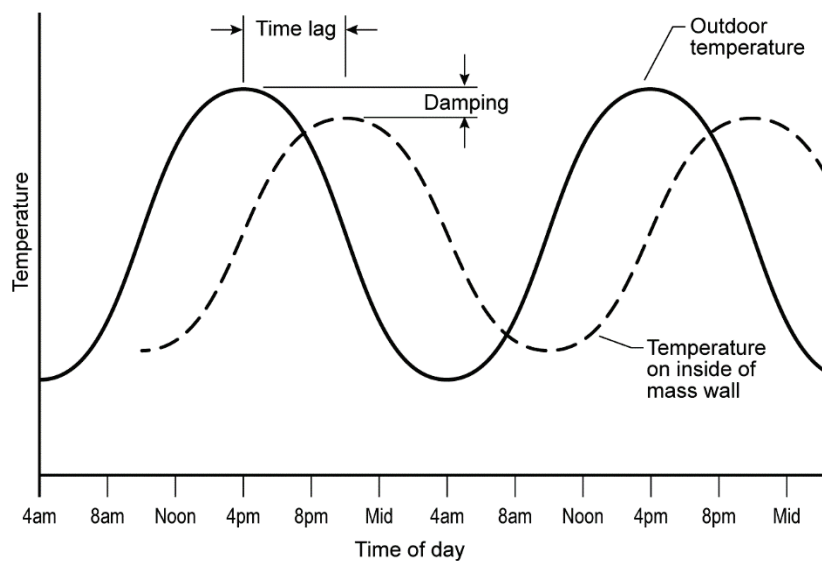
Mass walls typically fall into two categories:

1. Masonry types include clay and concrete units, which may be solid or hollow, and glazed or unglazed. Other masonry unit types include cast stone and calcium silicate units. Concrete masonry units (CMU) are made from a mixture of Portland cement and aggregates under controlled conditions. Concrete masonry units can be manufactured in different sizes and with a variety of face textures.
2. Concrete and concrete sandwich panels typically use a precast form by casting concrete in a reusable mold or "form" that is then cured in a controlled environment, transported to the construction site, and lifted into place. Precast stone is distinguished from precast concrete by using a fine aggregate in the mixture, giving the appearance of naturally occurring rock or stone.

Thermal mass consists of exposed tile floors over concrete, mass walls such as stone or brick, and other heavy elements within the building envelope that stabilizes indoor temperatures. Thermal mass helps temper interior temperature, storing heat or cooling for later use. In California's Central Valley and desert climates, the summer temperature range between night and day can be 30°F or more, and thermal mass can be an effective strategy to reduce daytime cooling loads.

When thermal mass exists in exterior walls, it stabilizes temperatures in two ways. First, there is a time delay between when the outside temperature of the wall reaches its peak and when the inside of the wall reaches its peak. For an 8-inch to 12-inch concrete wall, this time delay is between 6 to 10 hours. Second, there is a dampening effect whereby the temperature range on the inside of the house is less than the temperature range on the outside of the house. These effects are illustrated in the following figure.

Figure 3-55: Thermal Mass Performance



Source: California Energy Commission

When the performance method is used, credit is offered for increasing thermal mass in buildings. However, credit for thermal mass in the proposed design may be considered only when the proposed design qualifies as a high mass building. A *high-mass building* is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15 percent of the conditioned non-slab floor exposed with the equivalent of 2 inch-(50 mm)

thick concrete. This procedure is automated in Energy Commission-approved computer compliance software.

3.7.3 Alternative Construction Assemblies

A. Log Homes

Log walls are typically made from trees that have been cut into logs that have not been milled into conventional lumber. Logs used for walls, roofs, and/or floor systems may be milled and/ or laminated by the manufacturer or supplier to meet specific dimensions and fitting and finishing conditions.

Log homes are an alternative construction type used in some parts of the state. Log home companies promote the aesthetic qualities of solid wood construction and can "package" the logs and deliver them directly to a building site. Some companies provide log wall, roof, and floor systems with special insulating "channels" or other techniques to minimize the effect of air infiltration between log members and to increase the thermal benefit of the logs.

Log walls do not have framing members like conventional wood stud walls. Therefore, the mandatory requirement for a minimum of R-13 wall insulation does not apply.

Otherwise, in prescriptive compliance, log walls must meet the same thermal requirements as other construction types. For performance compliance, consult the compliance software vendor's documentation for any unique modeling requirements for mass walls using values from the reference appendices (RA). In prescriptive compliance, the walls will qualify as either light mass or heavy mass walls, depending on the thickness – remember a heat capacity (HC) of 8.0 Btu/°F-ft² is equivalent to a heavy mass wall (40 lb/ft³). The prescriptive requirements for heavy mass walls are less stringent than the criteria for wood-framed walls. Reduced insulation is allowed because the effects of the thermal mass (interior and exterior) can compensate for less insulation.

The thermal performance of log walls is shown in JA4, Table 4.3.11. The U-factor ranges from 0.133 for a 6-inch wall to 0.053 for a 16-inch wall. The U-factor of an 8-inch wall is 0.102, which complies with the R-13 prescriptive requirements. U-factors for other log wall constructions (not shown in JA4) would have to be approved by the Energy Commission through the exceptional methods process.

Log walls have a heat capacity that exceeds conventional construction. JA4, Table 4.3.11 (Thermal Properties of Log Home Walls) shows that a 6-inch wall has an HC of 4.04, which increases to 10.77 for a 16-inch wall. The thermal mass effects of log home construction can be accounted for within the performance approach.

Air infiltration between log walls can be considerably different among manufacturers depending upon the construction technique used. For compliance, infiltration is always assumed to be equivalent to a wood-frame building. However, the builder should consider using a blower door test to find and seal leaks through the exterior walls.

B. Straw Bale

Straw bale construction is a building method that uses bales of straw (commonly wheat, rice, rye, and oat straw) as structural and insulating elements of the building. Straw bale construction is regulated within the CBC, and specific guidelines are established for moisture content, bale density, seismic bracing, weather protection, and other structural requirements.

The Energy Commission has determined specific thermal properties for straw bale walls and thermal mass benefits associated with this type of construction. The performance compliance approach can be used to model the heat capacity characteristics of straw bales.

Straw bales that are 22 inch by 16 inch are assumed to have a thermal resistance of R-30, whether stacked so the walls are 23 inch wide or 16 inch wide. The minimum density of load bearing walls is 7.0 lb/ft³, and this value or the actual density may be used for modeling straw bale walls in the performance approach. Specific heat is set to 0.32 Btu/lb-°F. Volumetric heat capacity (used in some computer programs) is calculated as density times specific heat. At a density of 7 lb/ft³, for example, the volumetric heat capacity is 2.24 Btu/ft³-°F.

The minimum dimension of the straw bales when placed in the walls must be 22 inches by 16 inches, and there are no restrictions on how the bales are stacked. Due to the higher resistance to heat flow across the grain of the straw, a bale laid on edge with a nominal 16-inch horizontal thickness has the same R-Value (R-30) as a bale laid flat.

The nature of straw bale construction provides an effective air barrier. For compliance, infiltration is assumed to be equivalent to framed walls.

3.8 Compliance and Enforcement

For buildings in which the certificate of compliance (CF1R) requires HERS field verification for compliance with the Energy Standards, a HERS Rater must visit the site to perform field verification and diagnostic testing to complete the applicable envelope portions of a certificate of field verification and diagnostic testing (CF3R).

The following measures require field verification and diagnostic testing if they are used in the proposed design for compliance, and are listed on the CF1R as special features requiring HERS Rater verification:

1. Building Envelope Sealing
2. Quality Insulation Installation (QII)

Field verification is necessary only when credit is taken for the measure. For example, building envelope sealing need only be HERS-verified if building envelope sealing was used to achieve credit in the proposed design.

Registration of the CF3R is required. The HERS Rater must submit the CF3R information to the HERS provider data registry as described in Chapter 2. For additional detail describing HERS verification and the registration procedure, refer to RA2.

3.8.1 Design

The initial compliance documentation consists of the certificate of compliance (CF1R). MF1R is no longer a checklist, but a statement of the mandatory features that must be included with the CF1R forms. The mandatory features are also included in the CF2R forms. The CF1R must be filed on the plans and specifications. Included on the CF1R is a section where special envelope features are listed. The following are envelope features that should be listed in this section if they exist in the proposed design:

1. Interzone ventilation
2. Radiant barriers
3. Multiple orientation
4. Controlled ventilation crawlspace

5. Nonstandard ventilation height differences
6. Standard-free ventilation area greater than 10 percent of the window area
7. Metal-framed walls
8. Sunspace with interzone surfaces
9. Roofing products (Cool roof)
10. Air-retarding wrap

Plan checkers should verify that insulation levels, fenestration U-factors, and SHGCs listed on the CF1R are consistent with the plans and specifications.

If registration of the CF1R is required (see Chapter 2 for requirements), the building owner or the person responsible for the design must submit the CF1R to the HERS Provider data registry for retention following the procedures described in Chapter 2 and in RA2.

3.8.2 Construction

During construction, the contractor and/or the subcontractors shall complete the necessary sections of the certificate of installation (CF2R):

1. Fenestration/Glazing. The glazing contractor lists all the fenestration products that are installed in the building, along with the model number, the manufacturer number, the U-factor, and the SHGC. The installer should ensure that the dynamic glazing controls are functional with energy management systems or similar.
2. Building Envelope Leakage Diagnostics. This is applicable only if the builder/contractor does blower door testing to reduce building envelope leakage.
3. Insulation Installation Quality Certificate. The insulation contractor documents the insulation installation quality features that have been followed as shown on the CF2R checklist.
4. Description of Insulation. The insulation contractor documents the insulation materials installed in the walls, roofs, and floors, along with the brand name of the materials and the thermal resistance.

The building official (field inspector) will visit the site multiple times during construction. These visits verify that the equipment and materials installed are consistent with the plans and specifications.

If registration of the CF2R is required, the licensed person responsible for the installation must submit the portion of the CF2R information that applies to the installation to a HERS Provider data registry using procedures described in Chapter 2 and in RA2.

3.9 References

JA1 contains a glossary of terms. The following terms either expands on those listed in the reference appendices or are provided here to better clarify compliance issues for the building envelope.

3.9.1 Building Orientation

Orientation of the building, particularly walls and fenestration, can affect energy use. Orientation is also critical for sizing and installing renewable energy sources, such as solar thermal collectors for domestic water heating and solar electric collectors to help offset electrical demand.

- A. **East-Facing** – "East-facing is oriented to within 45 degrees of true east, including 45°0'0" south of east (SE), but excluding 45°0'0" north of east (NE)." [§100.1] The designation "east-facing" is also used in production buildings using orientation restrictions (for example, shaded areas: east-facing).
- B. **North-Facing** "North-facing is oriented to within 45 degrees of true north, including 45°0'0" east of north (NE), but excluding 45°0'0" west of north (NW)." [§100.1]
- C. **South-Facing** – "South-facing is oriented to within 45 degrees of true south, including 45°0'0" west of south (SW), but excluding 45°0'0" east of south (SE)." [§100.1] The designation "South-Facing" is also used in production buildings using orientation restrictions (e.g., Shaded Areas: East-Facing).
- D. **West-Facing** - "West-facing is oriented to within 45 degrees of true west, including 45°0'0" due north of west (NW) but excluding 45°0'0" south of west (SW)." [§100.1]. The designation "West-Facing" is also used in production buildings using orientation restrictions (for example, shaded areas: west-facing).

3.9.2 Fenestration Terminology

The following terms are used in describing fenestration products:

- 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 with an IG unit with an SHGC of 0.5 or greater.
- C. **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.
- D. **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 (for example, electrochromic) and passive materials (for example, photochromic and thermochromic) permanently integrated into the glazing assembly. Electro-chromatic 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 have the ability to reversibly change their performance properties, including U-factor, SHGC, and/or VT between well-defined end points.

Integrated shading systems is 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.

- E. **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.
- F. **Fixed glass.** The fenestration product cannot be opened.
- G. **Gap Width.** The distance between glazings 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.

H. **Grille.** See Divider.

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

J. **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.

K. **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.

L. **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.

In the residential market, 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. This is a major advantage for homeowners and can be a selling point for builders.

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

N. **Muntin.** See Dividers.

O. **National Fenestration Rating Council** is the entity recognized by the Energy Commission to supervise the rating and labeling of fenestration products. NFRC lists the Certified Product Directory, containing NFRC certified U-factors, SHGC and VT values for thousands of residential fenestration products see <http://www.nfrc.org>

Fenestration product performance data used in compliance calculations must be provided through the NFRC rating program and must be labeled by the manufacturer with the rated U-factor, SHGC and VT in accordance with §10-111 procedures.

Estimating the rate of heat transfer through a fenestration product is complicated by the variety of frame configurations for operable windows, the different combinations of materials used for sashes and frames, and the difference in sizes available in various applications. The NFRC rating system makes the differences uniform, so that an entire

fenestration product line is assumed to have only one typical size. The NFRC rated U-factor may be obtained from a directory of certified fenestration products, directly from a manufacturer's listing in product literature, or from the product label.

- P. **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.
- Q. **Operable.** The fenestration product can be opened for ventilation.
- R. **R-value.** A measure of a material's thermal resistance, expressed in $\text{ft}^2(\text{hr})^\circ\text{F}/\text{Btu}$. R-value is the inverse of U-factor. A higher R-value and lower U-factor indicate higher energy efficiency.

The rated R-value of fiberglass (batt) insulation is based upon its fully expanded thickness and may be obtained from the Reference Joint Appendices JA4, Table 4.6.2 or from the manufacturer's literature. When the insulation is compressed, the R-value is reduced. The most common insulation compression occurs with R-19 and R-22 insulation batts installed in locations with a nominal 6-inch framing that is actually only 5.5 in. thick. To achieve its rated insulation value, an R-19 batt of insulation expands to a thickness of six and one quarter inches. If it is compressed into 2x6 framing with an actual depth of 5.5 inches, the insulation R-Value is lowered to 17.8.

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

- U. **Spacer or Gap Space.** A material that separates multiple panes of glass in an insulating glass unit.
- V. **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.
- W. **Tinted.** Darker gray, brown or green visible tint. Also, low-e or IG unit with a VT less than 0.5.
- X. **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 ft^2 of window area per degree $^\circ\text{F}$ of temperature difference ($\text{Btu}/\text{hr}\text{-ft}^2\text{-}^\circ\text{F}$). 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.

- Y. **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.
- Z. **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.

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4. Building HVAC Requirements

4.1 Overview

4.1.1 Introduction and Organization

This chapter addresses the requirements for heating, ventilating, and air-conditioning (HVAC) systems. The requirements are presented in this chapter to serve as a source of information for mechanical system designers and mechanical system installers, as well as energy consultants, HERS Raters, and enforcement personnel.

Each section in this chapter outlines the mandatory measures and, when applicable, the prescriptive requirements or compliance options. These prescriptive requirements vary by climate zone. If the building design does not achieve the minimum prescriptive requirements, then the compliance options may be used under the performance approach to achieve compliance.

The chapter is organized under the following sections:

1. **Section 4.2** - Heating Equipment. This section addresses the requirements for heating equipment, including mandatory measures, prescriptive requirements, and compliance options.
2. **Section 4.3** - Cooling Equipment. This section addresses cooling equipment requirements, including mandatory measures, prescriptive requirements, and compliance options.
3. **Section 4.4** - Air Distribution System Ducts, Plenums, and Fans. This section covers mandatory requirements such as duct insulation, duct system construction practices, and duct diagnostic testing. This section also covers prescriptive requirements for duct location and duct insulation, and specifications for access holes in the supply and return plenums.
4. **Section 4.5** - Controls. This section addresses mandatory requirements for thermostats and the compliance option for zonal controls.
5. **Section 4.6**, Indoor Air Quality and Mechanical Ventilation. This section covers mandatory requirements for indoor air quality, including mechanical ventilation.
6. **Section 4.7** - Alternative Systems. This section covers several systems that are less common in California homes, including hydronic heating, radiant floor systems, evaporative cooling, gas cooling, ground-source heat pumps, and wood space heating.
7. **Section 4.8** - Compliance and Enforcement. In this section the documentation requirements at each phase of the project are highlighted.
8. **Section 4.9** - Refrigerant Charge. This section addresses the requirements for refrigerant charge verification including procedures, prescriptive requirements and compliance option

Chapter 9 covers the heating and cooling requirements for additions to existing dwellings and for alterations to existing heating and cooling systems.

4.1.2 What's New for the 2016 Energy Standards

The following is a summary of the new HVAC measures for the *2016 Building Energy Efficiency Standards* (Energy Standards), including new compliance options that provide greater flexibility in complying with the Energy Standards when using the performance method. See sections of this manual for more detail.

4.1.2.1 Mandatory Features and Devices - §150.0

1. Liquid line filter driers are required to be installed on all air-conditioning condensers, as specified by the manufacturer (§150.0(h)3).
2. There are some changes to the tables specifying mandatory minimum insulation on air-conditioning refrigerant lines (§150.0(j)2C).
3. There are some changes to the mandatory insulation protection for insulated pipes found outside conditioned space (§150.0(j)3).
4. The term *directly conditioned space* was replaced with *conditioned space* to capture ducts located in indirectly conditioned spaces. The mandatory minimum R-value for duct located in conditioned spaces is now R-4.2 (§150.0(m)1).
5. Duct sealing and leakage testing for single-family dwellings and townhouses has a new target for total duct leakage, which has been reduced to 5 percent total leakage (§150.0(m)11).
6. There are new mandatory requirements for filtration of all air passing through a ducted space-conditioning system. The requirements affect the pressure drop and labeling of the filtration devices (§150.0(m)12C).

4.1.2.2 Prescriptive and Performance Compliance Approaches – §150.1

1. The refrigerant charge requirement was restructured to clearly state that minimum system airflow is required in conjunction with refrigerant charge verification (§150.1(c)7).
2. The exception to 150.1(c)7 for packaged systems was amended to allow the installer to certify that they installed a packaged system that was charged by the manufacturer (§150.1(c)7).
3. New requirements for duct insulation and duct system location depending on the location of ceiling or roof insulation were added. (§150.1(c)9).
4. The prescriptive requirements for ventilation cooling have been changed. The total airflow requirement was reduced from 2 CFM/ft² to 1.5 and the vent-free area was reduced from 1 ft²/375 CFM to 1 ft²/750 CFM (§150.1(c)12).

4.1.2.3 Additions and Alterations – §150.2

The Energy Standards requirements for HVAC systems in homes that are altered or added to are summarized and discussed in Chapter 9.

4.1.3 Common System Types

New California homes in the Central Valley and the desert typically have a gas furnace and split-system air conditioner that distributes heating and cooling to each room through forced air ducts. Most mandatory measures and prescriptive requirements are based on this type of system. In some areas, a heat pump provides both heating and cooling, eliminating the

furnace. In coastal climates and in the mountains, air conditioning is rare, and most new homes are heated by gas furnaces.

Although the Energy Standards focus on the typical system, they also apply to other systems as well, including some radiant hydronic systems. These hydronic systems distribute hot water to parts of the home to provide heating to the conditioned spaces.

Electric resistance systems are used in some areas and applications, although it is difficult for them to comply under the Standards.

Ground-source or water-source heat pump (geo-exchange) systems are also used, especially in areas where there is no gas service. Unlike more typical air source systems, these systems use water circulated underground or in large ponds or lakes as the heat source (in heating mode) and heat sink (in cooling mode).

While the primary focus of this chapter is typical systems, a Section 4.7 discusses alternative systems.

4.1.4 California Appliance Standards and Equipment Certification

§110.0 and §110.1

Most heating and cooling equipment installed in new California homes is regulated by the National Appliance Efficiency Conservation Act (NAECA) and/or the California *Appliance Efficiency Regulations (Title 20)*. Both the federal and state appliance standards apply to the manufacturing of new equipment and are applicable for equipment used in replacements, repairs, or for any other purpose. The *Appliance Efficiency Regulations* are enforced at the point of sale (except central split system air conditioners and central single package air conditioners, see Table 4-6), while the Energy Standards explained in this compliance manual are enforced by local enforcement agencies.

The following types of equipment (in the list below) are covered by the *Appliance Efficiency Regulations*. For this equipment, the manufacturer must certify that the equipment complies with the current *Appliance Efficiency Regulations* at the time of manufacture.

Appliances covered by the *Appliance Efficiency Regulations* include:

1. Room air conditioners	6. Gas-fired boilers
2. Room air-conditioning heat pumps	7. Gas-fired furnaces
3. Central air conditioners with a cooling capacity of less than 135,000 British thermal units per hour (Btu/hr)	8. Gas-fired floor furnaces
4. Central air conditioning heat pumps	9. Gas-fired room heaters
5. Gas-fired central furnaces	10. Gas-fired duct furnaces
	11. Gas-fired unit heaters

The *Appliance Efficiency Regulations* do not require certification for:

1. Electric resistance space heaters.
2. Oil-fired wall furnaces, floor furnaces, and room heaters. (Some are voluntarily listed with certified gas-fired furnaces.)

Equipment that does not meet the federal appliance efficiency standards may not be sold in California. Any equipment covered by the *Appliance Efficiency Regulations* and sold in California must have the date of manufacture permanently displayed in an accessible place on that equipment. This date is frequently included as part of the serial number.

Note: Equipment manufactured before the effective date of a new standard may be sold and installed in California indefinitely, as long as the performance and prescriptive approach demonstrates energy compliance of the building using the lower efficiency of the relevant appliances. However, the Department of Energy (DOE) requires that central split-system air conditioners and central single package air conditioners *installed* in California on or after January 1, 2015 must comply with the minimum efficiencies as specified in Table 4-6.

The compliance and enforcement processes should ensure that all installed HVAC equipment regulated by the *Appliance Efficiency Regulations* is certified to the California Energy Commission.

4.1.4.1 Plan Review (Compliance)

During the plan review, the builder is responsible for demonstrating compliance with the *Appliance Efficiency Regulations* by providing the efficiency of the HVAC equipment that is to be installed. Typically the builder does not identify the exact make or model at this point of the process. The plans examiner is responsible for verifying that the specified equipment efficiency complies with the *Appliance Efficiency Regulations*.

4.1.4.2 Field Inspection (Enforcement)

It is the responsibility of the field inspector to visually verify that the product information on the installed HVAC equipment matches the efficiency that was approved by the plans examiner. To simplify the inspection, the field inspector may reference the CF2R-MCH-01-H form submitted by the builder/installing contractor. Moreover, the field inspector is responsible for verifying that the installed HVAC equipment is certified to the Energy Commission. The field inspector, at his or her discretion, may require the builder/installing contractor to provide a printout from the Energy Commission Appliance Efficiency Database of certified equipment listing the same make and model that is installed.

If the specifications labeled on the HVAC equipment do not match the equipment specifications on the Energy Commission Appliance Efficiency Database, the inspector is responsible for issuing a correction notice to the builder/installing contractor.

4.2 Heating Equipment

This section addresses the requirements for heating equipment, including furnaces, boilers, heat pumps, and electric resistance equipment.

4.2.1 Mandatory Measures for Heating Equipment

4.2.1.1 Equipment Efficiency

§110.1 and §110.2(a)

The efficiency of most heating equipment is regulated by NAECA (the federal appliance standard) and the California Appliance Efficiency Regulations. These regulations are not contained in the Energy Standards but are published separately. These regulations are referenced in §110.1. The Appliance Efficiency Regulations include definitions for all types of equipment and are regularly updated, which may change the minimum efficiencies of most equipment.

Note: The Appliance Efficiency Regulations that are in effect when the building permit is applied for will determine the minimum efficiency of the appliances identified in the compliance documentation.

The energy efficiency of other equipment is regulated by §110.2(a). Also, see the *Nonresidential Compliance Manual* for more information on larger equipment.

A. Gas and Oil-Fired Furnaces

The Appliance Efficiency Regulations (Title 20) require gas and oil-fired central furnaces with outputs less than 225,000 Btu/hr to be rated according to the associated Annual Fuel Utilization Efficiency (AFUE). Gas and oil-fired central furnaces with outputs greater than or equal to 225,000 Btu/hr are rated according to the respective thermal (or steady-state) efficiency. Refer to Table 4-1 for the applicable efficiency requirements.

Table 4-1: Minimum Efficiency for Gas and Oil-Fired Central Furnaces

Appliance	Rated Input (Btu/hr)	Minimum Efficiency (%)	
		AFUE	Thermal Efficiency
Weatherized gas central furnaces with single phase electrical supply	< 225,000	81	—
Non-weatherized gas central furnaces with single phase electrical supply	< 225,000	80	—
Weatherized oil central furnaces with single phase electrical supply	< 225,000	78	—
Non-weatherized oil central furnaces with single phase electrical supply	< 225,000	83	—
Gas central furnaces	≥ 225,000	—	80
Oil central furnaces	≥ 225,000	—	81

Source: *California Appliance Efficiency Regulations Title-20* - Table E-4 and E-6

Noncentral gas furnaces and space heaters shall be certified to have AFUE values greater than or equal to those listed in Table 4-2.

Table 4-2: Minimum Heating Efficiency for Nonducted, Noncentral, Gas-Fired Heating Equipment

Type	Capacity	AFUE
Wall Furnace (fan type)	≤ 42,000 Btu/h	75%
	> 42,000 Btu/h	76%
Wall Furnace (gravity type)	≤ 27,000 Btu/h	65%
	> 27,000 Btu/h and ≤ 46,000 Btu/h	66%
	> 46,000 Btu/h	67%
Floor Furnace	≤ 37,000 Btu/h	57%
	> 37,000 Btu/h	58%
Room Heater	≤ 20,000 Btu/h	61%
	> 20,000 Btu/h and ≤ 27,000 Btu/h	66%
	> 27,000 Btu/h and ≤ 46,000 Btu/h	67%
	> 46,000 Btu/h	68%

Source: *California Appliance Efficiency Regulations Title 20 - Table E-2*

B. Heat Pumps and Electric Heating

Heat pumps shall be certified to have a HSPF or COP equal to or better than those listed in Table 4-3.

There are no minimum appliance efficiency standards for electric-resistance or electric-radiant heating systems.

C. Gas- and Oil-Fired Central Boilers and Electric Boilers

Gas- and oil-fired central boilers shall be certified to have an AFUE or *Combustion Efficiency* equal to or better than those listed in

Table 4-3: Minimum Heating Efficiency for Heat Pumps

Equipment Type	Reference	Configuration/Size	Minimum Heating Efficiency
Packaged terminal heat pumps (heating mode)	Table 110.2 E	Newly constructed or newly conditioned buildings or additions	$3.7 - (0.052 \times \text{Cap}^{1/1000}) = \text{COP}$
Packaged terminal heat pumps (heating mode)	Table 110.2 E	Replacements	$2.9 - (0.026 \times \text{Cap}^{1/1000}) = \text{COP}$
Single-phase air source heat pumps (NAECA)	Table C-2	< 65,000 Btu/h cooling	Packaged 8.0 HSPF Split 8.2 HSPF
		Space constrained < 65,000 Btu/h cooling capacity	Packaged 7.4 HSPF Split 7.4 HSPF
		Small-duct, high-velocity < 65,000 Btu/h cooling capacity	7.7 HSPF
Three-phase air source heat pumps	Table C-3	< 65,000 Btu/h	Packaged 7.7 HSPF Split 7.7 HSPF
		≥ 65,000 and <135,000	3.3 COP
		≥ 135,000 and <240,000	3.2 COP
		≥ 240,000 and <760,000	3.2 COP
Water-source heat pumps	Table C-4	≥ 65,000 and < 135,000 Btu/h	4.2 COP
		≥ 135,000 Btu/h, < 240,000 Btu/h	2.9 COP
Single package vertical heat pumps	Table C-5	< 65,000 single-phase	3.0 COP
		< 65,000 3-Phase	3.0 COP
		≥ 65,000 and < 135,000	3.0 COP
		≥ 135,000 and < 240,000	2.9 COP

1. Cap = Cooling Capacity

Source: California Appliance Efficiency Regulation Title 20 and Energy Efficiency Standards

Table 4-4: Minimum Efficiency for Gas- and Oil-Fired Central Boilers

Appliance	Rated Input (Btu/hr)	Minimum Efficiency (%)	
		Thermal Efficiency	Combustion Efficiency
Gas steam boilers with single-phase electrical supply	< 300,000	80 ¹	AFUE
Gas hot water boilers with single-phase electrical supply	< 300,000	82 ^{1,2}	AFUE
Oil steam boilers with single-phase electrical supply	< 300,000	82	AFUE
Oil hot water boilers with single-phase electrical supply	< 300,000	84 ²	AFUE
Electric steam residential boilers	< 300,000	—	—
Electric hot water residential boilers	< 300,000	—	—
All other boilers with single-phase electrical supply	< 300,000	—	—
Steam boilers; gas-fired, except natural draft;	≥ 300,000	Thermal Efficiency	Combustion Efficiency
		79	80
		77	80
Steam boilers; oil-fired	≥ 300,000	81	83
¹ No constant burning pilot light design standard.			
² Automatic means for adjusting temperature design standard.			

Source: *California Appliance Efficiency Regulations Title 20 Table E-3 and E-4*

4.2.1.2 Heating System Controls

§150.0(i), §110.2(b), Exceptions to §110.2(b), §110.2(c), Exception to §110.2(c)

All unitary heating systems, including heat pumps, must be controlled by a setback thermostat. These thermostats must be capable of allowing the occupant to program temperature set points for at least four periods within a 24 hour time span. For example, the setback thermostat could be programmed with specific temperature set points starting at 6:30 a.m., 9 a.m., 4:30 p.m., and 9 p.m.

If the heating system is integrated into a central energy management control system (EMCS), then that system does not need to comply with the setback requirements. Furthermore, all gravity gas wall heaters, floor heaters, room heaters, fireplaces, decorative gas appliances, wood stoves, and noncentral electric heaters are not required to be controlled by a setback thermostat.

Any heat pump with supplementary electric resistance heating requires controls with two capabilities to limit the electric resistance heating. The first required capability is to set the cut-on and cut-off temperatures for the heat pump and supplementary electric resistance heating at different levels.

For example, if the heat pump begins heating when the inside temperature reaches 68°F, the electric resistance heating must be set to come on if the temperature goes below 65°F because the heat pump alone could not maintain the set point of 68°F. Also, there must be an opposite “off” mode that automatically shuts off the electric resistance when the inside temperature reaches 68°F.

The second control capability prevents the supplementary electric resistance heater from operating when the heat pump alone can meet the heating load, except during defrost. There is a limited exception to this second function for “smart thermostats” that provide the following: intelligent recovery, staging, ramping, or another control mechanism that prevents the unnecessary operation of supplementary electric resistance heating when the heat pump alone can meet the heating load.

To meet the thermostat requirements, a thermostat for a heat pump must be a “smart thermostat” that minimizes the use of supplementary heating during startup and recovery from setbacks.

Note: Room air conditioner heat pumps are not required to comply with the thermostat requirements.

4.2.1.3 Equipment Sizing

§150.0(h)1 and 2

The Energy Standards do not set limits on the sizing of heating equipment, but they do require that heating loads be calculated for new heating systems. Oversized equipment typically operates less efficiently and can create comfort problems due to excessive cycling and high airflow.

Acceptable load calculation procedures include methods described in the following publications:

1. *The ASHRAE Handbook – Equipment*
2. *The ASHRAE Handbook – Applications*
3. *The ASHRAE Handbook – Fundamentals*
4. *The SMACNA Residential Comfort System Installation Manual*
5. *ACCA Manual J*

The Energy Standards require that the outdoor design conditions for load calculations be selected from Reference Joint Appendix JA2 and that the indoor design temperature for heating load calculations be 68°F.

The outdoor design temperature must be no lower than the “heating winter median of extremes,” as listed in the Reference Joint Appendix JA2.

If the actual city location for a project is not included in the Reference Joint Appendix JA2, or if the data given for a particular city does not match the conditions at the actual site as well as that given for another nearby city, consult the local building department for guidance.

The load calculations must be submitted with the compliance documentation when requested by the building department.

The load calculations may be prepared by 1) a mechanical engineer, 2) the mechanical contractor who is installing the equipment or 3) someone who is qualified to do so in the State of California according to Division 3 of the Business and Professions Code.

Note: The Business and Professions Code does not prohibit an unlicensed person from preparing plans, drawings, or specifications for single-family dwelling units of wood-frame construction not more than two stories and basement in height, or for certain buildings containing no more than four dwelling units of wood-frame construction not more than two stories and basement in height. However, licensure is required for apartment or condominium complexes.

4.2.1.4 Furnace Temperature Rise

§150.0(h)4

High temperature rise in a furnace is an indicator of low airflow and/or over specification firing rate. High temperature rise causes low efficiency and may potentially damage the furnace. Central forced-air heating furnace installations must be configured to operate at or below the furnace manufacturer's maximum inlet-to-outlet temperature rise specification.

4.2.1.5 Standby Losses and Pilot Lights

§110.5 and §110.2(d)

Fan-type central furnaces may not have a continuously burning pilot light. This requirement does not apply to wall furnaces, floor furnaces, or any gravity-type furnace. Household cooking appliances also must not have a continuously burning pilot light, except for those without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/hr.

Larger gas-fired and oil-fired forced air furnaces with input ratings equal to or greater than 225,000 Btu/h (which is bigger than a typical residential furnace) must also have an intermittent ignition device (IID) and either power venting or a flue damper.

A vent damper is an acceptable alternative to a flue damper for furnaces where combustion air is drawn from the conditioned space. All furnaces with input ratings equal to or greater than 225,000 Btu/h, including electric furnaces, that are not within the conditioned space must have jacket losses not exceeding 0.75 percent of the input rating.

4.2.1.6 Pipe Insulation

§150.0(j)2C, §150.0(j)3, §120.3

The piping for heat pumps and for both steam and hydronic heating systems shall meet the insulation requirements provided below in Table 4-5 when the insulation is located outside conditioned space, it requires protection from damage caused by environmental conditions. The insulation must be rated for outdoor use or covered with a material that can withstand the outdoor conditions. Examples of these types of coverings are aluminum, sheet metal, painted canvas, plastic cover, or, if the insulation is cellular foam, a coating that is water-retardant and shields from solar radiation. Moreover, the insulation used for the refrigerant suction line of a heat pump must be Class I or Class II vapor retardant.

Table 4-5: Insulation Requirements for Heating System Piping

Fluid Temperature Range (°F)	Conductivity Range (in Btu-inch per hour per square foot per (°F)	Insulation Mean Rating Temperature(°F)	Nominal Pipe Diameter (in inches)				
			1 and less	1 to <1.5	1.5 to <4	4 to <8	8 and larger
			Insulation Thickness Required (in inches)				
Space Heating, Hot Water Systems (Steam, Steam Condensate and Hot Water), Service Water Heating Systems							
Above 350	0.32-0.34	250	4.5	5.0	5.0	5.0	5.0
251-350	0.29-0.32	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
Heat Pump Suction Line							
40-60	0.21-0.27	75	0.75	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

From Table 120.3 A of the *Building Energy Efficiency Standards*

4.2.2 Prescriptive Requirements for Heating Equipment

§150.1(c)6

Prescriptive Component Package A requires the installation of a gas heating system or heat pump that meet the required minimum energy efficiency. (See Table 4-1 through Table 4-4)

Supplemental heating systems are allowed prescriptively, and the designer may elect to provide supplemental heating to a space such as a bathroom. In this instance, the supplemental heating system must be installed in a space that is served by the primary heating system and must have a thermal capacity of less than 2 kilowatts (kW) or 7,000 Btu/hr while being controlled by a time-limiting device not exceeding 30 minutes. Electric resistance and electric radiant heating installation are allowed as the primary heating system only when using the performance compliance method.

When using the prescriptive compliance approach, no additional credit is given for selecting equipment that is higher than what is required by the prescriptive component package.

4.2.3 Compliance Options for Heating Equipment

There is one option for receiving compliance credit related to the heating system. This credit is available through the performance compliance method.

4.2.3.1 High-Efficiency Heating

Heating system efficiencies are explained in Section 4.2.1.1. The minimum efficiency is required according to the prescriptive package. When the performance compliance approach is used, additional compliance credit may be available when higher efficiency heating equipment, such as a high-efficiency furnace or heat pump, is modeled. For example, selecting a nonweatherized furnace with an AFUE higher than 81 will result in a compliance credit, which can be used to offset other building features that do not meet the prescriptive requirements. However, all mandatory requirements must be complied with.

4.3 Cooling Equipment

This section addresses the requirements for space-cooling equipment.

4.3.1 Mandatory Measures for Cooling Equipment

4.3.1.1 Equipment Efficiency

§110.1 and §110.2(a)

The efficiency of most cooling equipment is regulated by NAECA (the federal appliance standard) and the California Appliance Efficiency Regulations. These regulations are not contained in the Energy Standards but are referenced in §110.1. The energy efficiency of larger equipment is regulated by §110.2(a). See the *Nonresidential Compliance Manual* for information on larger equipment.

A. Central, Single-Phase Air Conditioners and Air Source Heat Pumps (under 65,000 Btu/h)

The central, single-phase air conditioners and air source heat pumps that are most commonly installed in residences have a capacity less than 65,000 Btu/h. The *Appliance Efficiency Regulations* for this equipment require minimum seasonal energy efficiency ratios (SEER).

The SEER of all new central, single-phase air conditioners and air source heat pumps with output less than 65,000 Btu/h shall be certified to the Energy Commission to have values no less than the values listed in Table 4-6.

Table 4-6: Minimum Cooling Efficiencies for Central Air Conditioners and Heat Pumps With Cooling Capacity Less Than 65,000 Btu per Hour (NR = No Requirement)

Appliance	Type	SEER Effective 1/1/2015	EER Effective 1/1/2015
Central Air Conditioners ¹	Split System <45,000 Btuh	14	12.2
	Split System ≥45,000 Btuh	14	11.7
	Single Package	14	11.0
Central Air Source Heat Pumps	Split System	14	NR
	Single Package	14	NR
Space Constrained Air Conditioner	Split System	12	NR
	Single Package	12	NR
Space-Constrained Heat Pump	Split System	12	NR
	Single Package	12	NR
Small-Duct, High-Velocity Air Conditioner	All	12	NR
Small-Duct, High-Velocity Heat Pump	All	12	NR
1. Central split system air conditioners and central single package air conditioners <i>installed</i> on or after January 1 st , 2015 must comply with the minimum SEER and EER requirements of this table regardless of date of manufacturer.			

Source: *California Appliance Efficiency Regulations, Title 20, Table C-2* and Federal Appliance Standards (NAECA)

B. Other Air Conditioners and Heat Pumps

Appliance Efficiency Regulations

The current *Appliance Efficiency Regulations* for three-phase models, larger capacity central air conditioners and heat pumps, and all room air conditioners and room air conditioner heat pumps shall be certified to the Energy Commission by the manufacturer to have values no less than the values listed in Table 4-7 and Table 4-8.

Table 4-7: Minimum Cooling Efficiency for Three-Phase Models and Larger Capacity Central Air Conditioners and Heat Pumps

Equipment Type	Size Category	SEER or EER
Central Air Conditioners	< 65,000 Split System*	13.0 SEER
	< 65,000 Single Packaged*	13.0 SEER
	≥65,000 Btu/h but <135,000 Btu/h	11.2 ¹ EER 11.0 ² EER
	≥135,000 Btu/h but <240,000 Btu/h	11.0 ¹ EER 10.8 ² EER
	≥240,000 Btu/h but <760,000 Btu/h	10.0 ¹ EER 9.8 ² EER
Central Air Source Heat Pumps	< 65,000 Split System*	13.0 SEER
	< 65,000 Single Packaged*	13.0 SEER
	≥ 65,000 Btu/h but <135,000 Btu/h	11.0 ¹ EER 10.8 ² EER
	≥135,000 Btu/h but <240,000 Btu/h	10.6 ¹ EER 10.4 ² EER
	≥240,000 Btu/h but <760,000 Btu/h	9.5 ¹ EER 9.3 ² EER
Central Water Source Heat Pumps	< 17,000 Btu/h	11.2 EER
	≥ 17,000 Btu/h and < 65,000 Btu/h	12.0 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	11.9 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	12.3 EER
	≥ 240,000 Btu/h and < 760,000 Btu/h	12.2 EER
Water-Cooled Air Conditioners	< 17,000 Btu/h	12.1 EER
	< 17,000 < 65,000 Btu/h	12.1 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	12.1 ³ EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	12.5 ³ EER
	≥ 240,000 Btu/h and < 760,000 Btu/h	12.4 ³ EER

* Three-phase models only

1 Applies to equipment that has electric resistance heat or no heating.

2 Applies to equipment with all other heating-system types that are integrated into the unitary equipment.

Deduct 0.2 from the required EER for units with heating sections other than electric resistance heat.

Source: *California Appliance Efficiency Regulations* Table C-3, C-4

Table 4-8: Minimum Cooling Efficiency for Noncentral Space-Cooling Equipment

Equipment Type	Size Category (Input)	Minimum Efficiency
Room Air Conditioners, With Louvered Sides	< 6,000 Btu/h	11.0 EER
	≥ 6,000 Btu/h and - 7,999 Btu/h	11.0 EER
	≥ 8,000 Btu/h and -13,999 Btu/h	10.9 EER
	≥ 14,000 Btu/h and - 19,999 Btu/h	10.7 EER
	≥ 20,000 Btu/h and 27,999 Btu/h	9.4 EER
	≥ 28,000 Btu/h	9.0 EER
Room Air Conditioners, Without Louvered Sides	< 6,000 Btu/h	10.0 EER
	≥ 6,000 Btu/h and - 7,999 Btu/h	10.0 EER
	≥ 8,000 Btu/h and - 10,999 Btu/h	9.6 EER
	≥ 11,000 Btu/h and - 13,999 Btu/h	9.5 EER
	≥ 14,000 Btu/h and - 19,999 Btu/h	9.3 EER
	≥ 20,000 Btu/h	9.4 EER
Room Air Conditioner Heat Pumps With Louvered Sides	< 20,000 Btu/h	9.8 EER
	≥ 20,000 Btu/h	9.3 EER
Room Air Conditioner Heat Pumps Without Louvered Sides	< 14,000 Btu/h	9.3 EER
	≥ 14,000 Btu/h	8.7 EER
Casement-Only Room Air Conditioner	All Capacities	9.5 EER
Casement-Slider Room Air Conditioner	All Capacities	10.4 EER
PTAC (cooling mode) Newly Constructed or Newly Conditioned Buildings or Additions	All Capacities	$14.0 - (0.300 \times \text{Cap}/1000) = \text{EER}$
PTAC (cooling mode) Replacements	All Capacities	$10.9 - (0.213 \times \text{Cap}/1000) = \text{EER}$
PTHP (cooling mode) Newly Constructed or newly conditioned buildings or Additions	All Capacities	$14.0 - (0.300 \times \text{Cap}/1000) = \text{EER}$
PTHP (cooling mode) Replacements	All Capacities	$10.8 - (0.213 \times \text{Cap}/1000) = \text{EER}$
SPVAC (cooling mode)	< 65,000 Btu/h	10.0 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	10.0 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	10.0 EER
SPVHP (cooling mode)	< 65,000 Btu/h	10 EER
	≥ 65,000 Btu/h and < 135,000 Btu/h	10 EER
	≥ 135,000 Btu/h and < 240,000 Btu/h	10 EER
Cap. = Cooling Capacity (Btu/hr)		
Note: Including room air conditioners and room air conditioner heat pumps, package terminal air conditioners (PTAC), package terminal heat pumps (PTHP), single-package vertical air conditioners (SPVAC), and heat pumps (SPVHP).		

Source: California Appliance Efficiency Regulations Title 20, Table B-2, the Energy Standards Table 110.2-E

4.3.1.2 Insulation for Refrigerant Lines in Split-System Air Conditioners

§150.0(j)2 and 3, §150.0(m)9

Two refrigerant lines connect the indoor and outdoor units of split-system air conditioners and heat pumps: the liquid line (the smaller diameter line) and the suction line (the larger diameter line).

If the liquid line is at an elevated temperature relative to outdoor and indoor temperatures, it should not be insulated. In those areas, heat escaping from it is helpful. When the liquid line runs through the attic, the attic temperature is higher than the liquid line temperature, so liquid lines running through attics should be insulated to reduce heat transfer from the surrounding environment into the refrigeration system.

The suction line carries refrigerant vapor that is cooler than ambient in the summer and (with heat pumps) warmer than ambient in the winter. This line must be insulated to the required thickness (in inches) as specified in Table 4-9.

Table 4-9: Insulation Requirements for Split-System Refrigerant Piping

Fluid Temperature Range (°F)	Conductivity Range (in Btu-inch per hour per square foot per °F)	Insulation Mean Rating Temperature(° F)	Nominal Pipe Diameter (in inches)				
			1 and less	1 to <1.5	1.5 to <4	4 to <8	8 and larger
			Insulation Thickness Required (in inches)				
Space cooling systems suction line							
40-60	0.21-0.27	75	0.75	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

From Table 120.3-A of the Energy Standards

Insulation used for refrigerant suction lines located outside a condition space, must include a Class I or Class II vapor retarder. The vapor retarder and insulation must be protected from physical damage, UV deterioration, and moisture with a covering that can be removed for equipment maintenance without destroying the insulation. Insulation is typically protected by aluminum, sheet metal jacket, painted canvas, or plastic cover. Adhesive tape should not be used as insulation protection because removal of the tape will damage the integrity of the original insulation during preventive maintenance.

Figure 4-1: Refrigerant Line Insulation

Source: Airex Manufacturing Inc.

4.3.1.3 Outdoor Condensing Units

§150.0(h)3

Any obstruction of the airflow through the outdoor unit of an air conditioner or heat pump lowers efficiency. Dryer vents are prime sources for substances that clog outdoor coils and sometimes discharge substances that can cause corrosion. Therefore, condensing units shall not be placed within 5 feet of a dryer vent. Regardless of location, condenser coils should be cleaned regularly in all homes. The manufacturer installation instructions may include requirements for minimum horizontal and vertical distance to surrounding objects that should be met if greater than the minimum distance required by the Energy Standards.

Figure 4-2: Noncompliant Condensing Unit Clearance From Dryer Vents

Source: California Energy Commission

Liquid line filter driers are components of split system air-conditioners and split system heat pumps that are installed in the refrigerant line to remove noncondensables, like moisture and particles, from the refrigerant stream. These noncondensables may appear in the refrigerant line due to improper charging procedures and result in reduced efficiency and capacity for the air conditioner. If required by manufacturer's instructions, liquid line filter

dryers must be installed. Sometimes, liquid line filter dryers are preinstalled by manufacturers within condensing units, which makes it difficult for technicians to access. Because of this difficulty, manufacturers have begun changing this practice by installing liquid line filter dryers outside condensers, so that they can be easily serviced by technicians and more easily verified by HERS Raters.

The quality of installation is important to the effectiveness of the liquid line filter dryer, as some liquid line filter dryers can be installed without regard to the direction of refrigerant flow. Heat pumps, for example, allow refrigerant flow in both directions. However, in other air conditioners where refrigerant flow occurs in only one direction, the orientation of the liquid line filter dryer will matter.

4.3.1.4 Equipment Sizing

§150.0(h)

Similar to heating equipment, the Energy Standards do not set limits on the size of cooling equipment, but they do require that cooling loads be calculated for new cooling systems. Avoid oversizing the cooling components since oversizing may adversely affect the efficiency of the system. Ducts must be sized correctly, otherwise the system airflow rate may be restricted, adversely affecting the efficiency of the system and preventing the system from meeting the mandatory minimum airflow rate requirements.

The outdoor design conditions for load calculations must be selected from Reference Joint Appendix JA2, Table 2-3, using values no greater than the “1.0 percent cooling dry bulb” and “mean coincident wet bulb” values listed. The indoor design temperature for cooling load calculations must be 75°F. Acceptable load calculation procedures include methods described in:

1. *The ASHRAE Handbook – Equipment*
2. *The ASHRAE Handbook – Applications*
3. *The ASHRAE Handbook – Fundamentals*
4. The SMACNA Residential Comfort System Installation Manual.
5. ACCA Manual J

Cooling load calculations must be submitted with compliance documentation when requested by the building department. The load calculations may be prepared by 1) a mechanical engineer, 2) the mechanical contractor who is installing the equipment or 3) someone who is qualified to do so in the State of California according to Division 3 of the Business and Professions Code.

4.3.1.5 Hole for Static Pressure Probe (HSPP) or Permanently Installed Static Pressure Probe (PSPP)

§150.0(m)13

Space-conditioning systems that use forced air ducts to cool occupiable space shall have a hole for the placement of a static pressure probe (HSPP) or permanently installed static pressure probe (PSPP) installed downstream from the evaporator coil.

The HSPP or PSPP must be installed in the required location, in accordance with the specifications detailed in Reference Residential Appendix RA3.3. The HSPP or PSPP is required to promote system airflow measurement when using devices/procedures that depend on supply plenum pressure measurements. The HSPP or PSPP allows HERS Raters to perform the required diagnostic airflow testing in a nonintrusive manner, by

eliminating the necessity for the Raters to drill holes in the supply plenum for placement of pressure measurement probes.

The size and placement of the HSPP/PSPP shall be in accordance with RA3.3.1.1 and shall be verified by a HERS Rater. In the event that the HSPP/PSPP cannot be installed as shown in Figure RA3.3-1, due to the configuration of the system or that the location is not accessible, an alternative location may be provided that can accurately measure the average static pressure in the supply plenum. If an alternative location cannot be provided, then the HSPP/PSPP is not required to be installed. The HERS Rater will verify this. Not installing an HSPP/PSPP will limit the airflow measurement method to either a powered flow hood or passive (traditional) flow hood.

When the mandatory measure for minimum system airflow rate is in effect (entirely new systems), there must be a hole in the supply plenum, provided by the installing contractor, for the placement of a static pressure probe (HSPP). Alternatively, a permanently installed static pressure probe (PSPP) must be installed in the same location.

This requirement also applies when the plenum pressure matching method or the flow grid method of airflow measurement is used by either the installer or the Rater to verify airflow in an altered system. The HSPP/PSPP must be installed by the installer, not the Rater.

See Air Distribution Ducts, Plenums, and Fans Section 4.4 for discussion regarding mandatory sizing/airflow requirements for ducted systems with cooling.

4.3.2 Prescriptive Requirements for Cooling Equipment

§150.1(c)7

Prescriptive Component Package A does not require that a cooling system be installed. However if one is to be installed, the cooling equipment efficiency requirements are specified by the mandatory measures (See Section 4.3.1 above)

Using the prescriptive compliance approach, no additional credit is given for selecting equipment that is higher than what is required by the prescriptive component package.

Prescriptive Component Package A, for air-cooled air conditioners and air-source heat pumps installed in Climate Zones 2 and 8 through 15, requires the installation of a measurement access hole (MAH), refrigerant charge verification (RCV), and minimum system airflow verification. The minimum system airflow installation and RCV must be performed by the installer and/or HERS Rater. The MAH provides a nonintrusive means of measuring return air temperature, which is a parameter important to the RCV process. The alternative to RCV by a HERS Rater is the installation of a refrigerant fault indicator display. When installing a fault indicator display, the installer must still perform a RCV.

Note: The refrigerant charge verification is discussed in greater detail later in Section 4.9.

4.3.2.1 Measurement Access Hole (MAH).

The MAH provides a nonintrusive means for refrigerant charge verification by HERS Raters and other third-party inspectors. They eliminate the need for Raters/inspectors to drill holes into the installed air conditioning equipment enclosures for placement of the temperature sensors required by the refrigerant charge verification test procedures described in the Reference Residential Appendix RA3.2.

Installation of MAH must be performed by the installer of the air conditioner or heat pump equipment according to the specifications given in Reference Residential Appendix RA3.2.

The MAH feature consists of one 5/8-inch (16 mm) diameter hole in the return plenum, upstream from the evaporator coil. (See figure RA3.2-1 in Reference Residential Appendix RA3.2.)

4.3.2.2 Minimum System Airflow

Ducted forced air systems must comply with the minimum system airflow rate of greater than or equal to 350 cfm per ton when performing the refrigerant charge verification. The airflow is important when performing the refrigerant charge verification to validate the measured values for pressure and temperature. The correct airflow will also improve the performance of the air-conditioning equipment.

The airflow verification procedure is documented in Reference Residential Appendix RA3.3.

4.3.2.3 Refrigerant Charge Verification (RCV)

The prescriptive standards require that a HERS Rater verify that air-cooled air conditioners and air-source heat pumps have the correct refrigerant charge. The RCV procedures are documented in Reference Residential Appendix RA1.2, RA2.4.4, and RA3.2.

Refrigerant charge refers to the actual amount of refrigerant present in the system. Excessive refrigerant charge (overcharge) reduces system efficiency and can lead to premature compressor failure. Insufficient refrigerant charge (undercharge) also reduces system efficiency and can cause compressors to overheat. Ensuring correct refrigerant charge can significantly improve the performance of air-conditioning equipment. *Refrigerants* are the working fluids in air-conditioning and heat-pump systems that absorb heat energy from one area (the evaporator), transfer, and reject it to another (the condenser).

4.3.2.4 Fault Indicator Display

The installation of a fault indicator display (FID) may be used as an alternative to the prescriptive requirement for HERS diagnostic testing of the refrigerant charge in air conditioners and heat pumps. The installation of a FID does not preclude the HVAC installer from having to properly charge the system with refrigerant. The FID provides real-time information to the building occupant about the status of the system refrigerant charge, metering device, and system airflow. The FID will monitor and determine the operating performance of air conditioners and heat pumps and provide visual indication to the system owner or operator if the refrigerant charge, airflow, or metering device performance of the system does not conform to approved target parameters for minimally efficient operation. Thus, if the FID signals the owner/occupant that the system requires service or repair, the occupant can immediately call for a service technician to make the necessary adjustments or repairs. A FID can provide significant benefit to the owner/occupant by alerting the owner/occupant to the presence of inefficient operation that could result in excessive energy use/costs over an extended period. A FID can also indicate system performance faults that could result in system component damage or failure if not corrected, thus helping the owner/occupant avoid unnecessary repair costs.

Fault indicator display technologies shall be installed in the factory or the field according to manufacturer's specifications. Reference Joint Appendix JA6 contains more information about FID technologies.

The presence of a FID on a system must be field-verified by a HERS Rater. See Reference Residential Appendix RA3.4.2 for the HERS verification procedure, which consists of a visual verification of the presence of the installed FID technology. The Rater must inspect to see that the visual indication display component of the installed FID technology is mounted adjacent to the thermostat of the split system. When the outdoor temperature is greater than

55°F, the rater must also observe that the system reports no system faults when the system is operated continuously for at least 15 minutes when the indoor air temperature returning to the air conditioner is at or above 70°F. When the outdoor temperature is below 55°F, the Rater must observe that the FID does a self-diagnosis and indicates that the sensors and internal processes are operating properly.

4.3.3 Performance Compliance Options for Cooling Equipment

There are several options for receiving compliance credit related to the cooling system. These credits are available through the performance compliance method.

4.3.3.1 High-Efficiency Air Conditioner

Air conditioner efficiencies are determined according to federal test procedures. The efficiencies are reported in terms of seasonal energy efficiency ratio (SEER) and energy efficiency ratio (EER). Savings can be achieved by choosing an air conditioner that exceeds the minimum efficiency requirements.

The EER is the full load efficiency at specific operating conditions. It is possible that two units with the same SEER can have different EERs. In cooling climate zones of California, for two units with a given SEER, the unit with the higher EER is more effective in saving energy. Using the performance compliance method, credit is available for specifying an air conditioner with an EER greater than 10. (See the compliance program vendor's compliance supplement.) When credit is taken for a high EER and/or SEER, field verification by a HERS Rater is required. (See Reference Residential Appendix RA3.4.)

4.3.3.2 Air Handler Watt Draw and System Airflow

It is mandatory that central forced air systems produce fan watt draws less than or equal to 0.58 watts/CFM and flow at least 350 CFM per nominal cooling ton. Performance compliance credits are available for demonstrating the installation of a high-efficiency system with a lower fan wattage and/or higher airflow than the mandatory requirements. These credits can be achieved by selecting good duct design and can be assisted by a high-efficiency fan. There are two possible performance compliance credits:

1. The performance compliance method allows the user's proposed fan watt draw to be entered and credit earned if it is lower than the default of 0.58 watts per CFM of system airflow. To obtain this credit, the system airflow must meet the mandatory requirement of at least 350 CFM/ton of nominal cooling capacity.
2. The performance compliance method allows the user's proposed airflow to be entered and credit earned if it is higher than the default of 350 CFM/ton of nominal cooling capacity. To obtain this credit, the fan watt draw must meet the mandatory requirement of no more than 0.58 watts per CFM of nominal cooling capacity.

After installation, the contractor must test the actual fan power and airflow of the system using the procedure in *Reference Residential Appendix RA3.3*, and show that it is equal or better than what was proposed in the compliance software analysis.

Field verification by a HERS Rater is required. (See Reference Residential Appendix RA3.3.)

4.4 Air Distribution System Ducts, Plenums, and Fans

Air distribution system performance can have a big effect on overall HVAC system efficiency. Therefore, air distribution systems face several mandatory measures and prescriptive requirements, discussed below.

The *2016 Energy Standards* specify mandatory requirements for air distribution ducts to be sealed and tested in all climate zones. There are also several compliance credits available related to duct system design.

Duct efficiency is affected by the following parameters:

1. Duct location (attic, crawlspace, basement, inside conditioned space, or other)
2. Specific conditions in the unconditioned space, for example, presence of a radiant barrier
3. Duct insulation characteristics
4. Duct surface area, and
5. Air leakage of the duct system

In performance calculations, duct efficiency can be calculated in one of two ways:

1. Default input assumptions; or
2. Diagnostic measurement values.

The computer program will use default assumptions for the proposed design when the user does not intend to make improvements in duct efficiency.

4.4.1 Mandatory Measures for Air Distribution System Ducts, Plenums, and Fans

4.4.1.1 Minimum Insulation

§150.0(m)1

Ducts that are entirely in conditioned space must comply with an installed R-value of R-4.2. In all other cases, the minimum allowed duct insulation value is R-6. Higher values may be required by the prescriptive requirements, as described below.

To determine whether ducts are entirely in conditioned space as defined in §100.1, a Rater must field verify by visual inspection and by using the protocols of RA 3.1.4.3.8.

RA 3.1.4.3.8 describes the duct leakage to outside test to help ensure that the ducts are within the pressure boundary of the space being served by the duct system. Passing the test alone is not enough to establish that the ducts are entirely within conditioned space. The test procedure is in addition to a basic visual inspection of the ducts to ensure that no portion of the duct system is obviously outside the apparent pressure/thermal boundary. Once this has been established, the leakage to outside test verifies that the pressure boundary is intact and preventing leakage from escaping to the outside.

Applying this procedure to multifamily dwelling units poses a unique situation. In this case, leakage to “outside” means conditioned air leaking from the ducts to anywhere outside the pressure boundary of the space being served by the duct system, including adjacent dwelling units. Duct leakage to adjacent dwelling units is not desirable and should be eliminated. When performing the leakage-to-outside test, it is necessary only to pressurize the dwelling unit served by the duct system being tested.

Exception to §150.0 (m)1: Ducts and fans integral to a wood heater or fireplace are exempt from §150.0(m)1.

§150.0(m)5

For determining installed R-value of duct insulation based on thickness, when not an integral part of a manufacturer-labeled, insulated duct product such as vinyl flex duct, the following shall be used:

1. For duct wrap, the installed thickness of insulation must be assumed to be 75 percent of the nominal thickness due to compression.
2. For duct board, duct liner, and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness shall be used.

4.4.1.2 Connections and Closures

§150.0(m)1 - §150.0(m)3

The Energy Standards set a number of mandatory measures related to duct connections and closures. These measures address both the materials and methods used for duct sealing. The following is a summary. Refer to the sections of the Energy Standards listed above for additional details.

4.4.1.3 Factory-Fabricated Duct Systems

Factory-fabricated duct systems must comply with the following requirements:

1. All factory-fabricated duct systems must comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL 181. UL181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.
2. All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts must comply with UL 181 and UL 181A.
3. All pressure-sensitive tapes and mastics used with flexible ducts must comply with UL 181 and UL 181B.
4. Joints and seams of duct systems and related components cannot be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands, or
5. It has on its backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums and junction box joints.

4.4.1.4 Field-Fabricated Duct Systems

Field-fabricated duct systems must comply with the following requirements:

1. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems must comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants, or other closure systems used for installing field-fabricated duct systems shall meet the applicable requirements of UL 181, UL 181A, and UL 181B.
2. Mastic sealants and mesh:
 - a. Sealants must comply with the applicable requirements of UL 181, UL 181A, and/or UL 181B and be nontoxic and water-resistant.

- b. Sealants for interior applications must be tested in accordance with ASTM C731 and D2202.
 - c. Sealants for exterior applications must be tested in accordance with ASTM C731, C732, and D 2202.
 - d. Sealants and meshes must be rated for exterior use.
3. Pressure-sensitive tapes must comply with the applicable requirements of UL 181, UL 181A, and UL 181B.
 4. Joints and seams of duct systems and their components must not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands: or
 5. It has on its backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums or junction box joints.

4.4.1.5 Draw Bands Used With Flexible Duct

1. Draw bands must be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties.
2. Draw bands must have a minimum tensile strength rating of 150 pounds.
3. Draw bands must be tightened as recommended by the manufacturer with an adjustable tensioning tool.

4.4.1.6 Aerosol-Sealant Closures

1. Aerosol sealants shall meet the requirements of UL 723 and be applied according to manufacturer specifications.
2. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this section.

If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape must be used.

Building spaces such as cavities between walls, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board, or flexible duct must not be used for conveying conditioned air, including return air and supply air. Using drywall materials as the interior surface of a return plenum is not allowed. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms must not be compressed to cause reductions in the cross-sectional area of the ducts. Although a HERS Rater may examine this as a part of his or her responsibilities when involved in a project, the enforcement of these minimum standards for ducts is the responsibility of the building official.

§150.0(m)2D, §150.0(m)3D

Duct systems may not use cloth-backed, rubber-adhesive duct tape (typical, “old fashioned,” nonrated duct tape) unless it is installed in combination with mastic and draw bands. Mastic and drawbands alone are adequate for sealing most connections. Cloth-backed, rubber-adhesive duct tape would then be used only to hold the outer vapor barrier in place or for some other superfluous purpose. It alone is not adequate to serve as an air-sealing method or as a mechanical connection.

The enforcement of these minimum standards is normally the responsibility of the building official; however, HERS Raters will also verify compliance with this requirement in conjunction with duct leakage verification.

4.4.1.7 Product Markings

§150.0(m)2A, §150.0(m)6

All factory-fabricated duct systems must meet UL 181 for ducts and closure systems and be labeled as complying with UL 181. Collars, connections, and splices are considered to be factory-fabricated duct systems and must meet the same requirement.

Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of 3 ft, showing the R-value for the duct insulation (excluding air films, vapor barriers, or other duct components), based on the tests and thickness specified in §150.0(m)4 and §150.0(m)5C.

4.4.1.8 Dampers to Prevent Air Leakage

§150.0(m)7

Fan systems that exhaust air from the building to the outside must be provided with back draft or automatic dampers.

§150.0(m)8

Gravity ventilating systems must have an automatic or readily accessible, manually operated damper in all openings to the outside, except combustion inlet and outlet air openings and elevator shaft vents. This includes clothes dryer exhaust vents when installed in conditioned space.

4.4.1.9 Protection of Insulation

§150.0(m)9

Insulation must be protected from damage, including damage due to sunlight, moisture, equipment maintenance, and wind, but not limited to the following:

1. Insulation exposed to weather must be suitable for outdoor service – for example, protected by aluminum, sheet metal, painted canvas, or plastic cover.
2. Cellular foam insulation shall be protected as above or painted with a coating that is water-retardant and shields from solar radiation that can degrade the material.

4.4.1.10 Ducts in Concrete Slab

Ducts located in a concrete slab must have R-6 insulation, but other issues will come into play. If ducts are in the soil beneath the slab or embedded in the slab, the insulation material should be designed and rated for such installation. Insulation installed in below-grade applications should resist moisture penetration. (Closed cell foam is one moisture-resistant product.) Common premanufactured duct systems are not suitable for below-grade installations. If concrete is to be poured directly over the ducts, then the duct construction and insulation system should be sturdy enough to resist the pressure and not collapse. Insulation should be of a type that will not compress, or it should be located inside a rigid duct enclosure. The only time that common flex ducts are suitable in a below-grade application is when a channel is provided in the slab.

4.4.1.11 Porous Inner Core Flex Duct

§150(m)10

Over time, the outer vapor barrier of flex duct can be compromised. Therefore, porous inner core flex duct is not allowed.

4.4.1.12 Duct System Sealing and Leakage Testing

§150(m)11

Duct system sealing and leakage testing is mandatory in all climate zones. Duct systems in newly constructed single-family dwellings, townhouses, and multifamily dwellings are required to comply with the requirements. For single-family dwellings and townhouses where the air-handling unit is installed and ducts are connected directly to the air handler, the total leakage of the duct system needs to be 5 percent or less of the nominal system air handler airflow. For single-family dwellings and townhouses where the air-handling unit is not installed, the total leakage of the duct system shall not exceed 4 percent of the nominal systems air handler airflow.

For multifamily dwellings with the air-handling unit installed and the ducts connected directly to the air handler, the total leakage of the duct system shall not exceed 12 percent of the nominal system air handler airflow or the duct system leakage to outside shall not exceed 6 percent of the nominal system air handler airflow.

The duct system leakage needs to be verified per the applicable procedures outlined in Reference Residential Appendix Section RA3.1.4.3.1 through RA3.1.4.3.4.

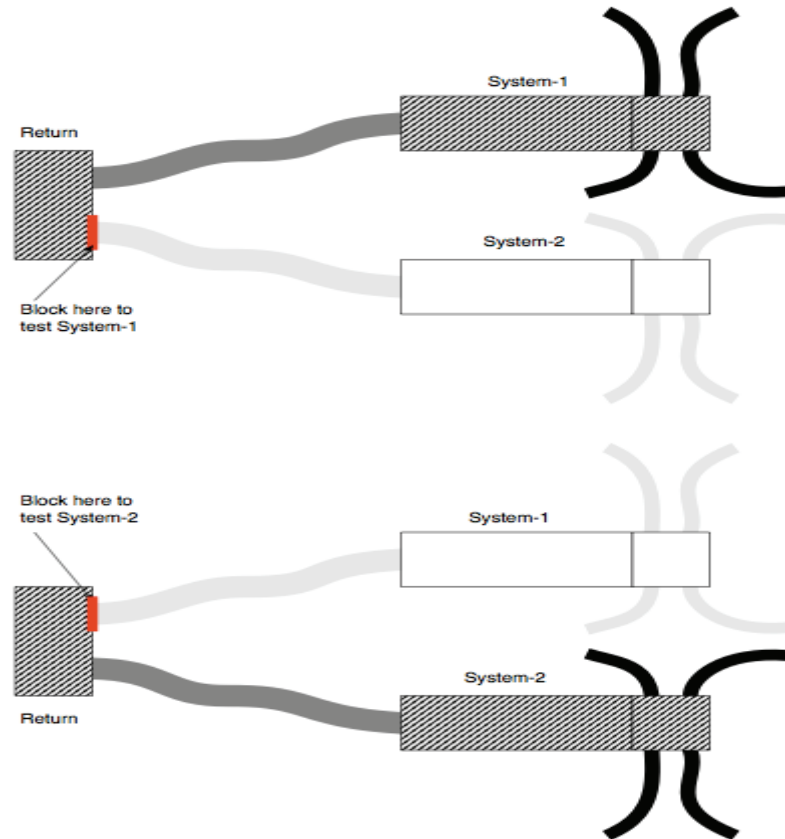
Alterations and additions to ducted systems in existing buildings in all climate zones are also required to comply with applicable maximum leakage criteria. Refer to Chapter 9 for more information on duct sealing and leakage testing for existing buildings.

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

If there are two or more duct systems in a building that are tied together at a common return duct, then each duct system should be tested separately, including the shared portion of the return duct system in each test. Under this scenario, the portions of the second duct system that is not being tested must be completely isolated from the portions of the ducts that are being tested, so the leakage from second duct system does not affect the leakage rate from the side that is being tested.

Figure 4-3 represents the systems that are attached to a shared return boot or remote return plenum. In this case, the point in the return system that needs to be blocked off is readily accessible through the return grille.

The “duct leakage averaging” where both systems are tested together as though it is one large system and divided by the combined tonnage to get the target leakage, may not be used as it allows a duct system with more the 5 percent leakage to pass if the leakage of the combined system is 5 percent or less.

Figure 4-3: Two Duct Systems With a Common Return Duct

Source: California Energy Commission

4.4.1.13 Air Filtration

§150.0(m)12

Air filtration is present in forced air systems to protect the equipment and may provide health benefits to building occupants. In addition to filtering particulates from the airstream, filters add flow resistance to the forced air system, potentially lowering the efficiency of the heating/cooling equipment. Flow resistance is measured as a pressure drop at a specific airflow.

Except for evaporative coolers, any mechanical forced air heating and/or cooling system with more than 10 feet of duct must meet four sets of criteria:

1. System Design Criteria:
 - a. All recirculated and outdoor air passing through the heating/cooling device must first pass through the filter.
 - b. The system design must accommodate the pressure drop through the filter at the designed airflow. To accomplish this, the design airflow and the design pressure drop through the filter must be determined by the designer. The design pressure drop will determine the size and depth of the filter media required for the device (return filter grille or filter rack).
 - c. If the system design elects compliance using the return duct design alternative specified in Tables 150.0-B and C (see Table 4-10 and Table 4-11), then the

designer must assume a design filter pressure drop of 0.05 IWC at the applicable design airflow rate.

- d. Replacing the filters, like for like, when they become dirty brings the resistance to airflow back to the design condition. Therefore, the filters must be located to allow access for regular service by the occupants.
- e. To maintain the energy efficiency of the system, it is necessary for the occupants to know which filters to select that will provide the designed airflow. Therefore, a clearly legible label, such as shown in Figure 4-4, shall be permanently placed in a location visible to a person changing the filter. As shown in Figure 4-4, the label shows the allowable maximum resistance at the airflow rate closest to the design airflow for that filter location. For example, Figure 4-4 is a label for a filter location designed for 400 CFM at 0.03 IWC. On air filter media product labeling, the AHRI Standard 680 test procedure reports pressure drop at airflow values in 400 CFM increments, and the ASHRAE Standard 52.2 test procedure reports pressure drop at five airflow values within the manufacturer's rated range of performance. Therefore values for air filter media pressure drop for airflow rates that fall between the reported cfm increments must be determined by interpolation of the values reported on the manufacturer's air filter product label, or by lookup methods made available by the filter media vendor or manufacturer.

Figure 4-4: Example of Filter Location Label

Air Filter Performance Requirement		Maintenance Instructions
Airflow (CFM)	Initial Resistance (inch WC)	USE ONLY REPLACEMENT FILTERS WITH AN INTIAL RESISTANCE LESS THAN 0.032 AT 400 CFM AIRFLOW RATE
400	0.03	

Source: California Energy Commission

- 2. Air Filter Media Efficiency Criteria: The filter media shall be MERV 6 or better to protect the equipment and to potentially provide health benefits. Filter media that provide at least 50% percent particle efficiency in the 3.0–10 µm range in AHRI 680 are considered to meet the MERV 6 criterion.
- 3. Air Filter Media Pressure Drop Criteria: To ensure airflow for efficient heating and cooling equipment operation, the installed filter media must conform to the design pressure drop specification shown in the Filter Location Label described in Item 1e above.
- 4. Air Filter Media Labeling Criteria: The filter device must be provided with a filter media product that has been labeled by the manufacturer to disclose performance ratings that meet both the Efficiency and Pressure drop criteria described in 2 and 3 above and as shown in the Filter Location Label described in Item 1.e above.

4.4.1.14 Forced Air System Duct Sizing, Airflow Rate and Fan Efficacy

§150.0(m)13

Adequate airflow is critical for cooling equipment efficiency. Further, it is important to maintain adequate airflow without expending excessive fan power. §150.0(m)13 requires system airflow and watt draw to be HERS-verified. See Reference Residential Appendices RA3.3 for the applicable HERS verification procedures.

Except for heating only systems, systems must comply with one of the following two methods:

1. Airflow and Watt Draw Measurement and Determination of Fan Efficacy:

When using the airflow (cfm/ton) and fan efficacy (watt/cfm) method the following criteria must be met:

- a. Provide airflow through the return grilles that is equal to or greater than 350 CFM per ton of nominal cooling capacity.
- b. At the same time, the fan watt draw must be less than or equal to 0.58 watts per CFM.

The methods of measuring the watt draw are described in Reference Residential Appendix RA3.3. Three acceptable apparatuses are:

- a. A portable watt meter,
- b. An analog utility revenue meter, or
- c. A digital utility revenue meter.

Note: When required to measure fan watt draw in package air conditioners or heat pumps, it is recommended to use a portable true power clamp-on meter to provide flexibility for isolating the correct fan wires. These meters may need to be high-voltage-capable.

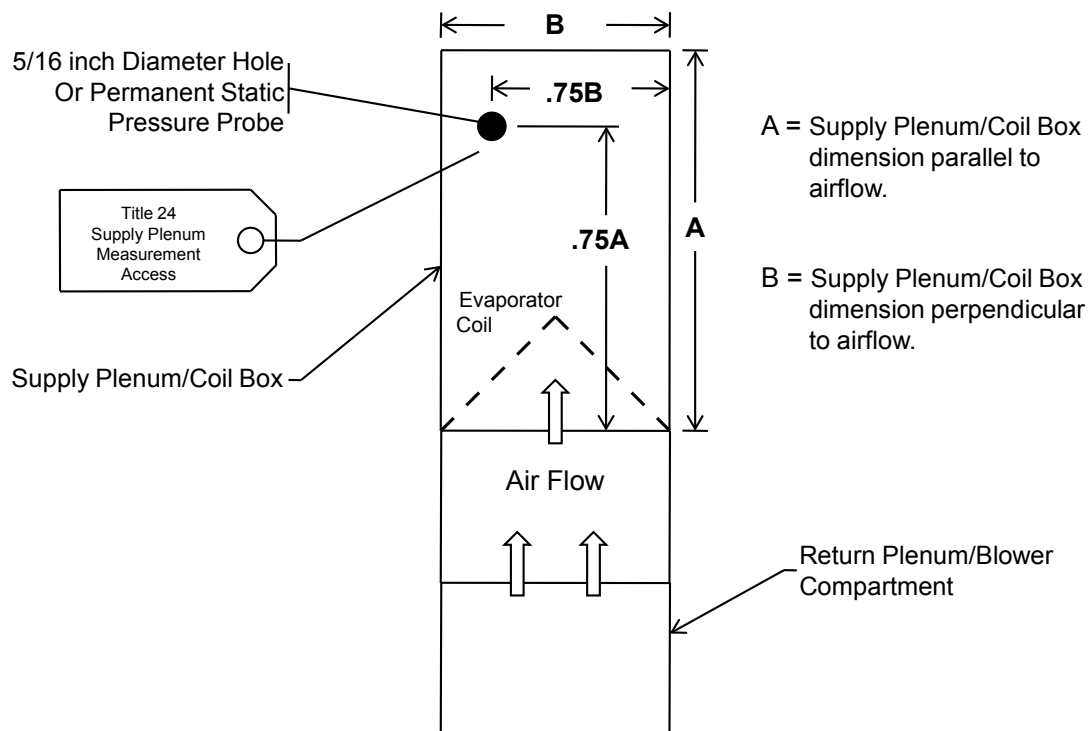
There are three acceptable methods to determine compliance with the system airflow requirement. They are described in Reference Residential Appendix RA3.3 and use one of the following:

- a. An active or passive flow capture hood to measure the total airflow through the return grill(s)
- b. Flow grid device(s) at the return grill(s) or other location where all the central fan airflow passes through the flow grid, or
- c. Fan flow meter device to perform the plenum pressure matching procedure.

The flow grid and the fan flow meter both require access to static pressure measurements of the airflow exiting the cooling coil, which uses a HSPP or PSPP (Section RA3.3.1.1).

The contractor must install either a hole for the placement of a static pressure probe (HSPP) or provide a permanently installed static pressure probe (PSPP) as shown in Figure 4-5 below and Reference Residential Appendix RA3.3

Figure 4-5: Location of the Static Pressure Probe



Source: California Energy Commission

The HSPP or PSPP simplifies cooling coil airflow measurement when using devices/procedures that depend on supply plenum pressure measurements.

2. Return Duct System Design Method – This method allows the designer to specify, and the contractor to install, a system that does not have to be tested for airflow and fan watt draw. This method can be used for return systems with two returns. Each return shall be no longer than 30 feet from the return plenum to the filter grille. When bends are needed, metal elbows are desirable. Each return can have up to 180 degrees of bend, and no more 90 degrees of bend can be flex duct. To use this method, the designer and installer must provide return system sizing that meets the appropriate criteria in Table 4-10 or Table 4-11.

4.4.1.15 Airflow and Fan Efficacy Testing Versus Return Duct Sizing

Studies have shown that adequate airflow is critical to the efficient operation of air-conditioning systems. §150.0(m)13B establishes mandatory requirements that are intended to ensure adequate cooling airflow through properly sized ducts and efficient fan motors.

There are two options allowed to ensure adequate air flow; option one is to design and install the systems using standard design criteria and then have the systems airflow and fan efficacy (AF/FE) tested and third-party verified in the field. The second option is to size the return ducts according to Table 4-10 and Table 4-11 (as specified by EXCEPTION 1 to §150.0(m)13B). These tables are very simplified and very conservative. (The return ducts are much larger than would normally be used.) They should be used only in situations where there is a serious concern that the system will not pass the diagnostic tests for airflow and fan efficacy, such as in alterations where duct modification opportunities are limited. The first option, AF/FE testing, is always preferable, especially in new construction.

The California Green Code and the California Mechanical Code both require that residential duct systems be designed according to ACCA Manual D, or equivalent. If reasonable care and judgment is used in designing the duct system (both return and supply ducts), and the system is designed to reasonable parameters for airflow per ton, static pressure across the fan, and friction rate, these systems should have no problem passing the diagnostic tests. Return ducts should not be sized according to Table 4-10 or Table 4-11 purely as a way to avoid the diagnostic testing. While undersized return ducts are very often the cause of poor airflow in many systems, they are only part of the overall system.

The following design guidelines will increase the chances of the system passing the AF/FE testing without sizing the return ducts according to Table 4-10 or Table 4-11:

1. Right-size the HVAC system; if a 3-ton unit is enough to satisfy the cooling load, do not install a 4-ton unit “just to be safe.” Oversizing equipment can cause comfort problems in addition to excessive energy use.
2. The HVAC designer must coordinate closely with the architect and structural engineer to make sure that the ducts will fit into the home as designed.
3. Prepare a detailed mechanical plan that can be followed in the field. If deviations must occur in the field, make sure that they are coordinated with the designer and that the design is adjusted as needed.
4. Follow Manual D for duct sizing:
 - a. Make sure that the correct duct type is being used (vinyl flex, sheet metal, rigid fiberglass, or other).
 - b. Make sure that all equivalent lengths and pressure drops are correctly accounted for (bends, plenum start collars, t-wyes, filters, grilles, registers, and so forth).
 - c. Select a furnace that will provide at least 400 cfm/ton at the desired static pressure of 125 to 150 Pa (0.5 to 0.6 inches water column).
 - d. Design the duct system to a static pressure across the fan of no more than 150 Pa (0.6 inches w.c.).
 - e. Consider upsizing the evaporator coil relative to the condenser to reduce the static pressure drop. This results in better airflow and slightly better capacity and efficiency. Manufacturers commonly provide performance data for such condenser coil combinations.
 - f. Consider specifying an air handler with a better quality fan motor.
5. Install a large grill area and use proper filter for the system; using a higher MERV filter than needed unnecessarily increases the static pressure.
6. Locate registers and equipment to make duct runs as short as possible.
7. Make all short-radius 90-degree bends out of rigid ducting.
8. Install flex duct properly by stretching all flex duct tight and cut off excess ducting, ensure the duct is not kinked or compressed, ensure flex duct is properly supported every four feet or less using one inch strapping having less than two inches of sag between supports.

Consider using better quality supply and filter grilles. “Bar-type” registers have considerably better airflow performance than standard “stamped-face” registers. Refer to manufacturer’s specifications and select accordingly.

Energy Standards Tables 150.0-B and C (Table 4-10 and Table 4-11) allow for only one or two returns. There may be times where three returns are necessary on a single system. Furthermore, Table 150.0-C does not allow for deviation from the two sizes specified. For example, the table requires two 16" return ducts for a 3.5-ton system, but specific airflow requirements and architectural constraints may dictate something more like a 20" and a 14". In this situation, the designers would have to rely on standard engineering principles and trust their design to pass the diagnostic tests.

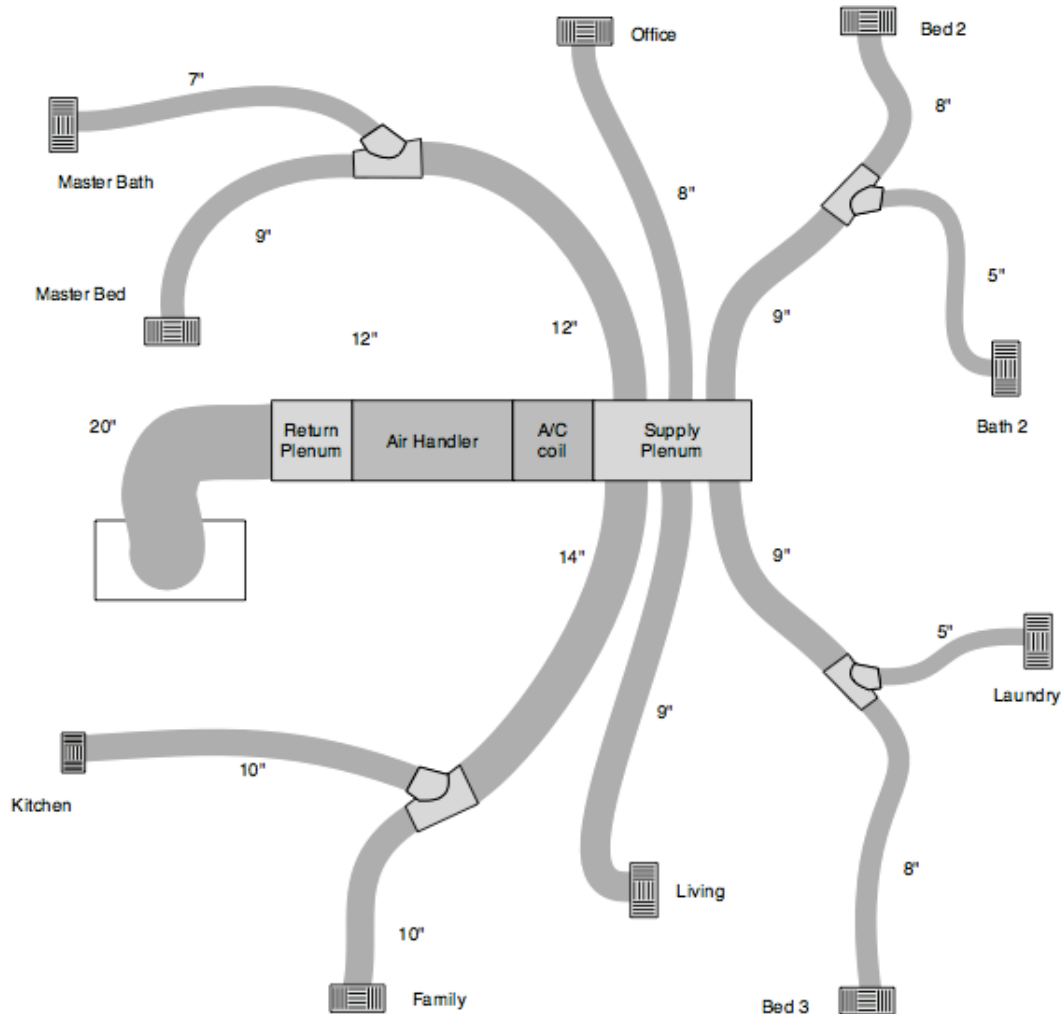
Having adequate room to run properly sized ducts has always been an issue. Historically, duct systems have been sized to fit into the home at the expense of proper airflow. The performance of these systems, in terms of efficiency and capacity, has suffered greatly because of this practice. It is the intent of these Standards to change these practices. The home should be designed to accommodate properly sized ducts. This requires improved coordination among the architect, structural engineer, and mechanical designer earlier in the process. This is not "best practice"; this is simply good design.

Tables 150.0-B and C require use of return grilles that are sized to achieve a reasonable face velocity and static pressure drop. Tables 150.0-B and C also require the return grille devices to be labeled in accordance with the requirements in §150.0(m)12A to disclose the design airflow rate of the grille determined taking into account a maximum allowable clean-filter pressure drop of 12 Pa (0.05 inches water) for the air filter media. The nominal size of the air filter grille or air filter media should be used to calculate the return filter grille gross area for determining compliance with Tables 150.0-B and C. The nominal size of the filter grille is expected to be the same as the nominal size of the air filter media that is used in the grille, and is most often the information used to identify these items for purchases. For example, a nominal 20 inch by 30 inch filter grille will use nominal 20 inch x 30 inch air filter media.

4.4.1.16 Return Duct Sizing Example

The mechanical contractor for a new home submitted the following mechanical design to the builder. It was designed using typical design specifications (400 cfm/ton at 125 Pa (0.5" w.c., friction rate = 0.1, etc.). The system is has 4-ton condenser, and the air handler is rated for 1,600 cfm.

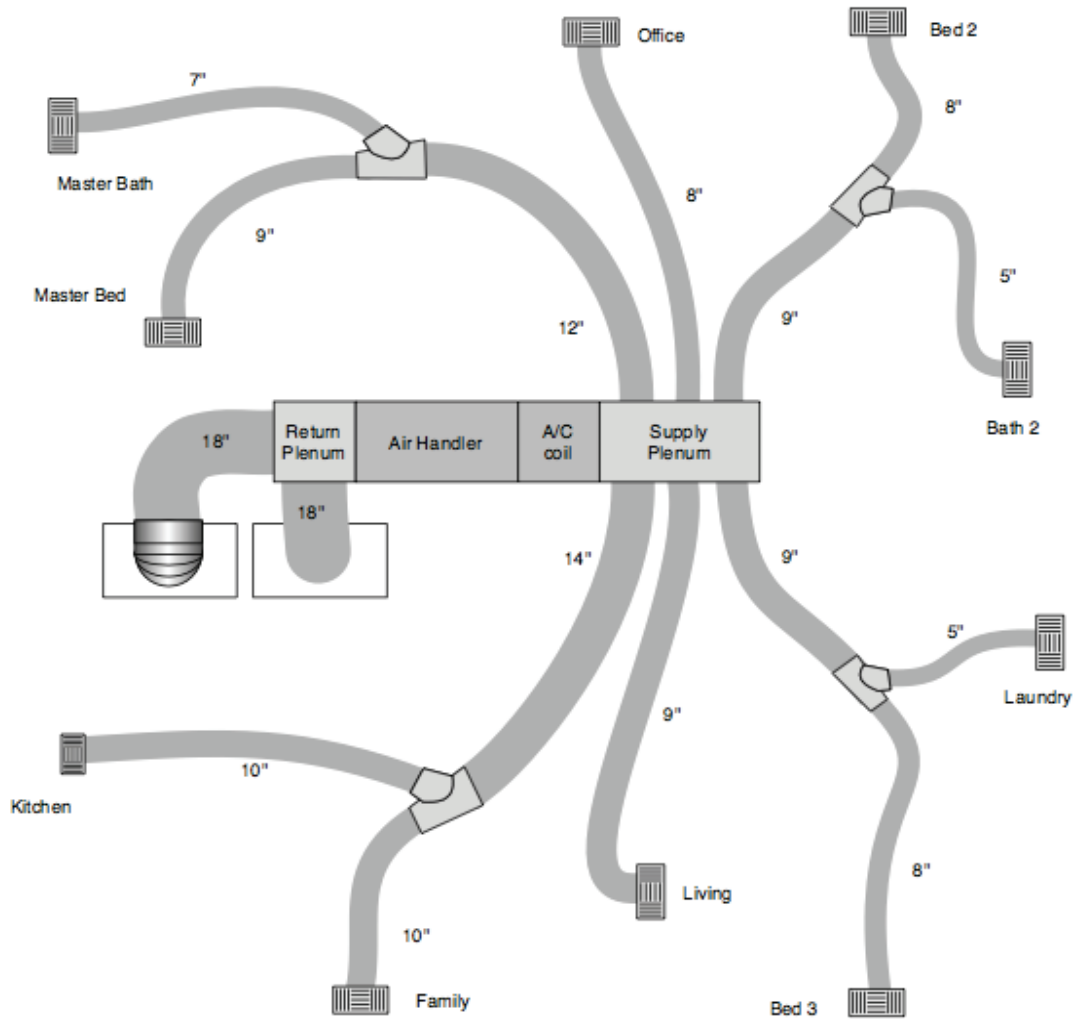
Figure 4-6: Return Duct Design Option 1



Source: California Energy Commission

Because the builder has specified a low-end air handler, he or she is concerned that the system may not pass the mandatory diagnostic testing requirement for airflow and fan efficacy. The builder requests that the system be redesigned with the return ducts sized according to Table 150.0-C. The following layout is the redesigned system (Figure 4-7). The only change is that the system now has two 18" return ducts and two filter grilles sized according to Table 150.0-C, rather than a single 20" return duct and a filter grille sized according to the manufacturer's specifications for 1,600 cfm. Because one of the return ducts had more than one 90 degree bend, one of the bends is required to be a metal elbow (to be insulated). The two return filters are 20"x30" each and are rated by the manufacturer to show that they have a pressure drop of less than 125 Pa (0.5" w.c.) at 800 cfm each.

Figure 4-7: Return Duct Design Option 2



Source: California Energy Commission

Table 4-10: Return Duct Sizing for Single Return Duct Systems

System Nominal Cooling Capacity (Ton)	Minimum Return Duct Diameter (inch)	Minimum Total Return Filter Grille Gross Area (Inch ²)
1.5	16	500
2.0	18	600
2.5	20	800

From Table 150-B of the Energy Standards

Table 4-11: Return Duct Sizing for Multiple Return Duct Systems

Two Returns			
System Nominal Cooling Capacity (Ton)	Return Duct 1 Minimum Diameter (inch)	Return Duct 2 Minimum Diameter (inch)	Minimum Total Return Filter Grille Gross Area (inch².)
1.5	12	10	500
2.0	14	12	600
2.5	14	14	800
3.0	16	14	900
3.5	16	16	1000
4.0	18	18	1200
5.0	20	20	1500

From Table 150-C of the Energy Standards

4.4.1.17 Zonally Controlled Central Forced Air Cooling Systems

The primary purpose of zoning ducted air conditioners, heat pumps, and furnaces is to improve comfort. Increased comfort is attained by having the capacity of the HVAC system (cooling or heating delivered) follow the shift in load as it changes across the house. For example, it is common for two-story homes to be too hot on the second floor in both summer and winter. Zoning has the capability of diverting more of the HVAC capacity to the area with the increased load. Another common example is a home with a significant area of west-facing and east-facing windows. In the summer, the east rooms overheat in the morning, and the west rooms overheat in the afternoon.

Providing the most agreeable temperature to all the zones is comfortable, but it carries with it the distinct possibility of increased energy consumption. Since the most common home is single-zoned and has only one thermostat placed near the center of the house, temperatures in the rooms distant from that thermostat will vary, sometimes significantly. If zoning is added, the more distant rooms may be conditioned to a more comfortable temperature. This increased conditioning requires more energy. When designed correctly, zoning allows only the zones that need conditioning to be conditioned, thus potentially saving energy.

It is common for zonally controlled central forced air cooling systems to produce lower airflow through the returns thus lowering the sensible efficiency of the single-stage heating or cooling equipment. There are two primary methods by which the common multizoned dampered system lowers airflow: additional restriction of zoning dampers and recirculation through the air conditioner from a bypass duct. To avoid this efficiency problem, zonally controlled central forced air cooling systems using a single-speed air conditioner must simultaneously meet the following criteria:

1. In every zonal control mode, the system shall provide airflow through the return grilles that is equal to or greater than 350 CFM per ton of nominal cooling capacity.
2. In every zonal control mode, the fan watt draw must be less than or equal to 0.58 watts per CFM.

The airflow and fan watt draw must be HERS-verified. See Reference Residential Appendix RA3.3 for the HERS verification procedures.

Zonally controlled central forced air cooling systems with multispeed or variable speed compressors need to be verified only to meet the above 350 CFM per nominal ton and 0.58 watts per CFM criteria with the compressor on high speed and all zones calling for cooling.

4.4.1.18 Zoned Systems and Airflow and Fan Efficacy Requirements

Recent studies have shown that zoned systems (multiple zones served by a single air handler with motorized zone dampers), with or without bypass dampers, usually do not meet the AF/FE requirements when fewer than all zones are calling. The energy penalty that results from this is greater than the benefit of having zonal control; therefore zonal control is no longer simply assumed to be a “better than minimum” condition, and there are special compliance requirements for them. Zonal control accomplished by using multiple single-zone systems is not subject to these requirements.

There are two choices for modeling zoned systems. One is for air conditioning condensers that have single-speed compressors, and the other is for condensers that have “multispeed” compressors. Two-speed and variable-speed compressors are considered multi-speed. Multispeed compressors allow the system capacity to vary to more closely match reduced cooling loads when fewer than all zones are calling for cooling. Therefore, multispeed compressor systems are given special consideration when used in zoned systems and are not required to verify performance in all zonal control modes. Instead, the airflow and fan efficacy testing is required to be performed only at the highest speed with all zones calling. Zoned systems with single-speed compressors must be tested and pass in all operating modes.

Because zoned systems, with or without bypass dampers, are less likely to meet the AF/FE requirements when fewer than all zones are calling, a way is provided in the performance compliance option to take this penalty and still allow use of zone dampers. Other energy features must offset the penalty. In the performance compliance software, if the system is modeled as a zoned system with a single-speed compressor, the default airflow drops to 150 CFM/ton. The standard house is assumed to have an airflow of 350 CFM/ton, so there is definitely a penalty unless the designer specifies a value of 350 or higher. Entering a value between 150 and 350 can lessen the penalty.

It is extremely important that the energy consultant model airflow and fan efficacy values are reasonable and obtainable; otherwise they will fail in the field and will need to be remodeled at actual values. Energy consultants should coordinate with the HVAC designer before registering the certificate of compliance.

Note: Bypass dampers may be installed only if the certificate of compliance specifically states that the system was modeled as having a bypass damper.

Example:

1. A home is to be built with a zoned system (two zones) with a single-speed compressor and bypass ducts. From experience, the HVAC contractor knows that it will not be possible to meet the 350 CFM/ton requirement, but 275 CFM/ton is likely.
2. The energy consultant models the system in the proposed house with 275 CFM/ton (better than default) and 0.58 W/CFM (default). Because the standard house assumes 350 CFM/ton, there is an energy penalty that must be made up with other better-than-standard features, but it is not nearly as bad as it would be at the default of 150 CFM/ton.
3. Because 275 CFM/ton is better than the default of 150, it must be tested in all individual control modes. Because the modeled fan efficacy is the default value, it needs to be tested only with all zones calling. If a better than default value was modeled for fan efficacy, it would need to be tested in all zonal control modes.
4. The home is built and the system is verified by a rater and passes at 287 CFM/ton with one zone calling, 298 CFM/ton with the other zone calling, and 372 CFM/ton with both

zones calling. It must still meet the mandatory requirements of 350 cfm/ton with all zones calling.

5. If this same home was to be built with a multispeed compressor, it would have to be tested only with both zones calling whether it has a bypass damper, but the target airflow would be no less than 350 CFM/ton. Compliance credit can be achieved by modeling airflows greater than 350 CFM/ton and/or fan efficacies less than 0.58 watts/CFM.

Table 4-12: Single-Zone Ducted Central Forced Air Cooling Systems

Single-Zone Ducted Cooling Systems (Single Zone Off of a Single Air Handler)			
Compressor Type	Mandatory Requirements for Airflow and Fan Efficacy	Performance Compliance Option	
		Proposed System Defaults	Modeled Improved Airflow and/or Fan Efficacy
Single Speed and Two Speed or Variable Speed (Testing Performed on Highest Speed only)	Airflow ≥ 350 CFM/ton, and Fan Efficacy ≤ 0.58 W/CFM (Airflow and Fan Efficacy testing not required if Return System Sized to Tables 150.0-B or C, but verification of sizing is required)	350 CFM/ton and 0.58 W/CFM	Airflow ≥ 350 CFM/ton and/or Fan Efficacy ≤ 0.58 W/CFM

Source: California Energy Commission

Table 4-13: Zonally Controlled Central Forced Air Cooling Systems

Zoned Ducted Cooling Systems (Multiple Zones Off a Single Air Handler)			
Compressor Type	Mandatory Requirements for Airflow and Fan Efficacy ¹	Performance Compliance ²	
		Proposed System Defaults ³	Modeled Improved Airflow and/or Fan Efficacy
Single Speed	Airflow ≥ 350 CFM/ton and Fan Efficacy ≤ 0.58 W/ CFM (For Prescriptive Compliance Method, verification is mandatory in all zonal control modes. For Performance Compliance Method, verification is mandatory using highest capacity with all zones calling)	150 CFM/ton and 0.58 W/CFM	Airflow ≥ 150 CFM/ton and/or Fan Efficacy ≤ 0.58 W/CFM (Verification of better-than-default values required in all individual control modes. Mandatory requirement of 350 CFM/ton and 0.58 W/CFM still applies for all zones calling)
Two Speed or Variable Speed	Airflow ≥ 350 CFM/ton and Fan Efficacy ≤ 0.58 W/ CFM (Verification Required Only on Highest Capacity and with All Zones Calling)	350 CFM/ton and 0.58 W/CFM	Airflow ≥ 350 CFM/ton and/or Fan Efficacy ≤ 0.58 W/CFM (Verification of modeled improved values required only on Highest Capacity and with All Zones Calling)
¹ For the Prescriptive Compliance Method, all Mandatory Requirements for airflow and fan efficacy must be met, and use of a bypass duct is not allowed. ² For the Performance Compliance Method, all Mandatory Requirements for airflow and fan efficacy must be met, and use of a bypass duct may be specified in the compliance software input for the zoned system type. ³ The Standard System Default for all cases is 350 CFM/ton and 0.58 W/CFM.			

Source: California Energy Commission

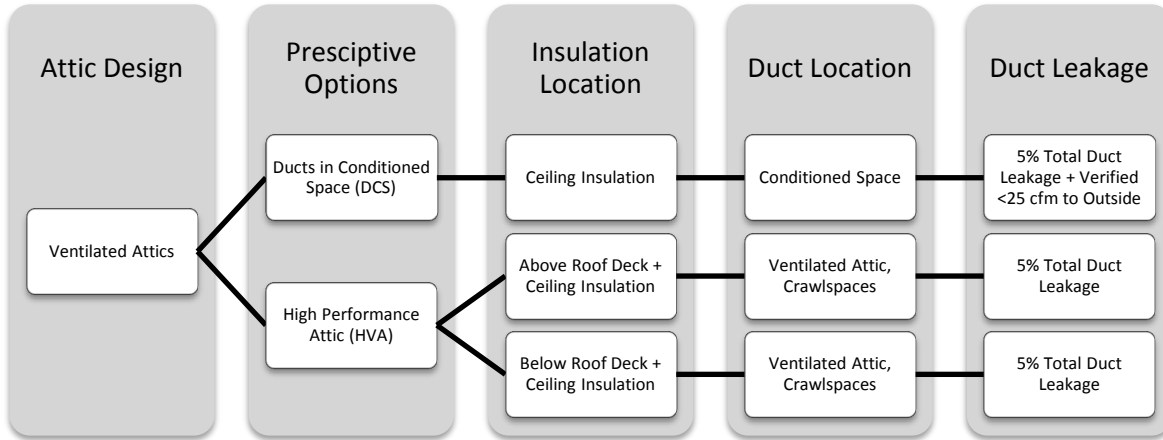
4.4.1.19 Indoor Air Quality and Mechanical Ventilation

§150.0(o)

See Section 4.6 of this chapter for details.

4.4.2 Prescriptive Requirements for Air Distribution System Ducts, Plenums, and Fans

The *2016 Energy Standards* are designed to offer flexibility to the builders and designers of residential new construction in terms of achieving the intended energy efficiency targets. As such, several options are offered for achieving one of two design objectives related to improving energy performance of homes built with ventilated attics in Climate Zones 4, 8-16 as shown in Figure 4-8.

Figure 4-8: Ventilated Attic Prescriptive Compliance Choices

Source: California Energy Commission

High-performance attic (HPA) implements measures that minimize temperature difference between the attic space and the conditioned air being transported through ductwork in the attic. The package consists of insulation either below the roof deck or insulation above the roof deck in addition to insulation at the ceiling, R-8 ducts, and 5 percent total duct leakage of the nominal air handler airflow. These requirements and approaches to meet the requirements are explained in Section 3.6.2 of this manual.

Ducts in conditioned space (DCS) is achieved when the ducts and air handler(s) are within the thermal envelope and air barrier of the building. This DCS option requires field verification in order to meet the prescriptive requirement. The following sections describe the duct related requirements for DCS.

4.4.2.1 Duct Location

§150.1(c)9

Standard residential construction practice in California is to place ducts and associated air handling equipment in the attic. When meeting the prescriptive requirements for the Energy Standards, there are two options for where this equipment can be located:

1. If meeting the prescriptive requirements of the high-performance attic (HPA) as explained above, the duct system and air handlers of HVAC systems are allowed to be located in the attic.
2. If meeting the prescriptive requirements of the ducts in conditioned space (DCS) as explained above, the duct system and air handlers of HVAC systems must be located in conditioned space, which includes a joist cavity between conditioned floors, or in sealed cavity below attic insulation.

If the DCS requirements are to be met, additional requirements apply:

1. Air handlers containing a combustion component should be direct-vent (sealed combustion chambers), and shall not use air from conditioned space as combustion air. Other types of combustion heating systems are possible given the system installer adheres to the combustion air requirements found in Chapter 7 of the California Mechanical Code.

2. Duct location needs to be verified through a visual inspection per Reference Residential Appendix RA 3.1.4.1.3.
3. Duct leakage to outside needs to be confirmed by field verification and diagnostic testing in accordance with Reference Residential Appendix RA3.1.4.3.8.
4. Ducts are insulated to a level required in Table 150.1-A.

Figure 4-9: Checklist for Prescriptive Requirement – Option C DCS (§ 150.1(c)1)

<p>§150.1(c)1 Option C (CZ 4, 8-16)</p> <ul style="list-style-type: none"> <input type="checkbox"/> Vented attic <input type="checkbox"/> R30 or R38 ceiling insulation (climate zone specific) <input type="checkbox"/> R6 or R8 ducts (climate zone specific) <input type="checkbox"/> Radiant Barrier <input type="checkbox"/> Verified ducts in conditioned space

Source: California Energy Commission

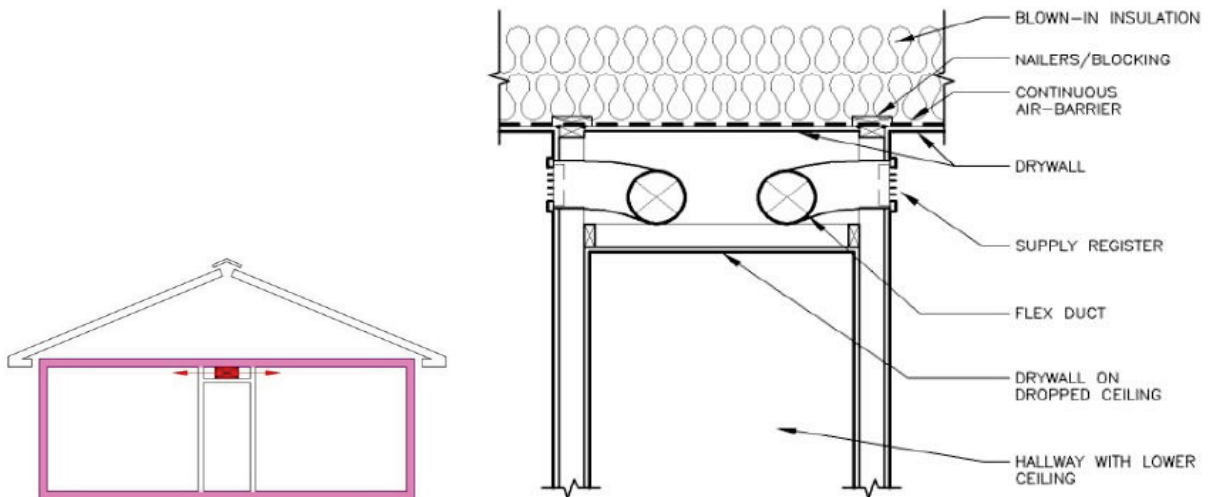
The checklist in Figure 4-9 lists all the prescriptive DCS requirements that must be met to meet prescriptive requirements using DCS strategy. It is not enough to only locate ducts in conditioned space, but insulation must also meet prescriptive values. If a building is not able to meet all of the requirements in this checklist, it must use the performance approach or Option A or B from the §150.1(c).1. Refer to Section 3.6 of the *Residential Compliance Manual* for more information on these options.

There are several methods of achieving the goal of DCS. The basic information of the strategies, their benefits, challenges, and potential solutions to those challenges are outlined below.

A. Vented Attic, Dropped Ceiling

This strategy places ducts within the thermal envelope without affecting the standard construction of the attic space. This strategy works well in linear plans where rooms branch out from a central hallway with the dropped ceiling.

Figure 4-10: Ducts in Conditioned Space using a Dropped Ceiling



Source: www.ductsinside.org/

Figure 4-11: Ducts Routed through a Dropped Ceiling

Source: BIRA Energy

Benefits of selecting this strategy include the following:

1. Attic ventilation remains the same as standard practice.
2. Does not affect attic assembly or insulation; no changes to truss design.
3. Works with simple and linear designs with rooms off main hallway but can work with more complex plans.
4. Can be integrated into architectural accents.

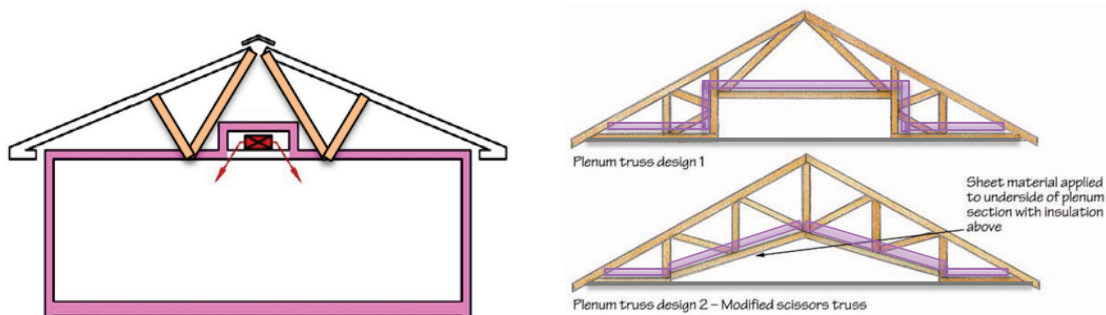
There are challenges associated with this strategy as outlined below, but they can be overcome with good design and installation practices.

1. Need to address air handler location – there may not be sufficient space (height, width) in the dropped ceiling to accommodate the air handler. In this case, the air handler would need to be installed in a separate closet within the thermal boundary of the home.
2. Coordination needed between trades – moving the ducts and air handlers and the need to isolate and seal the dropped ceiling would necessitate coordination between different trades (HVAC installer, dry-wall, framing, and electrical contractors) to ensure thermal integrity of the dropped ceiling.

B. Vented Attic, Conditioned Plenum Space

A conditioned plenum is created when a space within the attic is sealed off and insulated from the rest of the attic. To use this design option, a builder can specify two types of modified trusses: either scissor trusses or a truss configuration that creates a plenum box. Another way to create a conditioned plenum does not involve modified trusses, but rather to create the space by framing, sealing and insulating the plenum space above the ceiling plane.

Figure 4-12: Plenum Truss Design Example



Source: www.ductsinside.org

Similar to a dropped ceiling, this design is easier with a linear plan that allows for the conditioned space in the attic to cover a central “spine” throughout the floor plan that can reach all spaces in need of supply registers. This design option allows for ducts in the attic space and does not affect aesthetics of the home.

Benefits for selecting the strategy:

1. Vented attic space, same as standard construction
2. Aesthetically less disruptive than dropped ceiling
3. Works with simple and linear designs with rooms off main hallway

There are challenges associated with this strategy as outlined below, but they can be overcome with good design and installation practices.

1. Need to seal the plenum from attic – as with most of the DCS strategies, it is important that care and attention is provided to air sealing the plenum space from the attic space.
2. May require modified trusses in which case manufacturers need to be provided with specifications that can be met.

C. Vented Attic, Open Web Floor Truss

Figure 4-13: Open Web Floor Truss Example



Source: www.ductsinside.org

This option can work for two-story construction and makes use of the space between floors to house ducts. Open-web floor trusses are not a common component in residential construction but are available from several floor joist manufacturers. The depth of floor joists may need to be increased to create a large enough space for supply ducts. The

increased joist depth may affect interior details and wall heights. Because of the size constraints from using the floor truss, there is a need to preserve construction quality and prevent undesirable construction practices such as forcing 14" ducts into a 12" joist spaces. Another option is to use alternatives to wire helix plastic flexible ducts that take up less space. Coordination between the architect and the HVAC engineer and/or contractor is needed to ensure that ducts are correctly sized and truss depths are appropriately selected. Using the area between floors to house ducts prescribes that supply registers be at the floor or lower wall in the second story and the ceiling or upper wall in the first story.

D. Mechanical Closet (and Placement of Sealed Combustion Furnace)

Figure 4-14: Mechanical Closet Placement Example



Source: IBACOS 2013

As part of the requirement for moving the duct system and air handler into a conditioned space, construction of a mechanical closet is necessary with some DCS strategies. For example, if ducts are placed in dropped ceiling space but there is not enough room to accommodate the air handler in that space, the mechanical closet could be placed inside the thermal boundary of the building. A conditioned plenum could provide enough space for ducts and equipment; therefore, a mechanical closet may not be needed.

One potential location for a mechanical closet is within the garage or other spaces normally not conditioned. In such instances, the air handler must be located within a specially built closet that is insulated to the same level as the exterior of the house so that the closet is not a part of the unconditioned space. Combustion air for the air handler must be taken directly from the outside through a direct vent to the outside.

4.4.2.2 Duct Insulation

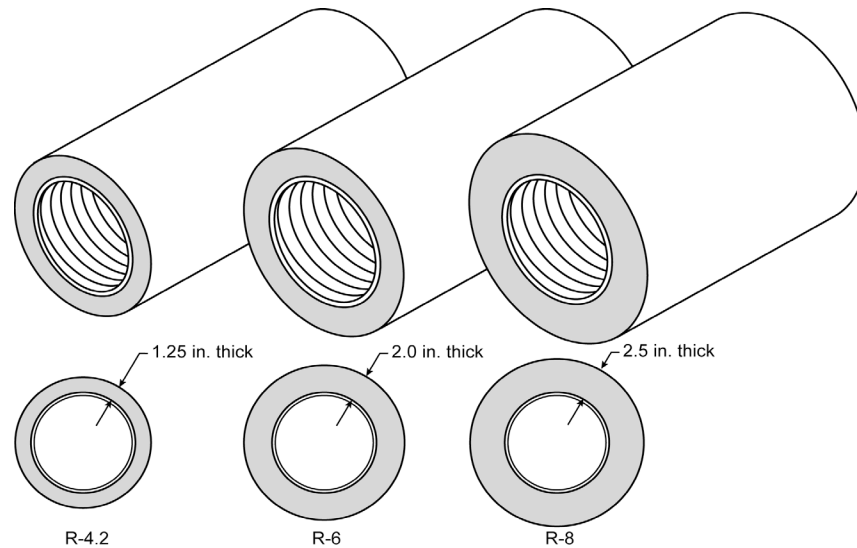
§150.1(c)9

All ducts shall be insulated to a minimum installed level as specified by Table 150.1-A, which requires either R-6 or R-8 depending on the climate zone and whether Option A/B or Option C is chosen for Roof/Ceiling Insulation. Since R-6 is the mandatory minimum for ducts in unconditioned space and R-4.2 for ducts in conditioned space, the prescriptive duct insulation requirement can be opted out by using the performance approach and trading off the energy penalty against some other features.

4.4.2.3 Central Fan Integrated (CFI) Ventilation

There is a prescriptive requirement for ducted systems that have cooling and a CFI ventilation system to have the fan efficacy verified. This can be opted out using the performance approach.

Figure 4-15: R-4.2, R-6, and R-8 Ducts



Source: California Energy Commission

4.4.3 Compliance Options for Air Distribution System Ducts, Plenums, and Fans

The Energy Standards provide credit for several compliance options related to duct design and construction.

4.4.3.1 System Airflow and Fan Efficacy

A performance compliance credit is available for demonstrating the installation of a high-efficiency fan and duct system with better performance than the mandatory requirement of 350 cfm/ton and 0.58 watts/cfm. This credit can be achieved by selecting a unit with a high-efficiency air handler fan and/or careful attention to efficient duct design. The performance compliance method allows the user's proposed fan power to be entered into the program, and credit will be earned if it is lower than the default of 0.58 watts per CFM of system airflow. To obtain this credit, the system airflow must meet the prescriptive requirements of at least 350 CFM/ton of nominal cooling capacity. After installation, the contractor must test the actual fan power of each system using the procedure in *Reference Residential Appendix RA3.3* and show that it is equal or less than what was proposed in the compliance software analysis.

The watt draw and airflow must also be verified by a HERS Rater.

4.4.3.2 Duct Location

There are three ways to achieve credit for favorable duct location when using the performance compliance method:

1. Credit is available if no more than 12 LF (linear feet) of duct are outside the conditioned space and the user chooses the high-performance attic (HPA) as explained in Section 3.6.2. This total must include the air handler and plenum lengths.

This credit results in a reduction of duct surface area in the computer compliance programs. This option requires certification by the installer and field verification by a HERS Rater.

2. The second alternative applies when 100 percent of the ducts are located in conditioned space and the user chooses high-performance attic (HPA) as explained in Section 3.6.2. This credit results in eliminating the conduction losses associated with both the return and supply ducts; however, leakage rates still apply. This option requires field verification of the duct system by means of a visual inspection by a HERS Rater.
3. Credit for a high-efficiency duct design is available through the diagnostic duct location, surface area, and R-value compliance option, which are described below. This option requires field verification of the duct design layout drawing(s) by a HERS Rater. Verified duct design, when required, will be included in the HERS Required Verification list on the certificate of compliance (CF-1R). This approach provides energy savings credits for having shorter duct runs, fewer ducts, ducts in beneficial locations of ductwork, and other benefits of a well-designed duct system. This credit is available regardless of whether a high-performance attic (HPA) or ducts in conditioned space (DCS) option is chosen, as explained in Section 3.6.2.

There is no compliance credit provided for choosing a heating system such as a wall furnace, floor heater, or room heater, even though those systems typically have no ducts. For these cases, the standard design in the compliance calculation uses the same type of system and has no ducts. However, other systems, such as hydronic heating systems with a central heater or boiler and multiple terminal units, are considered central HVAC systems that are compared to a ducted system in the standard design. If the hydronic system has no ducts, there may be a significant energy credit through the performance method.

4.4.3.3 Duct Insulation

Performance credit is also available if all of the ducts are insulated to a level higher than required by the prescriptive package. If ducts with multiple R-values are installed, the lowest duct R-value must be used for the entire duct system. However, the air handler, plenum, connectors, and boots can be insulated to the mandatory minimum R-value.

As an alternative when there is a mix of duct insulation R-values, credit is available through the method described in the next section.

4.4.3.4 Diagnostic Duct Location, Surface Area, and R-value

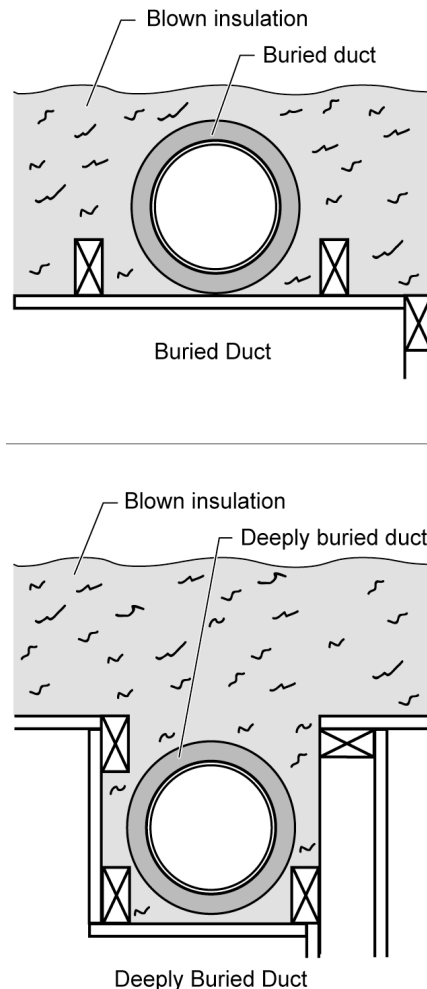
This compliance option allows the designer to take credit for a high-efficiency duct design that incorporates duct system features that may not meet the criteria for the duct location and/or insulation compliance options described above. This method requires that the designer must enter the design characteristics of all ducts that are not located within the conditioned space. The information required for the input to the compliance software includes the length, diameter, insulation R-value, and location of all ducts. This method will result in a credit if the proposed duct system is better than the standard design.

To claim this credit, the duct system design must be documented on plans that are submitted to the enforcement agency and posted at the construction site for use by the installers, the enforcement agency field inspector, and the HERS Rater. The duct system must be installed in accordance with the approved duct system plans, and the duct system installation must be certified by the installer on the CF2R form and verified by a HERS Rater on the CF3R form. Details of this compliance option are described in the *Residential ACM*

Reference Manual, and verification procedures are described in RA3.1 of the Reference Residential Appendix.

4.4.3.5 Buried and Deeply Buried Ducts

Figure 4-16: Buried Ducts on Ceiling and Deeply Buried Ducts



Source: California Energy Commission

This compliance option also allows credit for the special case of ducts that are buried by blown attic insulation. For ducts that lie on the ceiling (or within 3.5 inch of the ceiling), the effective R-value is calculated based on the duct size and the depth of ceiling insulation as shown in Table R3-38 in the *Residential ACM Manual*. This case is referred to as “Buried Ducts on the Ceiling.” For the case of deeply buried ducts, which are ducts that are enclosed in a lowered portion of the ceiling and completely covered by attic insulation, then the effective R-value allowance in the compliance calculations is R-25 when the attic insulation is fiberglass and R-31 for cellulose attic insulation. To take credit for buried ducts, the system must meet the verified duct design criteria described above, be diagnostically tested for duct sealing compliance by a HERS Rater according to Reference Residential Appendix RA3.1, and meet the requirements for high insulation installation quality described in Reference Residential Appendix RA3.5. Verified minimum airflow (350 cfm/ton or higher if higher is specified on the CF1R) is required when a measure is selected for compliance that has a verified duct design as a prerequisite.

4.4.3.6 Ducts in Attics With Radiant Barriers

Installation of a radiant barrier in the attic increases the duct efficiency by lowering attic summer temperatures. Compliance credit for radiant barriers is available in cases where the prescriptive standard does not require radiant barriers and requires listing of the radiant barrier in the special features and modeling assumptions to aid the local enforcement agency's inspections. Compliance credit for a radiant barrier does not require HERS Rater verification.

4.4.4 Duct Installation Standards

The mandatory duct construction measures referenced in Section 4.4.1 above state that duct installations must comply with the California Mechanical Code Sections 601, 602, 603, 604, 605, and the applicable requirements of the Energy Standards. Some highlights of these requirements are listed in this section, along with some guidance for recommended quality construction practice.

4.4.4.1 Tapes and Clamps

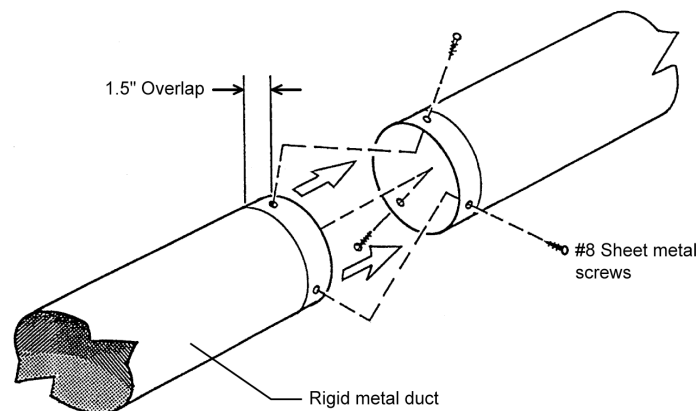
All tapes and clamps must meet the requirements of §150.0(m).

Cloth-backed, rubber-adhesive tapes must be used only in combination with mastic and draw bands, or have on its backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums and junction box joints.

4.4.4.2 All Joints Must Be Mechanically Fastened

For residential round metal ducts, installers must overlap the joint by at least 1½ inch and use three sheet metal screws equally spaced around the joint. (See Figure 4-17.)

Figure 4-17: Connecting Round Metallic Ducts

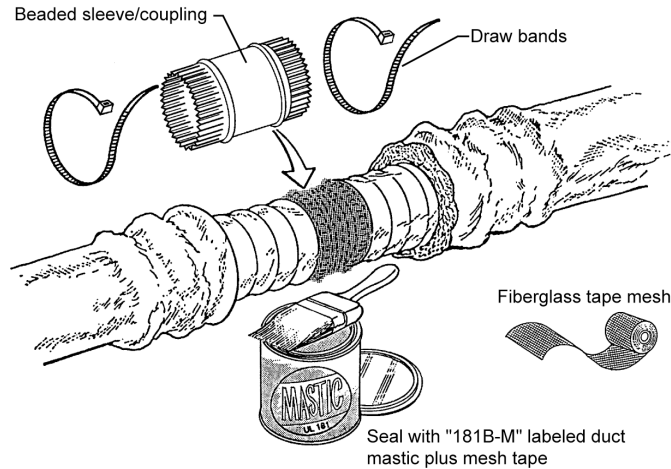


Source: Richard Heath & Associates/Pacific Gas & Electric

For round nonmetallic flex ducts, installers must insert the core over the metal collar or fitting by at least 1 in. This connection may be completed with either mesh, mastic and a clamp, or two wraps of tape and a clamp.

For a mesh and mastic connection, the installer must first tighten the clamp over the overlapping section of the core, apply a coat of mastic covering both the metal collar and the core by at least 1 in., and then firmly press the fiber mesh into the mastic and cover with a second coat of mastic over the fiber mesh. (See Figure 4-18.)

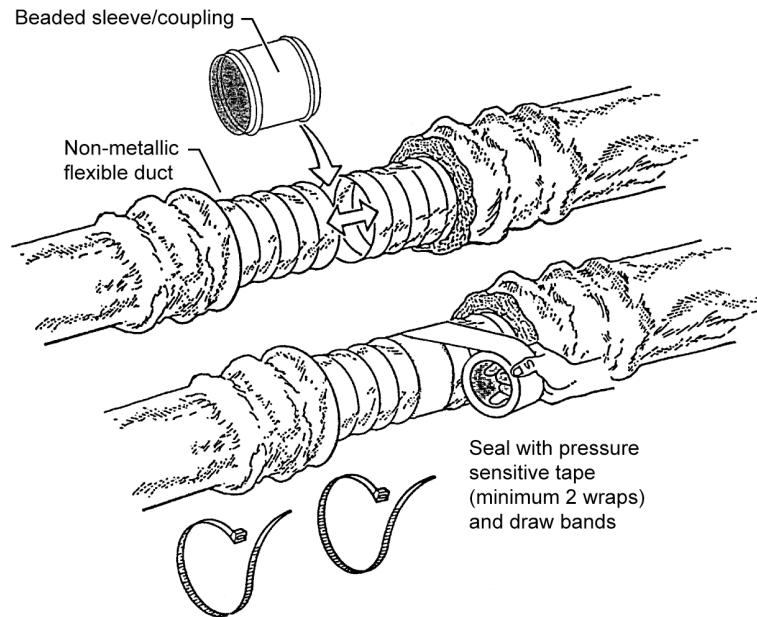
Figure 4-18: Connecting Flex Ducts Using Mastic and Mesh



Source: Richard Heath & Associates/Pacific Gas & Electric

For the tape connection first apply at least two wraps of approved tape covering both the core and the metal collar by at least 1 inch; then tighten the clamp over the overlapping section of the core. (See Figure 4-19.)

Figure 4-19: Connecting Flex Ducts Using Tape and Clamps



Source: Richard Heath & Associates/Pacific Gas & Electric

4.4.4.3 All Joints Must Be Made Airtight

§150(m)

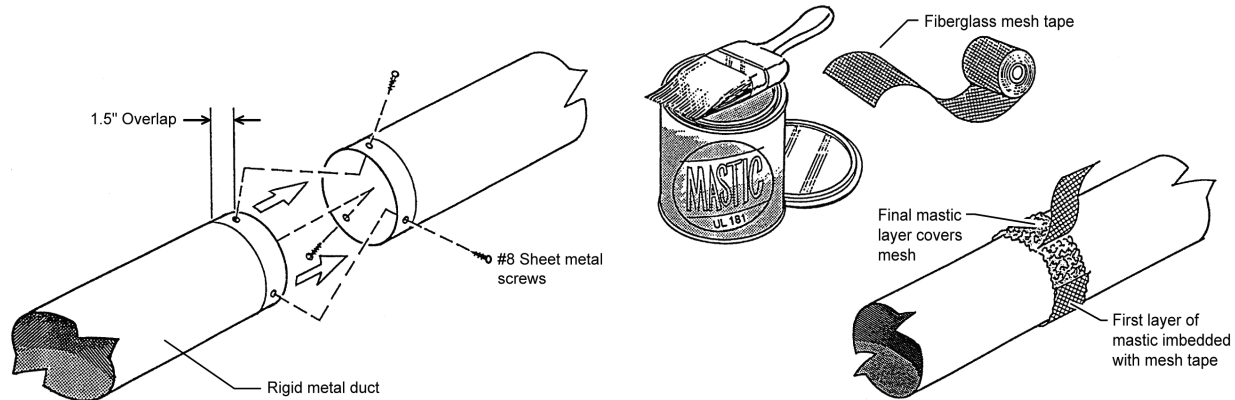
Seal all joints with either mastic, tape, aerosol sealant, or other duct-closure system that meets the applicable requirements of UL 181, UL 181A, UL 181B, or UL 723. Duct systems shall not use cloth-backed, rubber-adhesive duct tape regardless of UL designation, unless it is installed in combination with mastic and clamps. The Energy Commission has approved three cloth-backed duct tapes with special butyl synthetic adhesives rather than rubber adhesive to seal flex duct to fittings. These tapes are:

1. Polyken 558CA, Nashua 558CA, manufactured by Berry Plastics Tapes and Coatings Division.
2. Shurtape PC 858CA, manufactured by Shurtape Technologies, Inc.

These tapes passed Lawrence Berkeley Laboratory tests comparable to those that cloth-backed, rubber-adhesive duct tapes failed. (The LBNL test procedure has been adopted by the American Society of Testing and Materials as ASTM E2342.) These tapes are allowed to be used to seal flex duct to fittings without being in combination with mastic. These tapes cannot be used to seal other duct system joints, such as the attachment of fittings to plenums and junction boxes. These tapes have on the backing 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 packing boxes that explain how to install them on duct core to fittings, and a statement that the tapes cannot be used to seal fitting to plenum and junction box joints.

Mastic and mesh should be used where round or oval ducts join flat or round plenums. (See Figure 4-20.)

Figure 4-20: Sealing Metallic Ducts With Mastic and Mesh



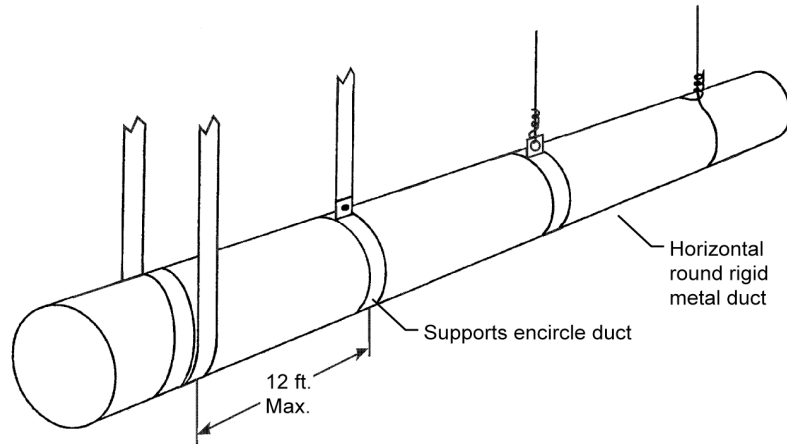
Source: Richard Heath & Associates/Pacific Gas & Electric

All ducts must be adequately supported.

Both rigid duct and flex duct may be supported on rigid building materials between ceiling joists or on ceiling joists.

For rigid round metal ducts that are suspended from above, hangers must occur 12 ft. apart or less. (See Figure 4-21)

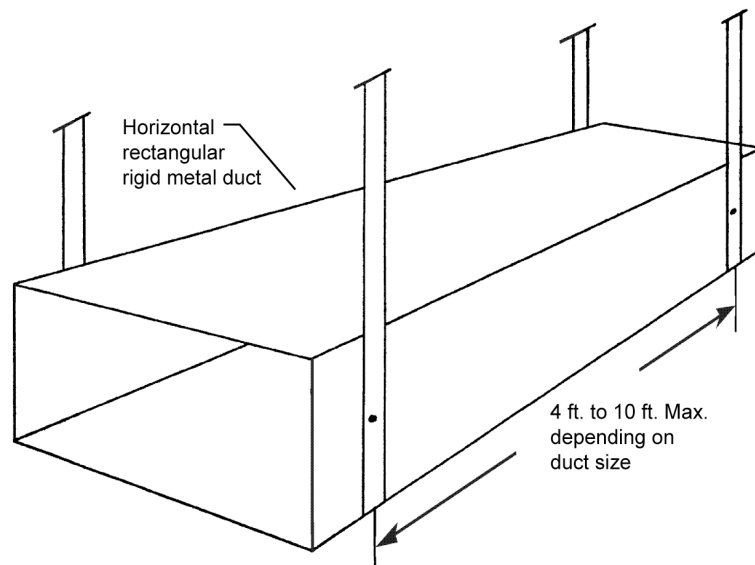
Figure 4-21: Options for Suspending Rigid Round Metal Ducts



Source: Richard Heath & Associates/Pacific Gas & Electric

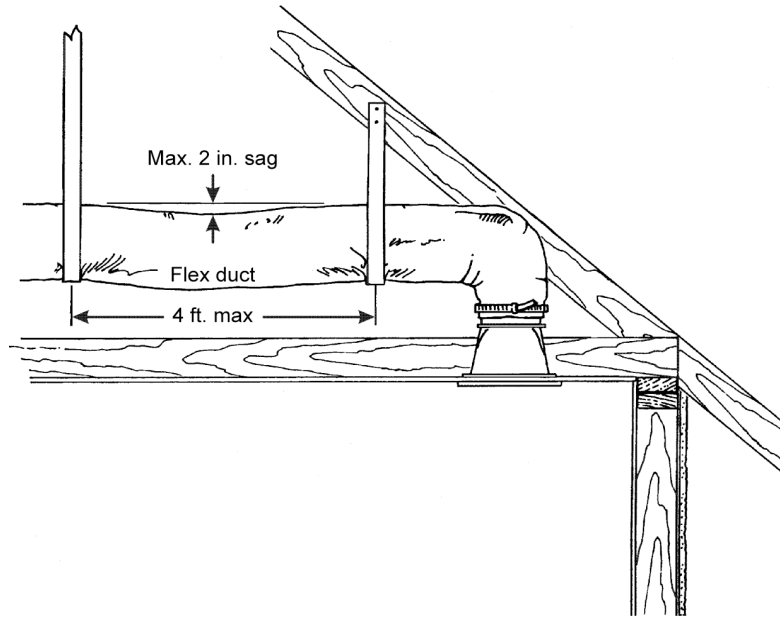
For rectangular metal ducts that are suspended from above, hangers must occur at a minimum of 4 ft. to 10 ft., depending on the size of the ducts. (See Table 6-2A in Appendix A of the California Mechanical Code and refer to Figure 4-22.)

Figure 4-22: Options for Suspending Rectangular Metal Ducts



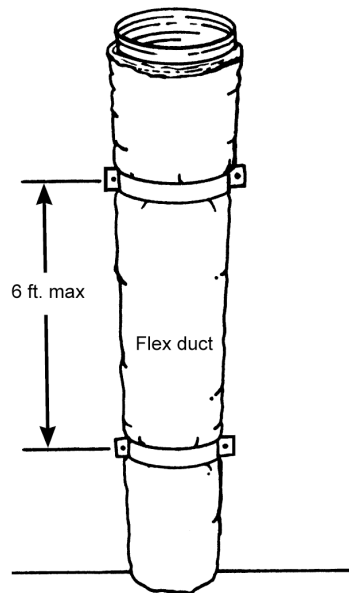
Source: Richard Heath & Associates/Pacific Gas & Electric

For flex ducts that are suspended from above, hangers must occur at 4 ft. apart or less and all fittings and accessories must be supported separately by hangers. (See Figure 4-23.)

Figure 4-23: Minimum Spacing for Suspended Flex Ducts

Source: Richard Heath & Associates/Pacific Gas & Electric

For vertical runs of flex duct, support must occur at 6 ft. intervals or less. (See Figure 4-24)

Figure 4-24: Minimum Spacing for Supporting Vertical Flex Ducts

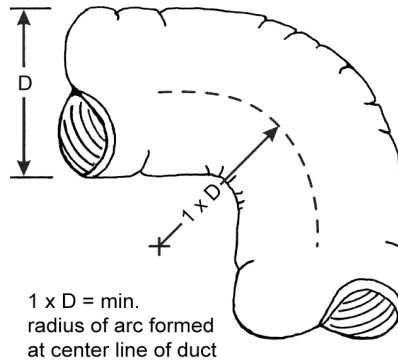
Source: Richard Heath & Associates/Pacific Gas & Electric

The routing and length of all duct systems can have significant effects on system performance due to possible increased airflow resistance. The Energy Commission recommends using the minimum length of duct to make connections and the minimum possible number of turns.

For flexible ducts, the Energy Commission recommends fully extending the duct by pulling the duct tightly, cutting off any excess duct, and avoiding bending ducts across sharp

corners or compressing them to fit between framing members. (See Figure 4-25) Also avoid incidental contact with metal fixtures, pipes, or conduits or installation of the duct near hot equipment such as furnaces, boilers, or steam pipes that are above the recommended flexible duct use temperature.

Figure 4-25: Minimizing Radius for Flex Duct Bends



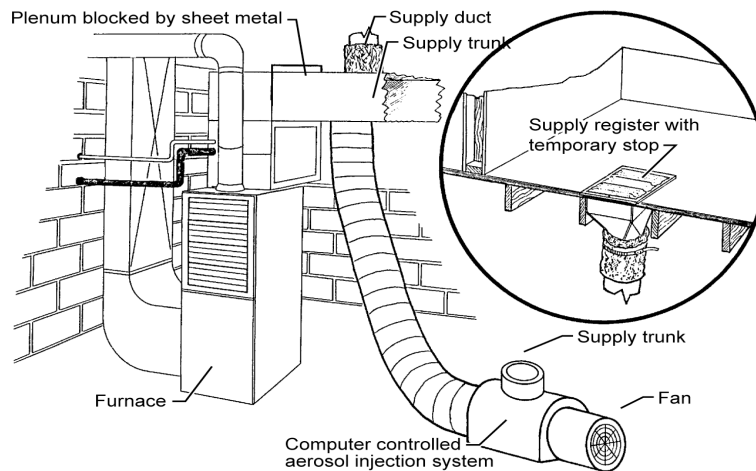
Source: Richard Heath & Associates/Pacific Gas & Electric

All joints between two sections of duct must be mechanically fastened and substantially airtight. For a flex duct, this must consist of a metal sleeve no less than 4 inches between the two sections of flex duct.

All joints must be properly insulated. For flex ducts, this must consist of pulling the insulation and jacket back over the joint and using a clamp or two wraps of tape. Aerosol sealant injection systems are an alternative that typically combines duct testing and duct sealing in one process.

Figure 4-26 shows the computer-controlled injection fan temporarily connected to the supply duct. The plenum is blocked off by sheet metal to prevent sealant from entering the furnace. Supply air registers are also blocked temporarily to keep the sealant out of the house. Ducts must still be mechanically fastened even if an aerosol sealant system is used.

Figure 4-26: Computer-Controlled Aerosol Injection System



Source: Richard Heath & Associates/Pacific Gas & Electric

4.5 Controls

4.5.1 Thermostats

Automatic setback thermostats can add comfort and convenience to a home. Occupants can wake up to a warm house in the winter and come home to a cool house in the summer without using unnecessary energy.

§110.2 (b) & (c), §150.0(i)

A thermostat is always required for central systems whether the prescriptive or performance compliance method is used. An exception is allowed only if:

1. The building complies using a computer performance approach with a non-setback thermostat.
2. The system is one of the following noncentral types:
 - a. Noncentral electric heaters.
 - b. Room air conditioners.
 - c. Room air conditioner heat pumps.
 - d. Gravity gas wall heaters.
 - e. Gravity floor heaters.
 - f. Gravity room heaters.
 - g. Wood stoves.
 - h. Fireplace or decorative gas appliances.

When it is required, the setback thermostat must have a clock or other mechanism that allows the building occupant to schedule the heating and/or cooling set points for at least four periods over 24 hours.

If more than one piece of heating equipment is installed in a residence or dwelling unit, the setback requirement may be met by controlling all heating units by one thermostat or by controlling each unit with a separate thermostat. Separate heating units may be provided with a separate on/off control capable of overriding the thermostat.

Thermostats for heat pumps must be “smart thermostats” that minimize the use of supplementary electric resistance heating during startup and recovery from setback, as discussed earlier in the heating equipment section.

Example 4-1

Question:

Am I exempt from the requirement for a thermostat if I have a gravity wall heater or any of the equipment types listed in the exception to §110.2(c)?

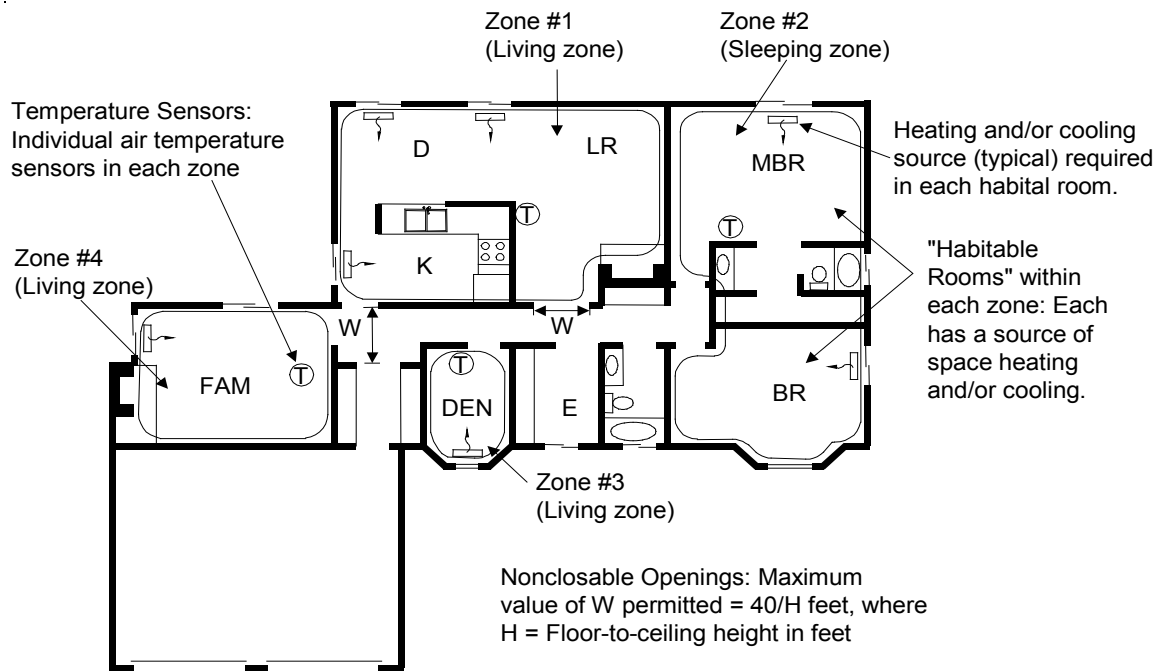
Answer:

The answer depends on the compliance approach. Under the prescriptive approach, the exception to §110.2(c) exempts gravity wall, floor and room heaters from the thermostat requirements. However, under the performance approach, the exception requires that “the resulting increase in energy use due to the elimination of the thermostat shall be factored into the compliance analysis.” This means that under the performance scenario, if the building is modeled with a nonsetback thermostat, any energy lost because of this will have to be made up using other efficiency features.

4.5.2 Zonal Control

An energy compliance credit is provided for zoned heating systems, which save energy by providing selective conditioning for only the occupied areas of a house. A house having at least two zones (living and sleeping) may qualify for this compliance credit. The equipment may consist of one heating system for the living areas and another system for sleeping areas or a single system with zoning capabilities, set to turn off the sleeping areas in the daytime and the living area unit at night. (See Figure 4-27)

Figure 4-27: Zonal Control Example



Source: Richard Heath & Associates/Pacific Gas & Electric

There are unique eligibility and installation requirements for zonal control to qualify under the Energy Standards. The following steps must be taken for the building to show compliance with the standards under this exceptional method:

1. **Temperature Sensors.** Each thermal zone, including a living zone and a sleeping zone, must have individual air temperature sensors that provide accurate temperature readings of the typical condition in that zone.
2. **Habitable Rooms.** For systems using central forced air or hydronic heating, each habitable room in each zone must have a source of space heating, such as forced air supply registers, radiant tubing, or a radiator. For systems using a combination of a central system and a gas vented fireplace or other individual conditioning units, the zone served by the individual conditioning unit can be limited to a single room. Bathrooms, laundry, halls and/or dressing rooms are not habitable rooms.
3. **Noncloseable Openings.** The total noncloseable opening area (W) between adjacent living and sleeping thermal zones (such as halls, stairwells, and other openings) must be less than or equal to 40 ft². All remaining zonal boundary areas must be separated by permanent floor-to-ceiling walls and/or fully solid, operable doors capable of restricting free air movement when closed.

4. **Thermostats.** Each zone must be controlled by a central automatic dual-setback thermostat that can control the conditioning equipment and maintain preset temperatures for varying periods in each zone independent of the other. Thermostats controlling vented gas fireplace heaters that are not permanently mounted to a wall are acceptable as long as they have the dual-setback capabilities.

Other requirements specific to forced air-ducted systems include the following:

1. Each zone must be served by a return air register located entirely within the zone. Return air dampers are not required.
2. Supply air dampers must be manufactured and installed so that when they are closed, there is no measurable airflow at the registers.
3. The system must be designed to operate within the equipment manufacturer's specifications.
4. Air is to positively flow into, though, and out of a zone only when the zone is being conditioned. No measurable amount of supply air is to be discharged into unconditioned or unoccupied space to maintain proper airflow in the system.

Although multiple thermally distinct living and/or sleeping zones may exist in a residence dwelling, the correct way to model zonal control for credit requires only two zones: a living zone and a sleeping zone. All separate living zone components must be modeled as one living zone; the same must be done for sleeping zones.

Example 4-2

Question:

In defining the living and sleeping zones for a home with a zonally controlled HVAC system, can laundry rooms and bathrooms (which are not habitable spaces) be included on whichever zone they are most suited to geographically (for example, a bathroom located near bedrooms)?

Answer:

Yes. For computer modeling purposes, include the square footage of any nonhabitable or indirectly conditioned spaces, with the closest zone.

Example 4-3

Question:

I have two HVAC systems and want to take zonal control credit. Can the return air grilles for both zones be located next to each other in the 5 ft. wide by 9 ft. high hallway (in the same zone)?

Answer:

No. Because of the need to prevent mixing of air between the conditioned zone and the unconditioned zone, it is necessary to (1) have the return air for each zone within that zone, and (2) limit any noncloseable openings between the two zones to 40 ft² or less. Unless these criteria and the other criteria listed in this chapter can be met, credit for a zonally controlled system cannot be taken.

Example 4-4

Question:

How do I model the energy efficiency of a gas-vented fireplace for zonal control heating?

Answer:

The efficiency of gas vented fireplaces is described as annual fuel utilization efficiency (AFUE) and is calculated by the manufacturer per the ANSI Z21.88-2009 Standard. Gas-vented fireplaces must meet all the other relevant requirements of zonal control.

Example 4-5

Question:

Does a gas-vented fireplace with a handheld remote thermostat meet the thermostat requirement for the two-zone modeling credit?

Answer:

Yes, as long as the thermostat has manual “on” to start, automatic setback capability, and temperature preset capability, it does not have to be permanently wall-mounted.

4.6 Indoor Air Quality and Mechanical Ventilation

§150.0(o), §150.2(a)1C, and §150.2(a)2C

As houses have been tightened up over the last several years due to rising energy cost and the availability of higher performing building materials, normal infiltration and exfiltration have significantly reduced. This condition has increased the effect of contaminants and pollutants introduced through common building materials, cleaners, finishes, packaging, furniture, carpets, clothing, and other products. The Energy Standards have always assumed adequate indoor air quality would be provided by a combination of infiltration and natural ventilation and that home occupants would open windows as necessary to make up any shortfall in infiltration. However, Energy Commission-sponsored research on houses built under the *2001 Standards* revealed that overall ventilation rates are lower than expected, indoor concentration of chemicals such as formaldehyde are higher than expected, and many occupants do not open windows regularly for ventilation. The 2013 Standards included mandatory mechanical ventilation intended to improve indoor air quality (IAQ) in homes. The *2016 Energy Standards* continue this effort.

As specified by §150.0(o), all low-rise residential buildings must meet the requirements of ASHRAE Standard 62.2-2010, including Addenda b, c, e, g, h, i, j, l, and n to ASHRAE 62.2-2010. The exception is that opening and closing windows and continuous operation of central fan-integrated ventilation systems are not allowable options for meeting whole-building ventilation requirements.

The requirements of ASHRAE Standard 62.2 focus on whole-building mechanical ventilation and local ventilation exhaust at known sources of pollutants or moisture, such as kitchens, baths, and laundries. While not required by the Energy Standards, builders and homeowners should select materials, finishes, and furnishings that have no or low emissions of air pollutants, such as formaldehyde and volatile organic compounds (VOCs), because keeping air pollutants out of the building in the first place is more effective than flushing them out later through ventilation.

Most building materials emit some level of VOCs, formaldehyde, or other pollutants, and the resultant indoor pollutants can pose a substantial risk to occupant health. Pollutant emissions are highest immediately after a new product is installed, but emissions may continue for days, weeks, months, or years. Buildup of these air pollutants in the home is affected by ventilation, infiltration, and filtration rates; thus, these rates are addressed by the requirements in ASHRAE Standard 62.2.

The California Air Resources Board (ARB) provides guidance for reducing indoor air pollution in homes. For more information, see the ARB Indoor Air Quality Guidelines:

<http://www.arb.ca.gov/research/indoor/guidelines.htm>

This Section will cover compliance and enforcement, typical design solutions, energy consumption issues, and other requirements specified by ASHRAE 62.2.

Compliance with the whole-building ventilation airflow specified in ASHRAE 62.2 is required in new buildings and in buildings with additions greater than 1,000 ft². All other mechanical ventilation requirements, including local exhaust, must be met (as applicable) in all additions and alterations. 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). Individual dwelling units in multifamily buildings are required to each meet the same requirements as single-family dwelling units, except as otherwise described in Section 4.6.8.

The following summarizes the key requirements for most newly constructed buildings:

1. A whole-building mechanical ventilation system shall be provided. The typical solutions are described in the Section 4.6.2 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 Residential Appendix RA3.7.
2. Kitchens and bathrooms shall have local exhaust systems vented to the outdoors.
3. Clothes dryers shall be vented to the outdoors.

Miscellaneous indoor air quality design requirements apply, including the following:

1. Ventilation air shall come from outdoors and shall not be transferred from adjacent dwelling units, garages, or crawl spaces.
2. Ventilation system controls shall be labeled, and the homeowner shall be provided with instructions on how to operate the system.
3. Combustion appliances shall be properly vented, and exhaust systems shall be designed to prevent back drafting.
4. The walls and openings between the house and the garage shall be sealed.
5. Habitable rooms shall have windows with a ventilation area of at least 4 percent of the floor area.
6. Mechanical systems including heating and air-conditioning systems that supply air to habitable spaces shall have MERV 6 filters or better and be designed to accommodate the system's air filter media rated pressure drop for the system design airflow rate.
7. Dedicated air inlets (not exhaust) that are part of the ventilation system design shall be located away from known contaminants.
8. A carbon monoxide alarm shall be installed in each dwelling unit in accordance with NFPA Standard 720.
9. Air-moving equipment used to meet the whole-building ventilation requirement and the local ventilation exhaust requirement shall be rated in terms of airflow and sound:
 - a. All continuously operating fans shall be rated at a maximum of 1.0 sone.

- b. Intermittently operated whole-building ventilation fans shall be rated at a maximum of 1.0 sone.
- c. Intermittently operated local exhaust fans shall be rated at a maximum of 3.0 sone.
- d. Remotely located air-moving equipment (mounted outside habitable spaces) need not meet sound requirements if there is at least 4 feet of ductwork between the fan and the intake grille.

4.6.1 Compliance and Enforcement

Compliance with ASHRAE 62.2 requirements must be verified by the enforcement agency, and the whole-building ventilation airflow rate must be verified by a HERS Rater in accordance with the procedures in Residential Appendix RA3.7. The applicable certificates of compliance, installation, and verification must be registered with an approved HERS Provider.

If a central heating/cooling system air-handler fan is used to ventilate the dwelling (central fan integrated ventilation), the air handler must meet or exceed the mandatory fan efficacy criteria. This requires the installer to perform the test given in Reference Appendix RA3.3, and a HERS Rater to verify the performance of the air handler.

4.6.1.1 Certificate of Compliance Reporting Requirements

When the performance compliance approach is used, the required whole-building ventilation airflow is calculated based on the total conditioned floor area (CFA) and the number of bedrooms. (See Section 4.6.3.1A.) Therefore, it is important that these values are input into the compliance software correctly and checked by the plans examiner. The performance certificate of compliance (CF1R) will report:

1. Required ventilation airflow rate (calculated value) that must be delivered by the system.
2. System type selected (that is, exhaust, supply, balanced, CFI).
3. Fan power ratio (watts/CFM) for the selected system.
4. The requirement of HERS verification of fan watt draw for the air handler when a CFI ventilation system is being used.

The installed whole-building ventilation system must conform to the performance requirements on the CF1R. For more information about the performance calculations for whole-building ventilation systems, see Section 4.6.4. There are no requirements to describe fans installed for other purposes, such as local exhaust, on the performance CF1R.

When using the prescriptive compliance approach, information that describes the whole-building ventilation system is not required on the CF1R. Unless otherwise required by the enforcement agency, calculation of the required ventilation airflow rate and selection of the system type can be done at installation. There are no requirements to describe fans installed for other purposes, such as local exhaust, on the prescriptive CF1R.

The enforcement agency may require additional information/documentation describing the ventilation systems be submitted along with the CF1R at plan check.

4.6.1.2 Certificate of Installation and Certificate of Verification Reporting Requirements

The builder/installer must complete a certificate of installation (CF2R-MCH-27) for the dwelling. The HERS Rater must complete a certificate of verification (CF3R-MCH-27) for the dwelling.

The following information must be provided on the CF2R-MCH-27 and CF3R-MCH-27 to document compliance with §150.0(o):

1. Required whole-building ventilation airflow rate for continuous or intermittent operation as specified by ASHRAE 62.2 equations. (See Section 4.6.3.)
2. Installed system type (that is, exhaust, supply, balanced, CFI).
3. Measured airflow rate of the installed whole-building ventilation system.
4. Confirmation from the builder/installer that the other applicable requirements given in ASHRAE 62.2 have been met. (See Sections 4.6.5 and 4.6.6.)

4.6.2 Typical Solutions for Whole-Building Ventilation

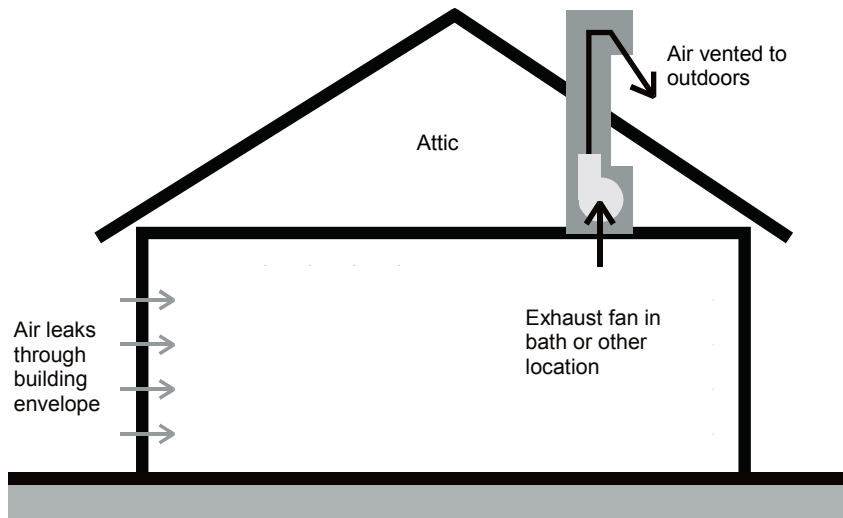
There are three typical solutions for meeting the outside air ventilation requirement:

1. Exhaust ventilation.
2. Supply ventilation.
3. Combination of supply and exhaust ventilation. (If the supply and exhaust flows are within 10 percent of each other, this is called a “balanced ventilation system.”)

Whole-building ventilation may be achieved through a single fan or a system of fans that are dedicated to whole-building ventilation only or by fans that also provide local exhaust or distribute heating and cooling.

4.6.2.1 Exhaust Ventilation

Figure 4-28: Exhaust Ventilation Example



Source: California Energy Commission

Exhaust ventilation is usually achieved by a quiet ceiling-mounted bath fan or remote-mounted inline or exterior-mounted fan. Air is drawn from the house by the exhaust fan, and outdoor air enters the house through infiltration.

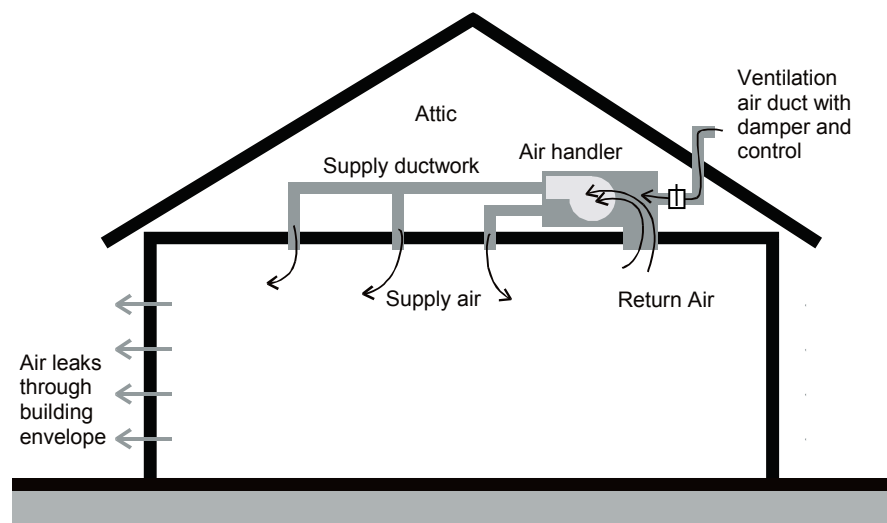
Many high-quality bath fans are available in the 30- to 150-cfm size range that are quiet enough to be used continuously. One or more fans of this size will meet the requirements of most homes. The exhaust fan can be a dedicated IAQ fan or a typical bath fan that is used for both whole-building ventilation and local ventilation.

Inline fans (either single pickup or multipoint pickup) can be a very effective method of providing quiet exhaust ventilation from one or several bathrooms. Inline fans can be located in the garage, attic, basement, or mechanical room.

Exterior-mounted fans can be mounted on the exterior wall or on the roof. A sound rating is not required for remote or exterior fans with at least 4 ft. of duct between the closest pickup grille and the fan.

4.6.2.2 Supply Ventilation

Figure 4-29: Supply Ventilation Example



Source: California Energy Commission

Supply ventilation works by bringing outside air into the house through a dedicated supply fan or the central forced-air system air handler and escapes through exfiltration.

The air handler or supply fans can be located on the exterior of the house or in the garage, attic, basement, or mechanical room, but the placement of the outdoor air inlet should avoid areas with contaminants, such as garages, barbeque areas, and chimneys. If a dedicated fan is used, care must be taken to avoid introducing too much outdoor air into one location and creating uncomfortable conditions. The ventilation air can be distributed by a dedicated duct system separate from the central forced air distribution duct system.

Alternatively, the central forced-air system air handler can be configured to function as a ventilation supply system by installing a dedicated ventilation air duct that connects to the return plenum of the air handler and to the dwelling exterior. This strategy, called *central fan integrated (CFI) ventilation*, uses negative pressure in the return plenum to pull outdoor air into the return plenum, then the central system air handler distributes the ventilation air through the house. A damper and controls must be

installed that ensure the air handler delivers the required ventilation airflow regardless of the size of the heating or cooling load.

When considering design and compliance for CFI ventilation systems, it is important to distinguish between the central forced-air system fan total airflow and the much smaller ventilation airflow (the airflow that is induced to flow into the return plenum from outdoors). Refer to Figure 4-29 and note that the total airflow through the air handler is the sum of the return airflow and the ventilation airflow.

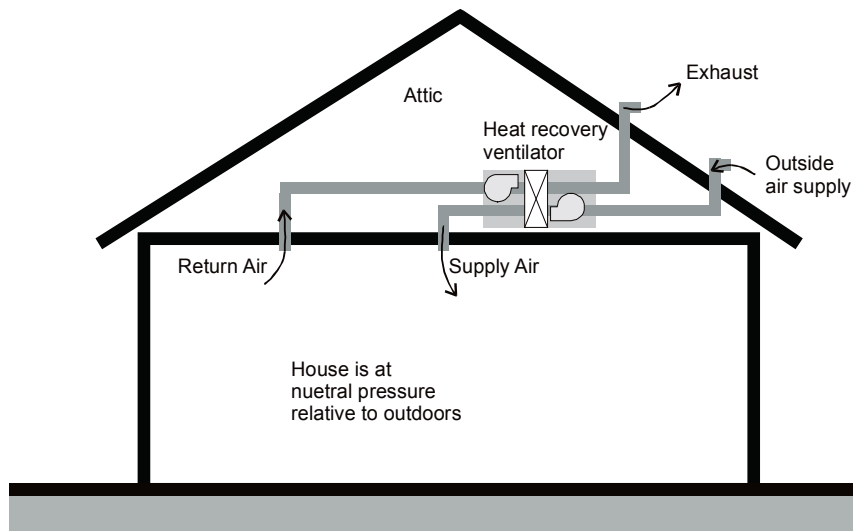
ASHRAE Standard 62.2, Section 4.3 requires the installer to measure the ventilation airflow rate in a CFI system in all operation modes to ensure that it will meet the ventilation rate requirements, regardless of whether the system operates to provide heating or cooling. Because §150.0(o) specifically prohibits continuously operating the central forced air system with CFI ventilation systems, CFI systems must be intermittent. The results of the airflow measurement of the installed CFI system and the intermittent ventilation control schedule used for the CFI system must be given on the Certificate of Installation. The whole-house ventilation rate must also be verified by a HERS Rater.

The outside air (OA) ducts for CFI ventilation systems cannot be sealed/taped off during duct leakage testing. However, CFI OA ducts that use controlled motorized dampers that open only when OA ventilation is required and close when OA ventilation is not required may be closed during duct leakage testing.

CFI ventilation systems can use a very significant amount of electricity annually. Air handlers used in CFI ventilation systems are required to meet the prescriptive fan watt draw requirements in all climate zones.

4.6.2.3 Combination Ventilation

Figure 4-30: Combination Ventilation Example



Source: California Energy Commission

Combination systems use both exhaust fans and supply fans. If both fans supply the same airflow, the system is balanced, and the house has a neutral pressure.

Combination systems are often integrated devices, sometimes with a heat exchanger or heat recovery wheel. The supply and exhaust airstreams are typically of equal flow.

Combination systems can also be a mixture of supply fans and exhaust fans, such as a quiet continuous bathroom exhaust fan matched to an outdoor air connection that introduces air into the return air plenum of a continuously operating central heating/cooling system air handler.

Note: Ventilation systems that constantly operation the central heating/cooling system air handler can use a very significant amount of electricity annually and are not permitted by the Energy Standards.

4.6.3 Whole-Building Ventilation Flow Rate (Section 4 of ASHRAE 62.2)

The whole-building ventilation system may operate continuously or intermittently. The whole-building ventilation rate is determined for continuous ventilation; if the system is operated intermittently, an adjustment is made.

4.6.3.1 Continuous Whole-Building Ventilation

There are two strategies for determining the continuous whole-building ventilation rate: the fan ventilation rate method, which assumes that all required ventilation will be provided mechanically, and the total ventilation rate method, which assumes that ventilation will be achieved by a combination of natural infiltration and mechanical ventilation.

Both methods are allowed for newly constructed homes and alterations. The fan ventilation rate method may be advantageous from a design perspective because the infiltration rate of the house does not need to be determined before construction. In either case, a fan system must be designed and installed that meets the whole-building ventilation airflow requirements, however it is determined.

A. Fan Ventilation Rate Method

The continuous whole-building ventilation rate is 1 cfm for each 100 ft² of conditioned floor area plus 7.5 cfm for each occupant. The number of occupants is calculated as the number of bedrooms plus one. For example, a three bedroom house is assumed to have four occupants. The required ventilation rate is given by the following Equation 4-1.

Equation 4-1

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

Where:

$$Q_{fan} = \text{fan flow rate (cfm)}$$

$$A_{floor} = \text{floor area of residence (ft}^2\text{)}$$

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

Instead of using one of the equations given above, Table 4-14 may be used to determine the required ventilation. This table allows the user to find the required ventilation rate directly if he or she knows the floor area and number of bedrooms. To comply with ASHRAE 62.2, the delivered airflow of the whole house ventilation fan must be greater than or equal to the required ventilation rate (cfm) from either Table 4-14 or Equation 4-1.

Table 4-14: Continuous Whole-Building Ventilation Rate (cfm) (from ASHRAE 62.2, Table 4.1a (I-P))

Conditioned Floor Area (ft ²)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
≤1500	30	45	60	75	90
1501-3000	45	60	75	90	105
3001-4500	60	75	90	105	120
4501-6000	75	90	105	120	135
6001-7500	90	105	120	135	150
>7500	105	120	135	150	165

Source: ASHRAE 62.2

Example 4-6 – Required Ventilation**Question:**

What is the required continuous ventilation rate for a three-bedroom, 1,800 ft² townhouse?

Answer:

$$A_{floor} = 1800$$

$$N_{br} = 3$$

Equation 4-1 gives a required ventilation rate of 48 cfm:

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1) = 0.01(1800) + 7.5(3 + 1) = 48$$

Table 4-14 gives a required ventilation rate of 60 cfm.

Example 4-7**Question:**

The house has a floor area of 2,240 ft² and three bedrooms. My calculations come out to 52.4 cfm. Can I use a 50 cfm fan?

Answer:

No. A 50 cfm fan does not meet the standard.

Also, note that the nominal rating of a fan can be very different than what a fan actually delivers when installed. Actual airflow depends greatly on the length and size of the duct needed to get the air outside. Proper fan sizing requires more detailed manufacturer's data, such as airflow vs. static pressure. This is why whole-building ventilation rates must be verified by a HERS Rater.

B. Total Ventilation Rate Method

This method for determining a continuous whole-building ventilation rate starts with calculating the total ventilation rate, which consists of both the natural and mechanical ventilation rates.

The total ventilation rate is calculated using an equation similar to that used in the fan ventilation rate method. Next, the natural ventilation (infiltration) rate is calculated from diagnostically tested values.

The infiltration rate is subtracted from the total ventilation rate, leaving the ventilation rate that must be provided mechanically.

The equation for calculating the total ventilation rate is:

Equation 4-2

$$Q_{total} = 0.03A_{floor} + 7.5(N_{br} + 1)$$

Where:

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

A_{floor} = floor area of residence (ft²)

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

The number multiplied times the floor area is three times greater than that used in Equation 4-1.

The ventilation rate associated with infiltration is calculated using an effective leakage area (ELA) value that must be diagnostically verified in the field.

The ELA value used for these equations is in square feet, not square inches as may be the case in other equations.

RA3.8 covers the protocols for blower door testing for verifying infiltration for reduced infiltration compliance credit. Unless specifically directed otherwise in this section, RA3.8 shall be met.

Because infiltration can occur by air coming into the home as well as air going out of the home, it is more accurate to measure ELA under depressurization and pressurization (using a 4 Pa reference pressure), then average the two values using Equation 4-3.

Equation 4-3

$$ELA = \frac{(L_{press} + L_{depress})}{2}$$

Where:

ELA = effective leakage area (ft²)

L_{press} = leakage area from pressurization (ft²)

$L_{depress}$ = leakage area from depressurization (ft²)

When designing for a house that is not built yet, the ELA values will be estimated numbers. If the actual (measured) number is different, the ventilation system design may need to be modified to comply.

The leakage is normalized based on the area of the house and the potential for stack effect using Equation 4-4.

Equation 4-4

$$NL = 1000 \left(\frac{ELA}{A_{floor}} \right) \left(\frac{H}{H_r} \right)^2$$

Where:

NL = normalized leakage

ELA = effective leakage area (ft²)

A_{floor} = floor area of residence (ft²)

H_r = reference height, 8.2 ft

H = vertical distance from lowest above grade floor to highest ceiling (ft)

$Z = 0.4$ for the purpose of calculating the effective annual infiltration rate

The effective annual infiltration rate is then calculated using Equation 4-5. This is the amount of infiltration that is considered to offset the need for fan-powered ventilation.

Equation 4-5

$$Q_{inf} = \frac{(NL)(wsf)(A_{floor})}{7.3}$$

Where:

Q_{inf} = effective annual average infiltration rate (cfm)

NL = normalized leakage

wsf = weather and shielding factor from ANSI/ASHRAE Standard 62.2-2010, Normative Appendix X, Table X1- US Climates

A_{floor} = floor area of residence (ft²)

The ventilation rate required by the fan is then calculated by subtracting the infiltration ventilation rate from the total ventilation rate.

Equation 4-6

$$Q_{fan} = Q_{total} - Q_{inf}$$

Where:

Q_{fan} = required mechanical ventilation rate (cfm)

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

Q_{inf} = effective annual average infiltration rate (cfm)

For well-sealed houses, the fan ventilation rate calculated using the total ventilation rate method may be higher than that calculated by the fan ventilation rate method, so it is worth checking both.

No whole-building ventilation is required if Q_{fan} is less than or equal to zero.

C. Ventilation Rate for Combination Systems

When a combination ventilation system is used, meaning that both supply and exhaust fans are installed, the provided ventilation rate is the larger of the total supply airflow or the total exhaust airflow. The airflow rates of the supply and exhaust fans cannot be added together to determine the provided ventilation rate.

Example 4-8

Question:

A 2,400 ft² house has exhaust fans running continuously in two bathrooms providing a total exhaust flow rate of 40 cfm, but the requirement is 60 cfm. What are the options for providing the required 60 cfm?

Answer:

The required 60 cfm could be provided either by increasing the exhaust flow by 20 cfm or by adding a ventilation system that blows 60 cfm of outdoor air into the building. It cannot be achieved by using a make-up air fan blowing 20 cfm into the house.

4.6.3.2 Intermittent Whole-Building Ventilation

In some cases, it may be desirable to design a whole-building ventilation system that operates intermittently. One common example of intermittent ventilation is when outside air is ducted to the return plenum of the central heating/cooling system, and thus the central heating/cooling system fan is used to distribute the ventilation air to the rooms in the building. (See CFI system described above in the supply ventilation section.)

Intermittent mechanical ventilation systems, devices, or controls may be approved for use for compliance with the HERS field verification requirements for whole-building mechanical ventilation airflow. A listing of certified intermittent mechanical ventilation systems is posted here: http://www.energy.ca.gov/title24/equipment_cert/imv/

Intermittent ventilation is permitted as long as the ventilation airflow is increased to respond to the fewer hours of fan operation and the tendency of pollutant concentrations to build up during off cycles.

Equation 4-7

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)}$$

Where:

Q_{on} = intermittent fan flow rate during the on-cycle (cfm)

Q_{fan} = continuous mechanical ventilation air requirement from Table 4-14 or Equation 4-1 (cfm)

ε = mechanical ventilation effectiveness (from Table 4–15)

f = fractional on-time

To obtain ε from Table 4–15, the required turnover, N , and fractional on-time, f , must be known. f is calculated by dividing the on-time for one cycle by the cycle time. N is calculated using Equation 4-8.

Equation 4-8

$$N = \frac{12.8(Q_{fan})(T_{cyc})}{A_{floor}}$$

Where

N = the required turnover

Q_{fan} = continuous mechanical ventilation air requirement from Table 4-14 or Equation 4-1 (cfm)

T_{cyc} = fan cycle time, defined as the total time for one off-cycle and one on-cycle (hours)

A_{floor} = floor area of residence (ft²)

The maximum allowable T_{cyc} is 24 hours.

To obtain ε , find the column in Table 4–15 with the calculated value for N at the top and the row in Table 4–15 with the calculated value for f on the left side. The number in the cell where that column and row intersect is the value of ε needed for Equation 4-7. If the calculated values for N and f are not listed on Table 4–15, use the next higher value for N , the next lower value for f , or linear interpolation.

Table 4–15: Mechanical Ventilation Effectiveness for Intermittent Fans

Mechanical Ventilation Effectiveness for Intermittent Fans															
Fractional On-Time, f	Turnover, N														
	0.0	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	8.0	12	20	40	100+
0.00	1.00	0.95	0.88	0.78	0.60	0.00									
0.05	1.00	0.96	0.90	0.81	0.67	0.41	0.00								
0.10	1.00	0.96	0.91	0.83	0.72	0.55	0.21	0.00							
0.15	1.00	0.96	0.92	0.85	0.76	0.63	0.44	0.18	0.00						
0.20	1.00	0.97	0.93	0.87	0.79	0.69	0.56	0.40	0.03	0.00					
0.25	1.00	0.97	0.94	0.89	0.82	0.74	0.64	0.53	0.26	0.02	0.00				
0.30	1.00	0.98	0.95	0.90	0.85	0.78	0.71	0.62	0.42	0.24	0.00				
0.35	1.00	0.98	0.95	0.92	0.87	0.82	0.76	0.69	0.54	0.39	0.14	0.00			
0.40	1.00	0.98	0.96	0.93	0.89	0.85	0.80	0.75	0.63	0.52	0.32	0.02	0.00		
0.45	1.00	0.99	0.97	0.94	0.91	0.88	0.84	0.79	0.70	0.61	0.45	0.21	0.00		
0.50	1.00	0.99	0.97	0.95	0.93	0.90	0.87	0.83	0.76	0.69	0.57	0.37	0.13	0.00	0.00
0.60	1.00	0.99	0.98	0.97	0.96	0.94	0.92	0.90	0.86	0.81	0.74	0.61	0.45	0.27	0.14
0.70	1.00	1.00	0.99	0.98	0.98	0.97	0.96	0.94	0.92	0.90	0.85	0.78	0.68	0.55	0.46
0.80	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.98	0.97	0.96	0.94	0.90	0.85	0.77	0.70
0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.98	0.97	0.96	0.93	0.88
1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: ASHRAE 62.2

Intermittent ventilation systems must be automatically controlled by a timer or other device that assures they will operate the minimum amount of time needed to meet the ventilation requirement. The scheduling of the automatic controls must be such that the fan operates at least 10 percent of the time and that a single on/off cycle occurs at least once per day.

Example 4-9 – Flowrate for Intermittent Fan**Question:**

The required ventilation rate is 56 cfm. If the ventilation fan runs for 80 percent of the day, what must the airflow rate be for a 2600 ft² townhouse?

Answer:

f is 0.8 (80 percent). The required turnover is calculated to be 7 using Equation 4-8:

$$N = \frac{12.8(Q_{fan})(T_{cyc})}{A_{floor}} = \frac{12.8(56)(24)}{2600} = 6.62 \approx 7$$

From Table 4–15, ε is 0.95. The fan flow rate is calculated to be 74 cfm using Equation 4-7:

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)} = \frac{56}{(0.95)(0.8)} = 73.7 \approx 74$$

Example 4-10

Question:

For the same house, if the fan runs half the day (12 hours per day), what is the required airflow?

Answer:

The fractional on-time, f is 0.5 (50 percent). T_{cyc} is still 24 hours, so N is still 7.

From Table 4–15, ε is now 0.63. The fan flow rate is calculated to be 178 cfm using Equation 4-7:

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)} = \frac{56}{(0.63)(0.5)} = 177.78 \approx 178$$

This is a much larger increase in fan size. More than double the fan size over Example 4-10 is required to move the same amount of air, even though the on-cycle was only decreased by less than half. In many designs, it may be better to consider a lower power, quieter fan that will run for longer over a high power fan that will run for a shorter period.

Example 4-11

Question:

A three-bedroom, 2250 ft² apartment, the flow required is 52.5 cfm. If the ventilation fan runs 20 minutes on and 10 minutes off, what is the required fan size?

Answer

Fractional on-time is 0.67:

$$f = \frac{20}{20 + 10} = 0.67$$

The required turnover is calculated to be 0.149 using Equation 4-8:

$$N = \frac{12.8(Q_{fan})(T_{cyc})}{A_{floor}} = \frac{12.8(52.5)(0.5)}{2250} = 0.149$$

From Table 4–15, ε is 1.0. The fan flow rate is calculated to be 78 cfm using Equation 4-7:

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)} = \frac{52.5}{(1.0)(0.67)} = 78.36 \approx 78$$

Example 4-12

Question:

For the same apartment, if the fan runs 8 hours on and 4 hours off, what flow rate is required?

Answer:

Fractional on-time is again 0.67, but T_{cyc} has changed, which changes N . N is now calculated to be 3.6 (round up from 3.584) using Equation 4-8:

$$N = \frac{12.8(Q_{fan})(T_{cyc})}{A_{floor}} = \frac{12.8(52.5)(12)}{2250} = 3.584$$

From Table 4–15, ε is now approximately 0.95. The fan flow rate is calculated to be 83 cfm using Equation 4-7:

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)} = \frac{52.5}{(0.95)(0.67)} = 82.5 \approx 83$$

Example 4-13

Question:

An electronic timer system on a 9001 ft² estate with 6 bedrooms can be set to operate a fan for 1 minute every hour. The timer runs the fan 2 hours in the morning and 8 hours in the evening. What is the required intermittent flow rate?

Answer:

The scheduling of the automatic controls must be such that the fan operates at least 10 percent of the time and that a single on/off cycle occurs at least once per day. An on/off cycle of 1 minute every hour is only 1.67 percent and does not meet this requirement.

Equation 4-1 gives a required ventilation rate of 142.5 cfm (Q_{fan} from Table 4-14 would be 150 cfm):

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1) = 0.01(9001) + 7.5(6 + 1) = 142.5$$

The fractional on-time for a fan running 2 hours in the morning and 8 hours in the evening is equivalent to 0.42:

$$f = \frac{2 + 8}{24} = 0.42$$

The required turnover is calculated to be 4.86 using Equation 4-8:

$$N = \frac{12.8(Q_{fan})(T_{cyc})}{A_{floor}} = \frac{12.8(142.5)(24)}{9001} = 4.86$$

From Table 4-15, ε is 0.68. The fan flow rate is calculated to be 500 cfm (rounded up from 498.95 cfm) using Equation 4-7:

$$Q_{on} = \frac{Q_{fan}}{(\varepsilon)(f)} = \frac{142.5}{(0.68)(0.42)} = 498.95 \approx 500$$

4.6.3.3 Control and Operation

From ASHRAE 62.2, Section 4.4, Control and Operation.

The "fan on" switch on a heating or air-conditioning system shall be permitted as an operational control for systems introducing ventilation air through a duct to the return side of an HVAC system. Readily accessible override control must be provided to the occupant. Local exhaust fan switches and "fan on" switches shall be permitted as override controls. Controls, including the "fan-on" switch of a conditioning system, must be appropriately labeled.

Exception: An intermittently operating, whole-house mechanical ventilation system may be used if the ventilation rate is adjusted, according to Section 4.5.1. The system must be designed so that it can operate automatically based on a timer. The intermittent mechanical ventilation system must operate at least once per day and must operate at least 10% of the time.

ASHRAE 62.2 requires that the ventilation system have an override control that is readily accessible to the occupants. The control must be capable of being accessed quickly and easily by the occupants without having to remove panels or doors. It can be a labeled wall switch by 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 the inside the fan. The occupant must be able to modify the settings or override the system.

If intermittent fans are used, they must be controlled by a timer, and they must have an increased airflow rate to compensate for the off time.

Time-of-day timers or duty cycle timers can be used to control intermittent whole-building ventilation. Manual crank timers cannot be used, since the system must operate automatically without intervention by the occupant. Some controls "look back" over a set

time interval to see if the air handler has already operated for heating or cooling before it turns on the air handler for ventilation only operation.

Example 4-14 – Control Options

Question:

A bathroom exhaust fan is used to provide whole-building ventilation for a house. 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 whole-building ventilation, a label is needed to inform the occupant that the fan should be operating whenever the home is occupied. If the exhaust fan were serving only the local exhaust requirement for the bathroom, then a label would not be required.

Example 4-15 – Thermostatic Control

Question:

Ventilation air is provided whenever the air handler operates via a duct run connecting the return side of the central air handler to the outdoors. The system is estimated to run on calls for heating and cooling about 40 percent of the time, averaged over the year. If it is assumed that the air handler only runs 25 percent of the time, and the airflow is sized accordingly, can the system be allowed to run under thermostatic control?

Answer:

No. A system under thermostatic control will go through periods with little or no operation when the outdoor temperature is near the indoor setpoint, or if the system is in setback mode. An intermittently operating ventilation system must be controlled by a timer that will cycle at least once within 24 hours to assure that adequate ventilation is provided regardless of outdoor conditions.

Cycle timer controls are available that function to keep track of when (and for how long) the system operates to satisfy heating/cooling requirements in the home. These controls turn on the central fan to provide additional ventilation air when heating/cooling operation of the central fan has not already operated enough to provide the required ventilation.

4.6.4 Whole-Building Mechanical Ventilation Energy Consumption

For builders using the performance compliance approach, the energy use of fans (other than CFI fans) installed to meet the whole-building ventilation requirement is usually not an issue. The reason is the standard design W/CFM is set equal to the proposed design W/CFM up to an energy use level sufficient to accommodate most well-designed ventilation systems. Also, the standard design whole-building ventilation system airflow rate is set equal to the proposed design whole-building ventilation system airflow rate, so there is no energy penalty or credit for most systems. Systems that use heat recovery or energy recovery ventilators (HR/ERV) may need to account for the heat recovery benefit in the performance calculation to make up for the high energy use.

The energy use of the central air handler fan used for a CFI ventilation system must conform to the same fan watt draw (W/CFM) limit as for cooling systems in all climate zones. CFI systems are the only type of ventilation system that must meet a prescriptive fan watt draw requirement that must be tested by the builder/installer and verified by a HERS Rater in accordance with the diagnostic test protocols given in RA3.3.

Energy use of fans installed for other purposes, such as local exhaust, is not regulated in the Energy Standards.

4.6.4.1 Central Fan Integrated Ventilation Systems – Watt Draw

§150.1(f)10

CFI system automatic controls must operate the central system air handler fan (generally part of every hour of the year) to draw in and/or distribute ventilation air around the home even when there is no heating or cooling required. CFI systems generally do not operate continuously, thus do not meet the whole-building ventilation requirement as a “continuous” system. Because the CFI ventilation control increases the central system air handler fan run time significantly, and because typical central system air handler fan and duct systems require a large amount of power, a CFI ventilation system can use a very significant amount of electricity annually.

The Energy Standards include mandatory requirements for ducted central cooling system air handlers to comply with maximum fan watt draw targets. The watt draw requirement also applies to any ducted central system air handler used for a CFI system. Compliance with this requirement involves a postconstruction measurement by the installing contractor of the airflow through the air handler, and the simultaneous measurement of the watt draw of the air handler fan motor. This fan watt draw measurement must be measured by the installer and verified by a HERS Rater. (See Reference Residential Appendix RA3.3.) The central system air handler must be operating in ventilation mode (outdoor air damper is open and ventilation air is flowing into the return plenum from outside the building). Furthermore, the airflow that must be measured is the total airflow through the air handler (system airflow), which is the sum of the return airflow, and the outside air ducted to the return plenum (ventilation airflow). To pass the test, the watt draw must be less than 0.58 W/CFM.

Builders who use CFI systems and comply using the performance approach have the option of accepting the default value for the central system fan watt draw of 0.8 W/CFM, which does not require a postconstruction measurement and HERS verification. Alternatively, the builder can specify a lower W/CFM value for compliance, which must be tested and verified by a HERS Rater. In either case the compliance software will check the furnace fan heating and cooling operation every hour, and if the air handler has not been operating for at least 20 minutes during that hour, the software will calculate energy use for operation in CFI mode until 20 minutes of fan operating occurs. The standard design ventilation energy consumption for that hour will be calculated as the extra fan run time at a watt draw of 0.58 W/CFM. The proposed design ventilation energy for that hour will be calculated as the extra fan run time at the watt draw that was specified for compliance, otherwise at the default Watt draw of 0.8 W/CFM.

4.6.4.2 Other Whole-Building Ventilation Systems – Watt Draw

There are no prescriptive or mandatory requirements for maximum fan energy (watt draw) for whole-building ventilation systems other than CFI systems.

Builders who specify other whole-building ventilation systems and comply using the performance approach have the option of accepting the default minimum whole-building ventilation airflow rate and a watt draw value of 0.25 W/CFM, which is typical of simple exhaust fans that meet the 1 sone requirement. Otherwise, the airflow rate and fan watt draw of the fan may be input. If the builder installs a whole-building ventilation system that has a fan watt draw specification greater than 1.2 W/CFM of ventilation airflow, then he or she must input the ventilation airflow (CFM) and watt draw (W/CFM) corresponding to the system that he or she proposes to install. The compliance software will simulate whole-building ventilation using the builder’s specified ventilation CFM and W/CFM for the proposed design. For the standard design, the builder’s proposed CFM and 1.2 W/CFM will be used. If the builder specifies a system with heat recovery, he or she inputs the recovery

efficiency of the proposed system and the compliance software uses it in the proposed design to calculate the heating and cooling effect of the whole-building ventilation. Ventilation heat recovery is never used in the standard design.

4.6.5 Local Exhaust (Section 5 of ASHRAE 62.2)

Local exhaust (sometimes called *spot ventilation*) has long been required for bathrooms and kitchens to deal with moisture and odors at the source. Building codes have required an operable window or an exhaust fan in baths for many years and have generally required kitchen exhaust either directly through a fan or indirectly through a ventless range hood and an operable window. The Energy Standards recognize the limitations of these indirect methods of providing ventilation to reduce moisture and odors and requires that these spaces be mechanically exhausted directly to outdoors, even if windows are present. As tighter homes with more insulation are built, the relative humidity in the home has increased, and the potential for condensation on cool or cold surfaces has increased as well. The presence of moisture condensation has been a leading cause of mold and mildew in both new and existing construction. The occurrence of asthma has also increased as the interior relative humidity has gotten higher. Therefore, it has become more important to remove the moisture from bathing and cooking right at the source.

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

The Energy Standards allow the designer to choose between intermittent operation or continuous operation for the local exhaust ventilation system. The ventilation rates are different because the ventilation effectiveness of an intermittent operation fan is different than the ventilation effectiveness of a continuous operation fan.

Building codes may require that fans used for kitchen range hood ventilation be safety-rated by UL or some other testing agency for the particular location and/or application. Typically, these requirements address the fire safety issues of fans placed within an area defined by a set of lines at 45° outward and upward from the cooktop. Few “bath” fans will have this rating and cannot be used in this area of the kitchen ceiling.

Example 4-16 – Local Exhaust Required for Toilet

Question:

I am building a house with 2½ 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 4-17**Question:**

The master bath suite in a house 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.

4.6.5.1 Intermittent Local Exhaust

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

Bathrooms can use a variety of exhaust strategies. They can use typical ceiling bath fans or may use one or two pickups for remote inline or exterior-mounted fans or heat recovery products. Intermittent local exhaust can be integrated with the whole-building ventilation system to provide both functions. Kitchens can have range hoods, down-draft exhausts, ceiling fans, wall fans, or pickups for remote inline or exterior-mounted fans. Generally, HVR/ERV manufacturers will not allow kitchen pickups to avoid the issue of grease buildup in the heat exchange core. Building codes typically require that the kitchen exhaust must be exhausted through metal ductwork for fire safety.

Example 4-18 – Ducting Kitchen Exhaust to the Outdoors**Question:**

How do I know what kind of duct I need to use? I've been using recirculating hoods my entire career, now I need to vent to outdoors. How do I do it?

Answer:

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 4-19**Question:**

How do I know what the requirements are in my area?

Answer:

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

A. Control and Operation for Intermittent Local Exhaust

The choice of control is left to the designer. It can be an automatic control like an occupancy sensor or a manual switch. Some products have multiple speeds, and some switches have a delay-off function that continues the exhaust fan flow 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.

B. Ventilation Rate for Intermittent Local Exhaust

A minimum intermittent ventilation airflow of 100 cfm is required for the kitchen range hood, and a minimum intermittent ventilation airflow of 50 cfm is required for the bath fan.

The 100 cfm requirement for the range hood or microwave/hood combination is the minimum to adequately capture the moisture and other products of cooking and/or combustion. The kitchen 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 the ASHRAE Standard 62.2 unless paired with an exhaust system that can provide at least five air changes of the kitchen volume per hour.

Most range hoods provide more than one speed, with the high speed at 150 cfm or more – sometimes much more. Range hoods are available that are rated for 1,000 or 1,500 cfm on high speed and are often specified when large commercial-style stoves are installed. Care must be taken to avoid backdrafting combustion appliances when large range hoods are used. Refer to Table 5.1 in ASHRAE 62.2 for intermittent local ventilation exhaust airflow rates and to Section 6.4 in ASHRAE 62.2 for makeup air requirements associated with large exhaust appliances.

Example 4-20 – Is an Intermittent Range Hood Required?

Question:

I am building a house with a kitchen that is 12 ft. x 14 ft. with a 10 ft. ceiling. What size ceiling exhaust fan is required?

Answer:

The kitchen volume is 12 ft x 14 ft x 10 ft = 1680 ft³. Five air changes are a flow rate of 1680 ft³ x 5/ hr ÷ 60 min/hr = 140 cfm. So this kitchen must have a ceiling or wall exhaust fan of 140 cfm or a 100 cfm vented range hood.

4.6.5.2 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 is generally specified when the local exhaust ventilation system is combined with a continuous whole-building ventilation system. For example, if the whole-building exhaust is provided by a continuously operating exhaust fan located in the bathroom, this fan satisfies the local exhaust requirement for the bathroom. The continuous local exhaust may also be part of the continuous whole-building ventilation system, such as a pickup for a remote fan or HRV/ERV system.

Continuously operating bathroom fans must operate at a minimum of 20 cfm and continuously operating kitchen fans must operate at five air changes per hour. These continuous ventilation airflow rates are different than the ventilation airflow rates required for intermittent local exhaust. Refer to Table 5.2 in ASHRAE 62.2 for continuous local ventilation exhaust airflow rates.

The requirement that continuous kitchen exhaust fans must provide five air changes per hour is due to the difficulty of a central exhaust to adequately remove contaminants released during cooking from large kitchens, have an open-plan design, or have high ceilings. The

only way to avoid a vented kitchen hood is to provide more than five air changes per hour of constant local exhaust ventilation.

Example 4-21 – Continuous Kitchen Exhaust

Question:

The kitchen in an apartment is 5 ft by 10 ft, with an 8 ft ceiling. If a continuous ceiling-mounted exhaust fan is used, what must the airflow be?

Answer:

The kitchen volume is 5 ft x 10 ft x 8 ft = 400 ft³. 5 air changes equates to 400 ft³ x 5/hr ÷ 60 min/hr = 34 cfm.

Example 4-22

Question:

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

Answer:

The kitchen volume is 12 ft x 18 ft x 12 ft = 2592 ft³. The airflow required is 2592 ft³ x 5/hr ÷ 60 min/hr = 216 cfm.

4.6.6 Other Requirements (Section 6 of ASHRAE 62.2)

4.6.6.1 Transfer Air

From ASHRAE 62.2,

6.1 Adjacent Spaces. Measures shall be taken to minimize air movement across envelope components to occupiable spaces from garages, unconditioned crawl spaces, and unconditioned attics. Supply and balanced ventilation systems shall be designed and constructed to provide ventilation air directly from the outdoors.

8.4.1 Transfer Air. Measures shall be taken to minimize air movement across envelope components separating dwelling units, including sealing penetrations in the common walls, ceilings, and floors of each unit and by sealing vertical chases adjacent to the units. All doors between dwelling units and common hallways shall be gasketed or made substantially airtight

ASHRAE Standard 62.2 requires that the air used for ventilation come from the outdoors. Air may not be drawn in as transfer air from other spaces that are outside the occupiable space of the dwelling unit, or from between dwelling units and corridors. This is to prevent airborne pollutants originating in those other spaces from contaminating the dwelling unit. For example, drawing ventilation air from the garage could introduce VOCs or pesticides into the indoor air. Drawing ventilation air from an unconditioned crawlspace could cause elevated allergen concentrations in the dwelling such as mold spores, insects or rodent allergens. Likewise, drawing air from an adjacent dwelling could introduce unwanted contaminants such as cooking products or cigarette smoke.

In addition to designing the ventilation system to draw air from the outdoors, the standard also requires that measures be taken to prevent air movement between adjacent dwelling units and between the dwelling unit and other nearby spaces, such as garages. The measures can include air sealing of envelope components, pressure management, and use of airtight recessed light fixtures. The measures must apply to adjacent units both above and below, as well as side by side.

Air sealing must include pathways in vertical components such as demising walls and walls common to the unit and an attached garage, and in horizontal components such as floors and ceilings. Pipe and electrical penetrations are examples of pathways that require sealing.

Section 6.1 of ASHRAE 62.2 does not prohibit whole-building exhaust or local exhaust ventilation systems and does not require mechanical systems to maintain pressure relationships with adjacent spaces except as required by Section 6.4 of ASHRAE 62.2.

4.6.6.2 Instructions and Labeling

From ASHRAE 62.2, Section 6.2, Instructions and Labeling.

Information on the ventilation design and/or ventilation systems installed, instructions on their proper operation to meet the requirements of this standard, and instructions detailing any required maintenance (similar to that provided for HVAC systems) shall be provided to the owner and the occupant of the dwelling unit. Controls shall be labeled as to their function (unless that function is obvious, such as toilet exhaust fan switches). See Chapter 13 of Guideline 24 for information on instructions and labeling.

There has been a history of ventilation systems that worked initially but failed due to lack of information for the occupant or lack of maintenance. ASHRAE Standard 62.2 requires that the installer or builder provide written information on the basic ventilation concept being used and the expected performance of the system. These instructions must include how to operate the system and what maintenance is required.

Because the concept of a designed whole-building ventilation system may be new to many occupants, the standard requires that ventilation system controls be labeled as to the function. No specific wording is mandated, but the wording must make clear what the control is for and the importance of operating the system. This may be as simple as “Ventilation Control” or might include wording such as “Operate whenever the house is in use” or “Keep on except when gone over 7 days.” If the system is designed to operate with a timer as an intermittent system, the labeling may need to be more detailed. One acceptable option is to affix a label to the electrical panel that provides some basic system operation information.

4.6.6.3 Clothes Dryers

From ASHRAE 62.2, Section 6.3, Clothes Dryers.

Clothes dryers shall be exhausted directly to the outdoors. Exception: Condensing dryers plumbed to a drain.

All laundry rooms must be built with a duct to the outdoors, designed to be connected to the dryer. Devices which allow the exhaust air to be diverted into the indoor space to provide extra heating are not permitted. This requirement is consistent with existing clothes dryer installation and design standards.

In multifamily buildings, multiple dryer exhaust ducts can be connected to a common exhaust only when dampers are provided to prevent recirculation of exhaust air from one apartment to another.

Example 4-23 – Clothes Dryer Exhaust Diverter

Question:

I am building a home that has been purchased prior to completion. The buyer has asked for an exhaust air diverter to be installed in the dryer exhaust duct. He says that it is wasteful of heating energy to exhaust the warm humid air to the outdoors during the winter when the furnace and humidifier are working. He says that the screen on the diverter will prevent excess dust being released into the space. Can I install the device for him?

Answer:

If you do, you will not comply with the Energy Standards. The device is specifically prohibited. Significant amounts of dust are released from such devices, and the moisture in the dryer exhaust can lead to humidity problems as well, particularly in warmer climates.

4.6.6.4 Combustion and Solid-Fuel Burning Appliances

From ASHRAE 62.2, Section 6.4, Combustion and Solid-Fuel Burning Appliances

Combustion and solid-fuel burning appliances must be provided with adequate combustion and ventilation air and vented in accordance with manufacturers' installation instructions, NFPA 54/ANSI Z223.1, National Fuel Gas Code, NFPA 31, Standard for the Installation of Oil- Burning Equipment, or NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel Burning Appliances, or other equivalent code acceptable to the building official. Where atmospherically vented combustion appliances or solid-fuel burning appliances are located inside the pressure boundary, the total net exhaust flow of the two largest exhaust fans (not including a summer cooling fan intended to be operated only when windows or other air inlets are open) shall not exceed 15 cfm/100 ft² (75 Lps/100 m²) of occupiable space when in operation at full capacity. If the designed total net flow exceeds this limit, the net exhaust flow must be reduced by reducing the exhaust flow or providing compensating outdoor airflow. Atmospherically vented combustion appliances do not include direct-vent appliances.

ASHRAE Standard 62.2 requires that the vent system for combustion appliances be properly installed, as specified by the instructions from the appliance manufacturer and by the California Building Code. Compliance with the venting requirements will involve determining the type of vent material to be used, the sizing of the vent system, and vent routing requirements.

ASHRAE Standard 62.2 includes a provision intended to prevent backdrafting where one or more large exhaust fans are installed in a home with atmospherically vented or solid fuel appliances. If the two largest exhaust fans have a combined capacity that exceeds 15 cfm/100 ft² of floor area, then makeup air must be provided. This provision applies only when the atmospherically vented appliance is inside the pressure boundary of the house and does not include a summer cooling fan that is designed to be operated with the windows open. Direct-vent appliances are not considered "atmospherically vented."

The two largest exhaust fans are normally the kitchen range hood and the clothes dryer (if located inside the dwelling unit pressure boundary). Large-range hoods, particularly downdraft range hoods, can have capacities of 1,000 cfm or more.

A problem with this requirement can be solved in one of three ways. First, all atmospherically vented combustion appliances can be moved outside the pressure boundary of the house (to the garage or other similar space). Second, the flow rate of one or more of the fans can be reduced so that the combined flow is less than 15 cfm/100 ft². Finally, makeup air can be provided to offset the net exhaust rate.

Example 4-24 – Large Exhaust Fan

Question:

I am building a 3,600 ft² custom home that has four bedrooms. The kitchen will have a high-end range hood that has three speeds, nominally 1000 cfm, 1400 cfm and 1600 cfm. The house will be heated with an atmospherically vented gas furnace located in the basement. If I am using a central exhaust fan for the whole-building ventilation of 75 cfm, and there is a clothes dryer installed, how much compensating outdoor airflow (makeup air) is needed?

Answer:

You must use the high speed value for the range hood of 1600 cfm. The clothes dryer will have a flow that is assumed to be 150 cfm for sizing purposes. These two flows must be added together for a total exhaust capacity of 1750 cfm. Since the whole-building ventilation fan is not one of the two largest exhaust fans, it does not figure into the makeup air calculation. Using the equation above, there must be at least 1750 cfm – (15 cfm x 3600 ft² / 100 ft²) = 1210 cfm of makeup airflow.

Example 4-25**Question:**

The same custom house will have the furnace located in the garage instead of the basement. Does that change anything?

Answer:

The garage and the attic would both normally be considered outside the pressure boundary, so no makeup airflow would be required. An exception to this would be if the attic is specially designed to be inside the pressure boundary, then the answer would be the same as for Example 4-24.

Example 4-26**Question:**

For this house, I need to keep the furnace in the basement. What are my options that would avoid the requirement to provide makeup air?

Answer:

There are several things you could do. First, you could use a direct vent furnace that would also provide higher fuel efficiency. You could use a lower capacity range hood, one that is less than 390 cfm (15 cfm x 3600 ft² / 100 ft² – 150 cfm). Use of supply-only whole-building ventilation would allow the hood capacity to increase to 465 cfm (15 cfm x 3600 ft² / 100 ft² – 150 cfm + 75 cfm). There are also range hoods available in the commercial market that provides makeup air.

4.6.6.5 Garages

From ASHRAE 62.2, Section 6.5.1, Garages.

When an occupiable space adjoins a garage, the design must prevent migration of contaminants to the adjoining occupiable space. Air seal the walls, ceilings, and floors that separate garages from occupiable space. To be considered air sealed, all joints, seams, penetrations, openings between door assemblies and their respective jambs and framing, and other sources of air leakage through wall and ceiling assemblies separating the garage from the residence and its attic area shall be caulked, gasketed, weather stripped, wrapped, or otherwise sealed to limit air movement. Doors between garages and occupiable spaces shall be gasketed or made substantially airtight with weather stripping.

Garages often contain numerous sources of contaminants. These include gasoline and exhaust from vehicles, pesticides, paints and solvents, and others. The Energy Standards require that when garages are attached to the house, these contaminants be prevented from entering the house. The wall between the unit and garage (or garage ceiling in designs with living space above garages) shall be designed and constructed so that no air migrates through the wall or ceiling. The common doors and any air handlers or ducts located in the garage shall also be sealed, weather-stripped, or gasketed. Use of an exterior door system would address this requirement.

ASHRAE 62.2 Section 6.5.2 requires a system with an air handling unit (furnace) located in the garage, or return ducts located in the garage (regardless of the air handler location) to meet a sealed and tested ducts criteria of 6 percent of system airflow.

Leakage testing is mandatory for all forced-air duct systems in newly constructed buildings as specified by §150.0(m)11. For additions and alterations to existing buildings, any length of new or altered duct in the garage, or any new or altered air-handling unit in the garage triggers duct leakage testing requirements for the entire system since §150.2(a) and §150.2(b) require new or altered components to meet all applicable requirements in §150.0(o).

Example 4-27 – Garages**Question:**

In a newly constructed building, the building designer located the air handler in the garage. The main return trunk from the dwelling is connected to the air handler. Is this acceptable?

Answer:

Yes. The duct system must be leak-tested at 25 Pa. and sealed, if necessary, to have leakage no greater than 5 percent of the total fan flow.

Example 4-28**Question:**

For an alteration to an existing building, the air handler is located in the dwelling unit, and a portion of the return duct is run through the garage to a bedroom above the garage. The return duct has 4 ft of length located in the garage, and this 4 ft section is being replaced. How do I test that length of the duct for leakage?

Answer:

The entire duct system must be leak-tested at 25 Pa. and sealed, if necessary, to have leakage no greater than 6 percent of the total fan flow as required by ASHRAE 62.2. There is no test available to leak test only the garage portion of the duct system.

4.6.6.6 Ventilation Opening Area

From ASHRAE 62.2, Section 6.6, Ventilation Opening Area.

Spaces shall have ventilation openings as listed below. Such openings shall meet the requirements of Section 6.8.

Exception: Spaces that meet the local ventilation requirements set for bathrooms in Section 5.

6.6.1 Habitable Spaces. Each habitable space shall be provided with ventilation openings with an openable area not less than 4% of the floor area nor less than 5 ft² (0.5 m²).

6.6.2 Toilets and Utility Rooms. Toilets and utility rooms shall be provided with ventilation openings with an openable area not less than 4% of the room floor area nor less than 1.5 ft² (0.15 m²).

Exceptions: (1) Utility rooms with a dryer exhaust duct; (2) toilet compartments in bathrooms.

The whole-building mechanical ventilation is intended to provide adequate ventilation to typical new homes under normal circumstances. On occasion, however, houses experience unusual circumstances where high levels of contaminants are released into the space. When this occurs, a means of providing the significantly higher levels of ventilation required to remove the contaminants is needed. Operable windows are the most likely means of providing the additional ventilation.

This section of ASHRAE Standard 62.2 requires ventilation openings in habitable spaces, toilets, and utility rooms. Ventilation openings usually mean operable windows, although a dedicated nonwindow opening for ventilation is acceptable. Spaces that meet the local exhaust requirements are exempted from this requirement.

4.6.6.7 Habitable Spaces

Habitable spaces are required to have ventilation openings with openable area equal to at least 4 percent of the space floor area (but not less than 5 ft²). Rooms people occupy are considered habitable space. Dining rooms, living rooms, family rooms, bedrooms and kitchens are considered habitable space. Closets, crawl spaces, garages and utility rooms are generally not. If the washer and dryer are located in an open basement that is also the family room, it would be considered habitable space.

The openings do not have to be provided by windows. They can also be provided by operable, insulated, weather-stripped panels.

Ventilation openings, which include windows, skylights, through-the-wall inlets, window air inlets, or similar devices, shall be readily accessible to the occupant. This means that the occupant must be able to operate the opening without having to climb on anything. An operable skylight must have some means of being operated while standing on the floor: a push rod, a long crank handle, or an electric motor.

If a ventilation opening is covered with louvers or otherwise obstructed, the openable area is the unobstructed free area through the opening.

Example 4-29 – Ventilation Openings

Question:

I am building a house with a 14 ft. by 12 ft. bedroom. What size window do I need to install?

Answer:

It depends on the type of window. The standard requires that the openable area of the window, not the window unit, be 4 percent of the floor area, or $14 \text{ ft} \times 12 \text{ ft} \times 0.04 = 6.7 \text{ ft}^2$. The fully opened area of the window or windows must be greater than 6.7 ft^2 . The requirement for this example can be met using two double-hung windows each with a fully opened area of 3.35 ft^2 . Any combination of windows whose opened areas add up to at least 6.7 ft^2 will meet the requirement.

Example 4-30 – Ventilation Opening Louvers

Question:

There are fixed wooden louvers over a window in a bedroom. The louvers have slats that are 1/8-in thick, and they are spaced 1 inch apart. What is the reduction in openable area?

Answer:

Assuming that the 1-inch spacing was measured perpendicular to the slats (the correct way), then the reduction is the slat thickness divided by the spacing, or 1/8 inch. So the credited opening area is the original opening area $\times (1 \text{ inch} - 1/8 \text{ inch})/1 \text{ inch} = 7/8$ inch of the original opening area.

4.6.6.8 Minimum Filtration

From ASHRAE 62.2, Section 6.7 Minimum Filtration.

Mechanical systems that supply air to an occupiable space through ductwork exceeding 10 ft (3 m) in length and through a thermal conditioning component, except evaporative coolers, shall be provided with a filter having a designated minimum efficiency of MERV 6 or better when tested in accordance with ANSI/ASHRAE Standard 52.2, Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size or a minimum Particle Size Efficiency of 50% in the 3.0–10 μm range in accordance with AHRI Standard 680, Performance Rating of Residential Air Filter Equipment. The system shall be designed such that all recirculated and mechanically supplied outdoor air is filtered before passing through the thermal conditioning components. The filter shall be located and installed in such a manner as to facilitate access and regular service by the owner.

6.7.1 Filter Pressure Drop. New mechanical and distribution systems covered by Section 6.7, installed after January 1, 2014, shall be designed to accommodate the clean-filter pressure drop as rated using AHRI Standard 680, Performance Rating of Residential Air Filter Equipment¹³, for the system design flow. The filter locations shall be labeled with the design airflow and maximum allowable clean-filter pressure drop. The label shall be visible to a person replacing the filter.

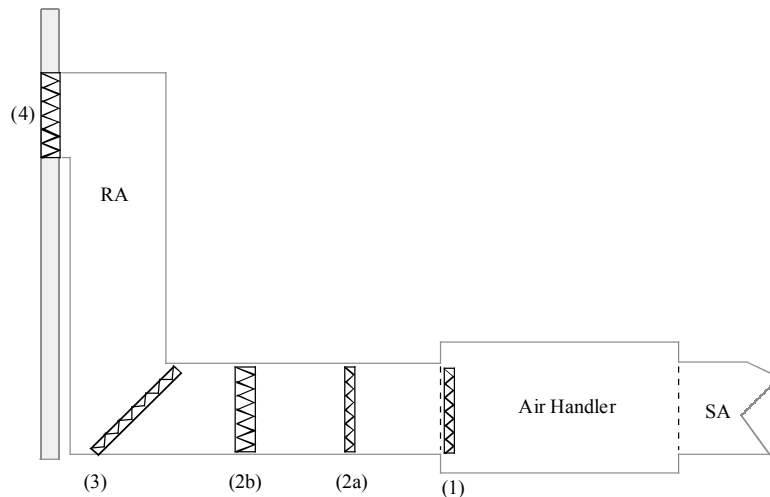
ASHRAE Standard 62.2 requires that particulate air filtration of no less than MERV 6 efficiency is installed in any HVAC system having more than 10 ft of ductwork. The particulate filter must be installed such that all the air circulated through the furnace or air handler is filtered before passing through the thermal conditioning portion of the system. In addition, the standard requires that the filter be located and installed for easy access and service by the homeowner. The filter must be of a type and size that allows the system to

operate at the design airflow rate and at less than the design pressure drop across the filter. Refer to Section 4.4.1.13 for additional information on air filtration requirements.

The filter retainer section must be easily accessible by the homeowner to assure continued monitoring and replacement. The filter bank may be located in the following locations:

1. The air handler/furnace
2. The return air plenum near the air handler
3. In the return air plenum with a deep pleat cartridge
4. Angled across the return air plenum to increase cross-sectional area
5. Situated in a wall return grille

Figure 4-31: Filter Location Options



Source: California Energy Commission

The MERV 6 pleated filter provides enhanced particulate arrestance but also provides longer service life than the conventional low efficiency panel filter. Typically, the pleated type filter will last three months or longer, depending upon operating conditions, as compared to the typical one-month life cycle of disposable fiberglass filters. The deeper pleated versions will typically provide even longer life cycles, up to a year or more.

Example 4-31– Filter Sizing

Question:

I am installing a 1200 cfm furnace in a new house. It has a 20 inches x 20 inches filter furnished and installed in the unit. Is this in compliance?

Answer:

Yes, you may assume that the equipment manufacturer has selected a compliant filter efficiency and pressure drop to match the features of the air handler.

Example 4-32

Question:

What if the above unit has no filter installed but recommends a 20 inches x 20 inches filter size? Which filter do I select?

Answer:

Several manufacturers produce a 1-inch deep MERV 6 for use in slide-in tracks and return air grills. If the pressure drop information is not furnished with the filter to assist with the selection, oversize the filter by at least one size multiple beyond the normal manufacturer recommendation. In this case, a filter selection of 20 inches x 25 inches to oversize the filter would reduce the face velocity by 25 percent, which in turn reduces the initial pressure drop by almost 50 percent.

Example 4-33

Question:

For the same 1200 cfm furnace, what other options do I have?

Answer:

For any filter, the pressure drop, efficiency, and life cycle can all be affected by velocity control. By enlarging the filter cartridge size, the approach velocity is decreased along with the pressure drop. If the depth of the filter is increased, likewise the air velocity through the media is decreased, and that, in turn, substantially reduces the actual pressure drop. Doubling the pleat depth will halve the velocity through the media and decrease pressure drop by up to 75 percent.

Example 4-34

Question:

I am installing an HVAC system with the filter to be installed at the return air grille. What should I do to accommodate a 1-inch pleated MERV 6 filter?

Answer:

You can reduce the face velocity and related pressure drop by employing multiple return air grilles. By doubling or tripling the return air filter surface area, the pressure drop is reduced by 75 percent or greater. Alternatively, you can increase the size of the return air grille similar to what was discussed in Example 4-32, above, or increase the depth of the filter as discussed in Example 4-33.

Example 4-35

Question:

I am installing a ductless split system in a space that is being added on to the house. Must I use the designated MERV 6 filter?

Answer:

No, the requirement does not apply since there is no ductwork attached to the unit.

Example 4-36

Question:

My builder supply house has only MERV 8 or greater efficiency filters. Is this in compliance?

Answer:

Yes, this is a better efficiency. However, higher MERV filters usually have higher pressure drop. Make sure that the pressure drop does not exceed the maximum design pressure drop at the design airflow rate for the system.

4.6.6.9 Air Inlets

From ASHRAE 62.2, Section 6.8, Air Inlets.

Air inlets that are part of the ventilation design shall be located a minimum of 10 ft (3 m) from known sources of contamination such as a stack, vent, exhaust hood, or vehicle exhaust. The intake shall be placed so that entering air is not obstructed by snow, plantings, or other material. Forced air inlets shall be provided with rodent/insect screens (mesh not larger than 1/2 in. [13 mm]).

Exceptions:

- a. Ventilation openings in the wall may be as close as a stretched-string distance of 3 ft (1 m) from sources of contamination exiting through the roof or dryer exhausts.*
- b. No minimum separation distance shall be required between windows and local exhaust outlets in kitchens and bathrooms.*
- c. Vent terminations covered by and meeting the requirements of the National Fuel Gas Code (NFPA 54/ANSI Z223.1, National Fuel Gas Code) or equivalent.*

When the ventilation system is designed with air inlets, the inlets must be located away from locations that can be expected to be sources of contamination. The minimum separation is 10 ft. Inlets include not only inlets to ducts, but windows that are needed to the opening area.

The Energy Standards list some likely sources of contaminants. For typical residential applications, the sources will include:

1. Vents from combustion appliances
2. Chimneys
3. Exhaust fan outlets
4. Barbeque grills
5. Locations where vehicles may be idling for any significant length of time
6. Any other locations where contaminants will be generated

The Energy Standards also require that air intakes be placed so that they will not become obstructed by snow, plants, or other material. Forced air inlets must also be equipped with insect/rodent screens, where the mesh is no larger than 1/2 inch.

There are three exceptions to the separation requirements.

1. Windows or ventilation openings in the wall can be as close as 3 feet to sources of contamination that exit through the roof or to dryer exhausts.
2. There is no minimum distance between windows and the outlet of a local exhaust outlet from kitchens or bathrooms.
3. Vent terminations that meet the requirements of the National Fuel Gas Code, which has separation and location requirements, do not need to meet the requirements.

4.6.7 Air-Moving Equipment (Section 7 of ASHRAE 62.2)

From ASHRAE 62.2, Section 7.1, Selection and Installation.

Ventilation devices and equipment shall be tested in accordance with ANSI/ASHRAE Standard 51/AMCA 210, Laboratory Methods of Testing Fans for Aerodynamic Performance Rating and ANSI/AMCA Standard 300, Reverberant Room Method for Sound Testing of Fans, and rated in accordance with the airflow and sound rating procedures of the Home Ventilating Institute (HVI 915, Procedure for Loudness Rating of Residential Fan Products, HVI 916, Air Flow Test Procedure, and HVI 920, Product Performance Certification Procedure Including Verification and Challenge). Installations of systems or equipment shall be carried out in accordance with manufacturers' design requirements and installation instructions.

Equipment used to meet the whole-building ventilation requirements or the local ventilation exhaust requirements shall be rated to deliver the required airflow and shall have sound ratings that meet the requirements of this section.

4.6.7.1 Selection and Installation

ASHRAE Standard 62.2 requires that equipment used to comply with the standard be selected based on tested and certified ratings of performance for airflow and sound. When selecting fans for use in meeting the requirements of the standard, you must check the Home Ventilating Institute-certified (HVI) products directory to confirm that the equipment you select has been tested, and the rated performance meets the requirements. The *HVI-Certified Products Directory* can be viewed here: <http://www.hvi.org/proddirectory/index.cfm>.

In addition, the Energy Standards require that the fans be installed in accordance with the manufacturer's instructions. You must review the installation instructions and other literature shipped with the fan and make sure that the installation complies with those instructions.

4.6.7.2 Sound Ratings for Fans

From ASHRAE 62.2, Section 7.2, Sound Ratings for Fans.

Ventilation fans shall be rated for sound at no less than the minimum airflow rate required by this standard, as noted below. These sound ratings shall be at a minimum of 0.1 in. w.c. (25 Pa) static pressure in accordance with the HVI procedures referenced in Section 7.1.

7.2.1 Whole-Building or Continuous Ventilation Fans.

These fans shall be rated for sound at a maximum of 1.0 sone.

7.2.2 Intermittent Local Exhaust Fans.

Fans used to comply with Section 5.2 shall be rated for sound at a maximum of 3 sone, unless their maximum rated airflow exceeds 400 cfm (200 L/s).

Exception: HVAC air handlers and remote-mounted fans need not meet sound requirements. To be considered for this exception, a remote-mounted fan must be mounted outside the habitable spaces, bathrooms, toilets, and hallways, and there must be at least 4 ft (1 m) of ductwork between the fan and the intake grille.

One common reason for not using ventilation equipment, particularly local exhaust fans, is the noise they create. To address this, ASHRAE Standard 62.2 requires that certain fans be rated for sound, and that installed fans shall have ratings below specified limits. The sound rating must be done at an airflow that is no less than the airflow that the fan must provide to meet the ventilation airflow requirement.

Because of the variables in length and type of duct and grille, there is no clearly repeatable way to specify a sound level for ventilation devices that are not mounted in the ceiling or wall surface. Consequently, air handlers, HRV/ERVs, inline fans, and remote fans are exempted from the sound rating requirements that apply to surface-mounted fans. However, to reduce the amount of fan and/or motor noise that could come down the duct to the grille, the Energy Standards sets a minimum of 4 ft of ductwork between the grille and the ventilation device. This may still produce an undesirable amount of noise for the occupant, especially if hard metal duct is used. Flexible insulated duct or a sound attenuator will reduce the transmitted sound into the space.

A. Continuous Ventilation Fans (surface mounted fans)

Continuously operated fans shall be rated at 1.0 sone or less. This 1.0 sone requirement applies to continuous whole-building ventilation fans, and also to continuous local ventilation exhaust fans.

B. Intermittent Fans (Surface-Mounted Fans)

Intermittently operated whole-building ventilation fans shall be rated at a maximum of 1.0 sone. Intermittently operated local exhaust fans shall be rated at a maximum of 3.0 sone, unless the maximum rated airflow is greater than 400 cfm.

Thus, ASHRAE Standard 62.2 extends the requirement for quiet fans to include range hoods and regular bath fans, not just whole-building ventilation system fans. The whole-building fan or other combined systems that operate continuously to provide whole-building ventilation must be rated at 1.0 sone or less, but intermittent local ventilation exhaust fans, including intermittently operated bath fans, must be rated at a maximum of 3.0 sones. Range hoods must also be rated at 3.0 sones or less, but this is at their required "working speed" of 100 cfm. Most range hoods have maximum speeds of much more than 100 cfm, but 100 cfm is the minimum airflow that is required by the Standards.

4.6.7.3 Airflow Rating

From ASHRAE 62.2.

4.3 Airflow Measurement (Whole-Building Ventilation). The airflow required by this section is the quantity of outdoor ventilation air supplied and/ or indoor air exhausted by the mechanical ventilation system as installed and shall be measured using a flow hood, flow grid, or other airflow measuring device. Ventilation airflow of systems with multiple operating modes shall be tested in all modes designed to meet this section.

5.4 Airflow Measurement. (Local Exhaust). The airflow required by this section is the quantity of indoor air exhausted by the ventilation system as installed and shall be measured using a flow hood, flow grid, or other airflow measuring device.

Exception: The airflow rating, according to Section 7.1, at a pressure of 0.25 in. w.c. (62.5 Pa) may be used, provided the duct sizing meets the prescriptive requirements of Table 5.3 or manufacturer's design criteria.5.4

All ventilation systems used to meet the whole-building airflow requirement must demonstrate compliance by direct measurement using a flow hood, flow grid, or other measuring device. HERS verification of whole-building airflow is required for newly constructed buildings and additions greater than 1,000 square feet to existing buildings.

Compliance with the ventilation airflow requirements for local exhaust ventilation systems can be demonstrated in one of two ways:

1. The ventilation system can be tested using an airflow measuring device after completion of the installation to confirm that the delivered ventilation airflow meets the requirement.
2. Simple exhaust systems can comply by conformance to a prescriptive requirement that the fan has a certified airflow rating that meets or exceeds the required ventilation airflow, and the ducts for the ventilation system meet either the fan manufacturer's published duct design specifications or the prescriptive duct design requirements given in Table 4-16 (Table 5.3 of ASHRAE 62.2).

When using the prescriptive duct sizing table or manufacturer's design criteria for compliance, the certified airflow rating of the fan must be based on tested performance at the 0.25 inch w.c. operating point. The certified airflow rating of a ventilation device is generally available from the manufacturer and is available for hundreds of products in the Home Ventilating Institute (HVI) Certified Products Directory at the HVI website (www.hvi.org). Manufacturers can choose whether to provide the certified data for posting at

the HVI website, but all of them should have available the rated data at 0.25 inches of water column static pressure.

If the manufacturer's duct system design specifications are used for compliance, the enforcement agency may require that the manufacturer's published system design documentation be provided for use in inspection of the installation(s).

The prescriptive duct design criteria given in Table 4-16 provides maximum duct lengths based on various duct diameters and duct type. As can be seen, the higher the flow, the larger in diameter or shorter in length the duct has to be. Moreover, smooth duct can be used to manage longer duct runs. Interpolation and extrapolation of Table 4-16 are not allowed. For airflow values not listed, use the next higher value. The table is not applicable for systems with airflow greater than 125 cfm at 62 Pa (0.25 inches of water column) static pressure.

Table 4-16: Prescriptive Duct Sizing for Single-Fan Exhaust Systems

Duct Type	Flex Duct				Smooth Duct			
Fan Rating 62 Pa (cfm@ 0.25 in. w.c.)	50	80	100	125	50	80	100	125
Diameter inch	Maximum Length ft.							
3	X	X	X	X	5	X	X	X
4	70	3	X	X	105	35	5	X
5	NL	70	35	20	NL	135	85	55
6	NL	NL	125	95	NL	NL	NL	145
7 and above	NL	NL	NL	NL	NL	NL	NL	NL

*This table assumes no elbows. Deduct 15 feet of allowable duct length for each elbow.
 NL = no limit on duct length of this size.
 X = not allowed, any length of duct of this size with assumed turns and fitting will exceed the rated pressure drop.*

ASHRAE 62.2, Table 5.3

Example 4-37 – Prescriptive Duct Sizing

Question:

I need to provide 75 cfm of continuous ventilation, which I plan to do using a central exhaust fan. I plan to connect the fan to a roof vent termination using flex duct. The duct will be about 8 ft long, with no real elbows, but some slight bends in the duct. What size duct do I need to use?

Answer:

From Table 4-16, using the 80 cfm, flex duct column, the maximum length with a 4-inch duct is 3 ft, so you cannot use 4 inches of duct. With a 5-inch duct, the maximum length is 70 ft, so that will clearly be adequate. Even if the bend in the duct is treated as an elbow, the allowable length only drops to 55 ft, more than adequate for the 8 ft required.

Example 4-38

Question:

For the situation in Example 4-37, again providing 75 cfm, what size duct would I need if smooth metal duct were used? In this case the total length would increase to about 10 ft, and there would be two elbows.

Answer:

Using the 80 cfm, smooth duct column of Table 4-16, the maximum length of 4 inches duct is 35 ft. Subtracting 15 ft for each of the two elbows leaves 5 ft, which is not long enough. With a 5-inch duct the maximum length is 135 ft. Subtracting 15 ft for each of the 2 elbows leaves 105 ft, so that will clearly be adequate.

Example 4-39

Question:

I will need a 100 cfm range hood. I have two possible duct routings. One is 15 ft long and will require three elbows. The other is 35 ft long but requires only one elbow. What size flex duct do I need to use?

Answer:

First, take the two routings and add in the correction for the elbows. Elbow corrections can be either added to the desired length or subtracted from the allowable length. In this case, we know the desired length, so we'll add the elbows. We get 15 ft plus 3 times 15 ft for a total of 60 ft, or 35 ft plus 15 ft equals 50 ft.

Looking at Table 4-16, in the 100 cfm, flex duct column, the maximum length with 5 inches duct is 35 ft, which is less than the adjusted length for either routing. With a 6-inch duct, the maximum length is 125 ft, longer than either adjusted length. A 6-inch duct would need to be used for either routing.

Note: The building code may not allow flex duct to be used for the range hood, in which case a smooth duct would be required. For a smooth duct, 5 inches would be acceptable.

4.6.7.4 Multibranch Exhaust Ducting

From ASHRAE 62.2, Section 7.3, Multibranch Exhaust Ducting.

If more than one of the exhaust fans in a dwelling unit shares a common exhaust duct, each fan shall be equipped with a back-draft damper to prevent the recirculation of exhaust air from one room to another through the exhaust ducting system.

ASHRAE Standard 62.2 contains restrictions on several situations where multiple exhausts are connected through a combined duct system. These restrictions are intended to prevent air from moving between spaces through the exhaust ducts.

The first restriction is that if more than one exhaust fan in a dwelling shares a common duct, then each fan must be equipped with a backdraft damper so that air exhausted from one bathroom or unit is not allowed to go into another space. Exhaust fans in multiple dwelling units may not share a common duct.

The other restriction applies to remote fans serving more than one dwelling unit. Sometimes a single remote fan or HRV/ERV will exhaust from several units in a multifamily building. This section does not preclude the use of that type of system, but it does require that either the shared exhaust fan operate continuously or that each unit be equipped with a backdraft damper so that air cannot flow from unit to unit when the fan is off.

In multifamily buildings, fire codes may impose additional restrictions.

4.6.8 Multifamily Buildings (Section 8 of ASHRAE 62.2)

Individual dwelling units in multifamily buildings are each required to meet all the IAQ and whole-building ventilation requirements for ASHRAE 62.2 discussed in the preceding section, as modified by this section. This means that the terms “building” and “dwelling” in the preceding sections are referring to single dwelling units for multifamily buildings.

4.6.8.1 Whole-Building Mechanical Ventilation

From ASHRAE 62.2, Section 8.2, Whole-Building Mechanical Ventilation.

8.2.1 Ventilation Rate. The required dwelling unit mechanical ventilation rate, Q_{fan} , shall be the rate in Section 4.1.1 plus 0.02 cfm per ft² (10 L/s per 100 m²) of floor area or, equivalently, the rate from Tables 8.2.1a and 8.2.1b. The required mechanical ventilation rate shall not be reduced as described in Section 4.1.2.

The methods for determining the required whole-building ventilation rate for multifamily buildings are almost the same as those used for single-family buildings.

As this section will discuss only the differences, it would be beneficial for the reader to review Section 4.6.3 before continuing.

Multifamily buildings must use the fan ventilation rate method to determine the required ventilation rate, specified in this section. The total ventilation rate method cannot be used for multifamily buildings.

The fan system may use an intermittent ventilation option using the same method as Section 4.6.3.2 to determine the required minimum intermittent ventilation flow rate, replacing the use of Equation 4-1 and Table 4-14 in Section 4.6.3.2 with Equation 4-9 and Table 4-17.

The continuous whole-building ventilation rate is larger for multifamily buildings, but is given by an equation similar to Equation 4-1 and is calculated in the same manner:

Equation 4-9

$$Q_{fan} = 0.03A_{floor} + 7.5(N_{br} + 1)$$

Where:

$$Q_{fan} = \text{fan flow rate (cfm)}$$

$$A_{floor} = \text{floor area of residence (ft}^2\text{)}$$

$$N_{br} = \text{number of bedrooms (no fewer than one)}$$

The required ventilation rate may also be found using Table 4-17. This table allows users to find the required ventilation rate directly if they know the floor area and number of bedrooms.

Table 4-17: Dwelling Unit Ventilation Air Requirements, cfm

Floor Area (ft ²)	Number of Bedrooms				
	1	2	3	4	≥5
<500	30	40	45	55	60
500-1000	45	55	60	70	75
1001-1500	60	70	75	85	90
1501-2000	75	85	90	100	105
2001-2500	90	100	105	115	120
2501-3000	105	115	120	130	135
3001-3500	120	130	135	145	150
>3501	135	145	150	160	165

From ASHRAE 62.2, Table 8.2.1a

Corridors and other common areas within conditioned space must be provided a ventilation rate of 0.06 cfm per ft² of floor area. This required ventilation rate for common areas can be calculated using Equation 4-10:

Equation 4-10

$$Q_{fan} = 0.06A_{common}$$

Where:

Q_{fan} = fan flow rate (cfm)

A_{common} = floor area of common area (ft²)

Nonresidential spaces in mixed-use buildings must meet the requirements of ASHRAE 62.1, Ventilation for Acceptable Indoor Air Quality.

Common parking garages adjoining occupiable spaces, except parking garages with at least two walls that are at least 5 percent open to the outside, must be provided with exhaust ventilation at a rate given by Equation 4-11:

Equation 4-11

$$Q_{fan} = 0.4A_{garage}$$

Where:

Q_{fan} = fan flow rate (cfm)

A_{garage} = floor area of Parking Garage (ft²)

This ventilation rate is much higher per ft² of floor area than most ventilation requirements due to vehicle emission concerns.

4.6.8.2 Other Requirements

From ASHRAE 62.2, Section 8.4, Other Requirements

8.4.1 Transfer Air. Measures shall be taken to minimize air movement across envelope components separating dwelling units, including sealing penetrations in the common walls, ceilings, and floors of each unit and by sealing vertical chases adjacent to the units. All doors between dwelling units and common hallways shall be gasketed or made substantially airtight.

8.4.1.1 Compliance. One method of demonstrating compliance with Section 8.4.1 shall be to verify a leakage rate below a maximum of 0.2 cfm per ft² (100 L/s per 100 m²) of the dwelling unit envelope area (i.e., the sum of the area of the walls between dwelling units, exterior walls, ceiling and floor) at a test pressure of 50 Pa by a blower door test conducted in accordance with either ANSI/ASTM-E779-10, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization, or ANSI/ASTM E1827, Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door. The test shall be conducted with the dwelling unit as if it were exposed to outdoor air on all sides, top, and bottom by opening doors and windows of adjacent dwelling units.

ASHRAE Standard 62.2 requires that measures be taken to minimize air movement across envelope components separating dwelling units from adjacent dwelling units and nearby spaces outside the occupiable space of the dwelling unit. This should include sealing all penetrations in envelope components (for example, light fixtures in roofs, outlets in walls, and base boards around the edge of floors) and sealing vertical chases adjacent to units. Pipe and electrical penetrations are also examples of envelope component penetrations that require sealing. The measures must apply to adjacent units both above and below, as well as side by side.

All doors between dwelling units and common areas must be gasketed or made substantially airtight.

The Energy Standards do not require HERS verification of multifamily envelope leakage rates. The builder or installer must implement measures that meet the ASHRAE 62.2 Section 8.4.1 transfer air requirements. The enforcement agency is responsible for determining compliance, thus may specify inspection criteria or other methods such as the diagnostic method detailed in ASHRAE 62.2 Section 8.4.1.1.

4.6.8.3 Air-Moving Equipment

From ASHRAE 62.2, Section 8.5, Air-Moving Equipment.

8.5.1 Exhaust Ducts. Exhaust fans in separate dwelling units shall not share a common exhaust duct. Exhaust inlets from more than one dwelling unit may be served by a single exhaust fan downstream of all the exhaust inlets if the fan is designed and intended to run continuously or if each inlet is equipped with a back-draft damper to prevent cross-contamination when the fan is not running.

8.5.2 Supply Ducts. Supply outlets to more than one dwelling unit may be served by a single fan upstream of all the supply outlets if the fan is designed and intended to run continuously or if each supply outlet is equipped with a back-draft damper to prevent cross-contamination when the fan is not running.

Exhaust fans in separate dwelling units cannot share a common exhaust duct. Exhaust inlets from more than one dwelling unit may be served by a single exhaust fan downstream of all the exhaust inlets if the fan is designed and intended to run continuously or if each inlet is equipped with a backdraft damper to prevent cross-contamination when the fan is not running.

Supply outlets to more than one dwelling unit may be served by a single fan upstream of all the supply outlets if the fan is designed and intended to run continuously or if each supply outlet is equipped with a backdraft damper to prevent cross-contamination when the fan is not running.

4.7 Alternative Systems

4.7.1 Hydronic Heating Systems

Hydronic heating is the use of hot water to distribute heat. Hydronic heating is discussed in this compliance manual as an “alternative system” because it is much less common in California than in other parts of the United States.

A hydronic heating system consists of a heat source, which is either a boiler or water heater, and a distribution system. There are three main types of hydronic distribution systems, and they may be used individually or in combination: baseboard convectors or radiators, hot water air handlers, and radiant panel heating systems. These three options are illustrated in Figure 4-32.

Baseboard convectors or radiators are most effective when mounted near the floor. Cool air drawn by gravity over heated panels or finned tubes is heated and pushed upward to warm the room. These devices also increase the mean radiant temperature of the space, improving comfort. Baseboard convectors or radiators do not require ducting.

Air handlers consist of a blower and finned tube coil enclosed in a sheet metal box (similar to a typical residential furnace) and may be ducted or nonducted. Air handlers may also include refrigerant coils for air conditioning. Some air handlers are compact and can fit under cabinets.

Radiant panels may be mounted on or integrated with floors, walls, and ceilings. Radiant floor panels are most typical. See the separate section below for additional requirements specific to radiant floor designs.

4.7.1.1 Mandatory Requirements

For hydronic heating systems without ducts, the mandatory measures cover only pipe insulation, tank insulation, and boiler efficiency. Otherwise, for fan coils with ducted air distribution, the mandatory air distribution measures also apply. For combined hydronic systems, as described below, mandatory water heating requirements also apply to the water heating portion of the system.

A. Pipe and Tank Insulation

§150.0(j) Water System Pipe and Tank Insulation and Cooling Systems Line Insulation, §123.0 Requirements for Pipe Insulation

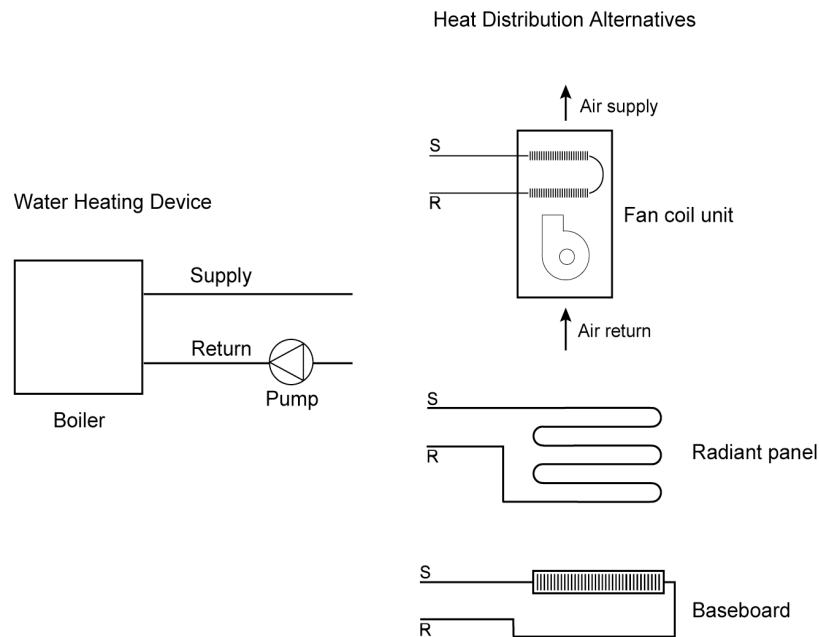
The typical residential hydronic heating system operating between 105° and 140° F must have at least 1 inch (25 mm) of insulation on pipes less than 1 inch in diameter and 1.5 inch (38 mm) of insulation on pipes between 1 inch and less than 1.5 inches in diameter. Systems operating between 141° and 200° F must have at least 1.5 inches of insulation on pipes less than 1.5 inches in diameter. For other temperatures and pipe insulation characteristics, see Table 4-5.

There are a few exceptions where insulation is not required:

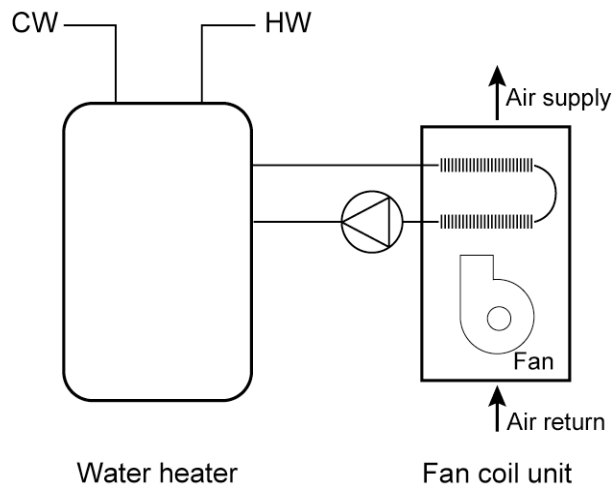
1. Sections of pipes where they penetrate framing members.
2. Pipes that provide the heat exchange surface for radiant floor heating.
3. Piping in the attic that is covered by at least 4 inches (100 mm) of blown insulation on top.
4. Piping installed within walls if all the requirements for Insulation Installation Quality are met (see Chapter 3 Building Envelope Requirements).

If the system includes an unfired hot water storage tank, then the tank must be either wrapped with R-12 insulation or insulated internally to at least R-16.

Figure 4-32: Hydronic Heating System Components



Source: Richard Heath & Associates/Pacific Gas & Electric

Figure 4-33: Combined Hydronic System With Water Heater as Heat Source

Source: Richard Heath & Associates/Pacific Gas & Electric

For pipes in hydronic heating systems that operate at pressure greater than 15 psi, the requirements of §120.3 apply. These are the same requirements that apply to nonresidential piping systems.

B. Boiler Efficiency

Gas or oil boilers of the size typically used for residential space heating (less than 300,000 Btu/h capacity) must be rated with an AFUE of 80 percent or greater. (See *Appliance Efficiency Regulations, Title 20 for minimum efficiencies of other heating equipment.*) A gas or oil water heater may also be used as a dedicated source for space heating. Other hot water sources, including heat pumps or electric resistance water heaters, are not allowed for use in dedicated space-heating systems. Therefore, some water heaters may be used for space heating only if used as part of a combined hydronic system as described below. In that case, the mandatory water heater requirements apply.

Thermostat requirements also apply to hydronic systems as described in Section 4.5.1.

4.7.1.2 Prescriptive Requirements

There are no specific prescriptive requirements that apply to hydronic systems. However, if the system has a fan coil with ducted air distribution, the relevant prescriptive requirements apply, including duct insulation and duct sealing.

4.7.1.3 Performance Compliance Options

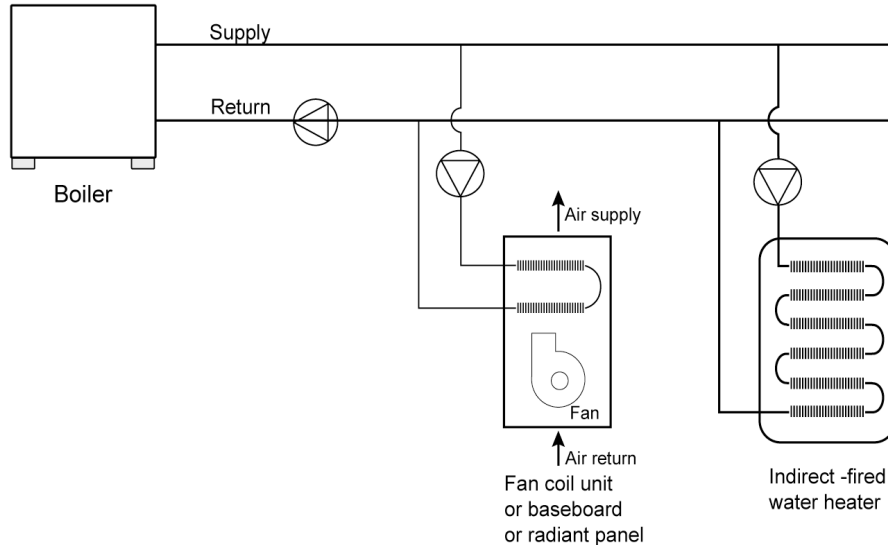
Credit for choosing a hydronic heating system is possible using the performance compliance method. The standard design is assumed to have a furnace and ducted air distribution system. Therefore, hydronic systems without ducts can take credit for avoiding duct leakage penalties. In addition, minimizing the amount of pipe outside conditioned space will provide some savings. Hydronic heating compliance calculations are described in the *Residential ACM Manual*.

If the proposed hydronic system includes ducted air distribution, then the associated compliance options described earlier in this chapter may apply, such as adequate airflow (if there is air conditioning) and supply duct location.

A “combined hydronic” system is another compliance option that is possible when using the performance method. *Combined hydronic heating* refers to the use of a single water heating device as the heat source for both space and domestic hot water heating.

There are two types of combined hydronic systems. One uses a boiler as a heat source for the hydronic space heating system. The boiler also heats domestic water by circulating hot water through a heat exchanger in an indirect-fired water heater.

Figure 4-34: Combined Hydronic System With Boiler and Indirect Fired Water Heater



Source: Richard Heath & Associates/Pacific Gas & Electric

The other type of hydronic heating uses a water heater as a heat source. The water heater provides domestic hot water as usual. Space heating is accomplished by circulating water from the water heater through the space heating delivery system. Sometimes a heat exchanger is used to isolate potable water from the water circulated through the delivery system. Some water heaters have built-in heat exchangers for this purpose.

For compliance calculations, the water-heating function of a combined hydronic system is analyzed for water-heating performance as if the space-heating function were separate. For the space-heating function, an “effective” AFUE or HSPF rating is calculated. These calculations are performed automatically by the compliance software.

4.7.2 Radiant Floor System

§110.8(g) and Table 118.0-A

One type of distribution system is the radiant floor system, either hydronic or electric, which must meet mandatory insulation measures. (See below.) Radiant floors may take one of several forms. Tubing or electric elements for radiant floor systems may be:

1. Embedded in a concrete floor slab.
2. Installed over the top of a wood subfloor and covered with a concrete topping.
3. Installed over the top of wood subfloor in between wood furring strips.
4. Installed on the underside surface of wood subfloor

In the latter two types of installations, aluminum fins are typically installed to spread the heat evenly over the floor surface and to reduce the temperature of the water as required. All

hydronic systems use one or more pumps to circulate hot water. Pumps are controlled directly or indirectly by thermostats, or by special outdoor reset controls.

Table 4–18: Slab Insulation Requirements for Heated Slabs

Location of Insulation	Orientation of Insulation	Installation Criteria	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 frost line, whichever is greater.	1-15	5
			16	10
			1-15	5
Between heated slab and outside foundation wall	Vertical and Horizontal	Vertical insulation from the top of the slab at the inside edge of the 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 the plan view.	16	10 vertical and 7 horizontal

Source: 2016 Energy Standards Table 110.8-A

Radiant floor systems in concrete slabs must have insulation between the heated portion of the slab and the outdoors.

When space heating hot water pipes or heating elements are set into a concrete slab-on-grade floor, slab-edge insulation from the level of the top of the slab, down 16 inches (200 mm) 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) is required. Alternatively, insulation may be installed down from the top of the slab and wrapped under the slab for a minimum of 4 ft toward the middle of the slab. The required insulation value for each of these insulating methods is either R-5 or R-10 depending on climate zone as shown in Table 4–18. Any part of the slab extending outward horizontally must be insulated to the level specified in Table 4–18.

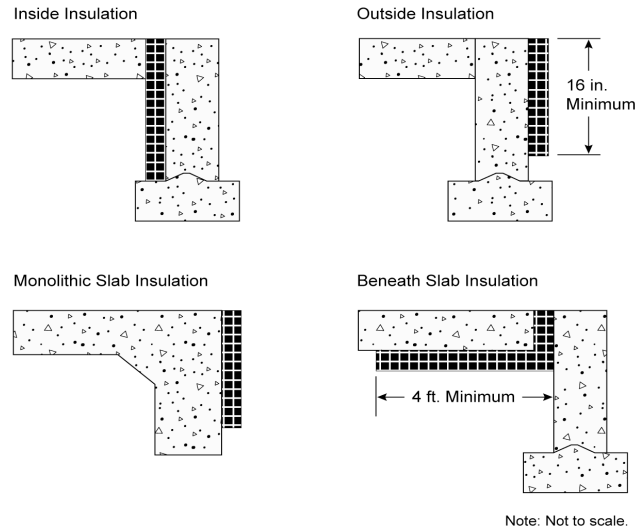
When using the performance compliance method with slab-on-grade construction, the standard design includes slab edge insulation as described above using the F-factors in Reference Joint Appendix JA4, Table 4.4.8.

When space-heating hot water pipes or heating elements are set into a lightweight concrete topping slab laid over a raised floor, insulation must be applied to the exterior of any slab surface from the top of the slab where it meets the exterior wall, to the distance below ground level as described in Table 4–18. If the slab does not meet the ground on the bottom surface, the specified insulation level must be installed on the entire bottom surface of the raised slab. Any part of the slab extending outward horizontally must be insulated to the level specified in Table 4–18. For lightweight slabs installed on raised floors and inside exterior walls, the overall wall R-value and overall floor R-value (determined as 1/(U-factor)) may be counted toward meeting the minimum R-value requirements specified in Table 4–18.

Raised floor insulation that meets the mandatory minimum R-value for wood floor assemblies also meets the requirement for insulation wrapping under the lightweight topping slab.

Slab edge insulation applied to basement or retaining walls (with heated slab below grade) must be installed so that insulation starts at or above ground level and extends down to the bottom of the foundation or to the frost line, whichever is greater.

Figure 4-35: Heated Slab-On-Grade Floor Insulation Options



Source: California Energy Commission

Local conditions (such as a high water table) may require special insulation treatment to achieve satisfactory system performance and efficiency. To determine the need for additional insulation, follow the recommendations of the manufacturer of the hydronic tubing or heating element being installed. Where there is a danger of termite infestation, install termite barriers, as required, to prevent hidden access for insects from the ground to the building framing.

In addition to the insulation R-value requirements, §110.8(g)1 also sets mandatory measures related to moisture absorption properties of the insulation and protection of the insulation from physical damage or pest intrusion.

Example 4-40

Question:

My client wants a dedicated hydronic-heating system (space heating only), but a few things are unclear: (1) What piping insulation is required? (2) Can I use any compliance approach? (3) Do I have to insulate the slab with slab edge insulation? (4) What special documentation must be submitted for this system type?

Answer:

(1) The supply lines not installed within a concrete radiant floor must be insulated in accordance with §150.0(j)2— Systems operating between 105° and 140° F must have at least 1 inch of insulation on pipes less than 1 inch in diameter, and 1.5 inches of insulation on pipes between 1 inch and less than 1.5 inches in diameter. Systems operating between 141° and 200° F must have at least 1.5 inches of insulation on pipes less than 1.5 inches in diameter.

(2) You can use any compliance approach, but the boiler must meet the mandatory efficiency 80 percent AFUE.

(3) The slab edge insulation shown in Table 4–18 is required only when the distribution system is a radiant floor system (pipes in the slab). When this is the case, the insulation values shown are mandatory measures (no modeling or credit).

(4) No special documentation is required.

Example 4-41

Question:

What are the slab edge insulation requirements for a hydronic-heating system with the hot water pipes in the slab?

Answer:

The requirements for slab edge insulation can be found in §110.8 and §150.0(l).

Material and installation specifications are as follows:

Insulation values as shown in

1. Table 4–18
2. Protected from physical damage and ultra-violet light deterioration
3. Water absorption rate no greater than 0.3 percent (ASTM-C272)
4. Water vapor permeance no greater than 2.0 per inch (ASTM-E96-14).

4.7.3 Evaporative Cooling

Evaporative coolers cool a building by either passing outdoor air through a wetted evaporative medium (direct evaporative cooler), by indirect cooling through a nonporous heat exchanger separating evaporatively cooled secondary air from outdoor air, or by a combination indirect-direct system that combines an indirect heat exchanger with a downstream direct evaporative process. Although direct coolers are the most common systems available, the more advanced indirect and indirect-direct systems offer generally lower supply air temperatures with less moisture introduced to the indoor space. For the Energy Standards, performance credit is allowed only for indirect and indirect-direct evaporative cooling systems. All coolers receiving credits within the *ACM Manual* must be listed in the Energy Commission’s Title 20 Evaporative Cooler appliance database (<https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx>).

Evaporative coolers may be used with any compliance approach. In the prescriptive compliance approach, all evaporative coolers are treated as a minimum efficiency 13.0 SEER air conditioner.

In the performance approach, the compliance software uses an hourly model based on unit effectiveness, supply airflow, and power to determine the magnitude of the credit based on climate conditions and unit sizing relative to the loads. Typical cooling budget credits are 20-30 percent, depending upon these factors.

The evaporative cooling system must meet the following requirements to receive credit based on the hourly performance method described above. Direct coolers, as well as indirect and indirect-direct coolers not meeting these criteria, shall be modeled as a minimum efficiency (13.0 SEER) central air conditioner.

1. The equipment manufacturer shall certify to the Energy Commission that water use does not exceed 7.5 gallons per ton hour based on the Title 20 Appliance Efficiency Regulations testing criteria.

2. Equipment shall be permanently installed (no window or portable units).
3. Installation shall provide for automatic relief of supply air from the house with maximum air velocity through the relief dampers not exceeding 800 fpm (at the Title 20 rated airflow). Pressure relief dampers and ductwork shall be distributed to provide adequate airflow through all habitable rooms. For installations with an attic, ceiling dampers shall be installed to relieve air into the attic and then outside through attic vents. For installations without an attic, sidewall relief dampers are acceptable.
4. To minimize water consumption, bleed systems are not allowed.
5. A water quality management system (either “pump down” or conductivity sensor) is required. “Pump down” systems can either be integral to the evaporative cooler or they can be accessories that operate on a timed interval. The time interval between pumps shall be set to a minimum of 6 hours of cooler operation. Longer intervals are encouraged if local water quality allows. Automatic systems that use conductivity sensors provide the best water efficiency compared to a timed pump down system. These sensors monitor the water quality and don’t unnecessarily drain the water based on elapsed time.
6. Automatic thermostats are required. Manual on/off controls are not allowed.
7. If the evaporative cooler duct system is shared with a heating and/or cooling system, the installed duct system shall employ backdraft dampers at the evaporative cooler supply.
8. The installing contractor must provide a winter closure device that substantially blocks outdoor air from entering the indoor space.
9. The size of the water inlet connection at the evaporative cooler shall not exceed 3/8 inch.
10. Unless prohibited by local code, the sump overflow line shall not be directly connected to a drain and shall terminate in a location that is normally visible to the building occupants.

Example 4-42**Question:**

How are applications with vapor compression cooling systems and evaporative cooling systems handled?

Answer:

In situations where both evaporative cooling system(s) and vapor compression system(s) are installed in a house, the size of the evaporative cooler will dictate the magnitude of the credit. The performance approach will ensure that an evaporative cooler sized to meet most of the cooling loads will generate a higher credit than one sized to meet a fraction of the design cooling load.

Example 4-43**Question:**

How do you model multiple evaporative coolers on one house?

Answer:

In situations with multiple evaporative coolers, effectiveness inputs should be averaged, and airflow and power inputs should be totaled. Performance characteristics of each piece of equipment should be listed on the compliance forms.

4.7.4 Ground-Source Heat Pumps

Table 4–19 – Standards for Ground Water-Source and Ground-Source Heat Pumps Manufactured on or After October 29, 2003

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

Source: Section 1605.3 Table C-8 of the 2012 *California Appliance Efficiency Regulations*

A geothermal or ground-source heat pump uses the earth as a source of energy for heating and as a heat sink for energy when cooling. Some systems pump water from an aquifer in the ground and return the water to the ground after exchanging heat with the water. A few systems use refrigerant directly in a loop of piping buried in the ground. Those heat pumps that either use a water loop or pump water from an aquifer have efficiency test methods that are accepted by the Energy Commission.

The mandatory efficiencies for ground water source heat pumps are specified in the *California Appliance Efficiency Regulations* and repeated in Table 4–19. These efficiency values are certified to the Energy Commission by the manufacturer and are expressed in terms of coefficient of performance (COP) for heating and EER for cooling.

For the performance compliance approach, the COP must be converted to HSPF. To take appropriate credit, the EER should be entered as a HERS-verified EER, which requires that a HERS Rater verify the equipment efficiency. When this approach is used, a significant portion of the ground-source heat pumps efficiency will not be accounted for. If credit is not taken, the EER may be used in place of the SEER. When heat pump equipment is not tested for HSPF, calculate the HSPF as follows:

Equation 4-12

$$HSPF = (3.2 \times COP) - 2.4$$

The efficiency of geothermal heat pump systems depends on how well the portion of the system in the ground works. Manufacturers' recommendations must be followed carefully to ensure that the system is appropriately matched to the soil types and weather conditions. Local codes may require special installation practices for the ground-installed portions of the system. Verify that the system will meet local code conditions before choosing this type of system to meet the Standards.

4.7.5 Solar Space Heating

Solar space-heating systems are not recognized within either the prescriptive packages or the performance compliance method.

4.7.6 Wood Space Heating

The Energy Commission's exceptional method for wood heaters with any type of backup heating is available in areas where natural gas is not available. If the required eligibility criteria are met, a building with one or more wood heaters may be shown to comply with the Energy Standards using either the prescriptive or performance approaches as described below.

4.7.6.1 Prescriptive Approach

The building envelope conservation measures of the component package must be installed. The overall heating system efficiency (wood stove plus backup system) must comply with the prescriptive requirements.

4.7.6.2 Performance Approach

A computer method may be used for compliance when a home has wood space heat. There is no credit, however. Both the proposed design and the standard building are modeled with the same system, for example, with the overall heating system efficiency equivalent to a 80 percent AFUE central furnace with ducts in the attic insulated to Package A and with diagnostic duct testing.

4.7.6.3 Wood Heater Qualification Criteria

The Energy Standards establish exceptional method guidelines for the use of wood heaters. If all the criteria for the wood heat exceptional method are not met, a backup heating system must be included in the compliance calculations as the primary heat source.

The building department having jurisdiction must determine that natural gas is not available.

Note: Liquefied petroleum gas, or propane, is not considered natural gas.

The following eligibility criteria apply:

1. The local or regional air quality authority must determine that its authorization of this exceptional method is consistent with state and regional ambient air quality requirements according to Sections 39000 to 42708 of the California Health and Safety Code.
2. The wood heater must be installed in a manner that meets the requirements of all applicable health and safety codes, including, but not limited to, the requirements for maintaining indoor air quality in the CMC, in particular those homes where vapor barriers are.
3. The wood heater must meet the EPA definition of a wood heater as defined in Title 40, Part 60, Subpart AAA of the Code of Federal Regulations (40CFR60 Subpart AAA) (See below.)
4. The performance of the wood heater must be certified by a nationally recognized agency and approved by the building department having jurisdiction to meet the performance standards of the EPA.
5. The rated output of the wood heater must be at least 60 percent of the design heating load, using calculation methods and design conditions as specified in §150(h).
6. At the discretion of the local enforcement agency, a backup heating system may be required and be designed to provide all or part of the design heating load, using calculation methods and design conditions as specified in §150(h).
7. The wood heater must be located such that transfer of heat from the wood heater is effectively distributed throughout the entire residential dwelling unit, or it must be used in conjunction with a mechanical means of providing heat distribution throughout the dwelling.
8. Habitable rooms separated from the wood heater by one free opening of less than 15 ft² or two or more doors must be provided with a positive heat distribution system, such as a thermostatically controlled fan system. Habitable rooms do not include closets or bathrooms.

9. Wood heaters on a lower level are considered to heat rooms on the next level up, provided they are not separated by two or more doors.
10. The wood heater must be installed according to manufacturer and local enforcement agency specifications and must include instructions for homeowners that describe safe operation.
11. The local enforcement agency may require documentation that demonstrates that a particular wood heater meets all these requirements.

Federal regulation in 40CFR60 Subpart AAA includes minimum criteria for wood heaters established by the U.S. EPA. These criteria define a wood heater as an enclosed, wood-burning appliance capable of and intended for space heating or domestic water heating that meets all the following criteria:

1. An air-to-fuel ratio averaging less than 35 to 1
2. A firebox volume less than 20 ft³.
3. A minimum burn rate less than 5 kilogram/hour (11.0 lbs/hr)
4. A maximum weight of less than 800 kilograms (1760 lbs)
5. The federal rules explicitly exclude furnaces, boilers, cook stoves, and open masonry fireplaces constructed on site, but include wood-heater inserts.

Example 4-44

Question:

Are pellet stoves treated the same as wood stoves for compliance with the Standards?

Answer:

Yes.

Example 4-45

Question: If a wood stove is installed in a wall, does it have to meet the fireplace requirements of §150(e)?

Answer:

No. A wood stove that meets EPA certification requirements does not have to meet any requirements applicable to fireplaces.

4.7.7 Gas Appliances

§110.5 Pilot Lights

As noted in an earlier section, pilot lights are prohibited in fan-type central furnaces. The Energy Standards also prohibit pilot lights in cooking appliances, pool heaters, and spa heaters. However, one exception is provided for household cooking appliances without an electrical supply voltage connection and in which each pilot consumes less than 150 Btu/h.

For requirements related to installation of fireplaces, decorative gas appliances, and gas logs, see Chapter 3 of this manual.

4.7.8 Evaporatively Cooled Condensers

Evaporatively cooled condenser air conditioners are a type of air-conditioning system that can provide significant space cooling savings, especially in hot dry climates such as the Central Valley, the interior South Coast, and the deserts of California. The equipment

minimal efficiencies are determined according to federal test procedures. Their efficiencies are reported in terms of energy efficiency rating (EER).

The EER is the full load efficiency at specific operating conditions. In cooling climate zones of California, high EER units are more effective in saving energy than high SEER units. Using the performance compliance method, credit is available for specifying an evaporatively cooled air conditioner. When credit is taken for a high EER, field verification by a HERS Rater is required.

If an evaporatively cooled air conditioner is installed, HERS-verified measures must be installed, including duct sealing, airflow, and refrigerant charge or fault indicator display. Besides the HERS verification, there are additional special requirements for evaporatively cooled condensing air conditioners. These include that the manufacturer provide certification that water use is limited to no more than 0.15 gallon per minute per ton of capacity and that the supply line be no larger than ¼-inch in diameter. For a listing of all the requirements for evaporatively cooled condensing air conditioners, see the CF2R compliance form.

4.7.9 Nonducted Systems

Several manufacturers offer equipment that does not use air distribution ducts to heat or cool spaces. These systems use either refrigerant or water that has been heated and/or cooled to condition the space. Besides not using duct work, these systems have advanced controls and full range multispeed compressors that will allow for optimal performance through a wide range of conditioning loads without losing efficiency.

These systems must be modeled as though they were minimally efficient units. The Energy Commission expects that the manufacturers will apply for a compliance option in the near future that will allow for the development of appropriate modeling rules to be included in the performance calculation approach.

As with all other high-performance systems, the Energy Commission recommends that all associated HERS verified measure be conducted to assure that all the efficiency of this equipment is captured.

4.7.10 Ventilation Cooling

Ventilation cooling is differentiated from fresh air ventilation in that the primary focus is not to provide a minimum amount of air to meet ventilation requirements, but to use higher volumes of outdoor air to cool the indoor space in lieu of air conditioning.

The simplest form of ventilation cooling uses windows to promote the flow of cooler air from outside to inside.

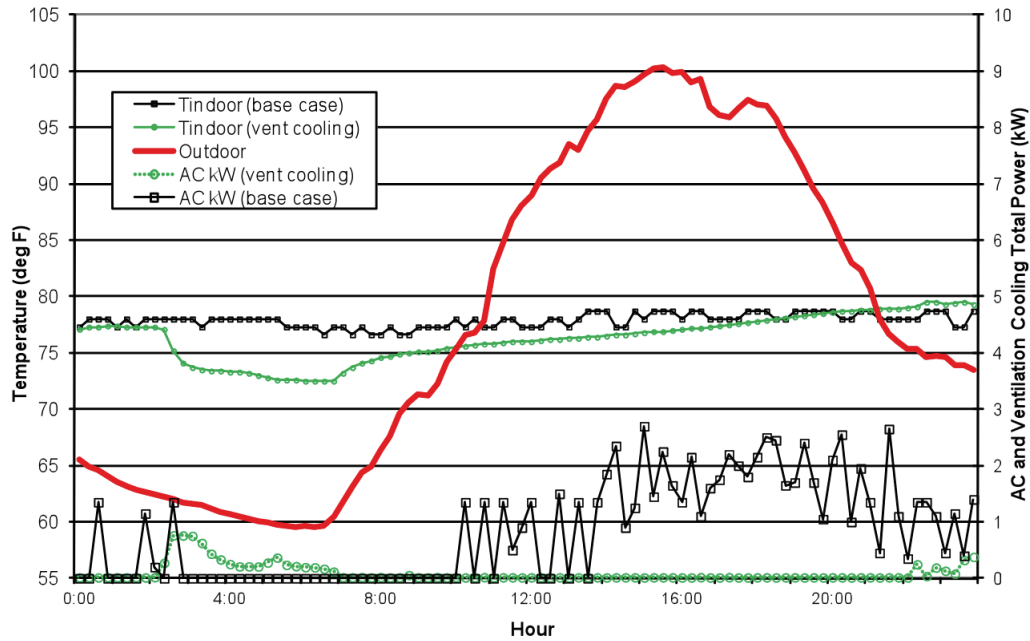
Whole house fans incorporate a fan (typically located in the attic) to pull cooler outdoor air through open windows and up into the attic, exhausting the air to the outside through attic vents. By pulling cooler outdoor air throughout the house, indoor air temperatures and the temperature of building mass are reduced, offsetting next day cooling loads. The effectiveness of night ventilation cooling depends upon the climate conditions and how much indoor temperature variation the occupant will tolerate.

Another type of ventilation cooling system is characterized as a central fan system, whereby the HVAC air handler is integrated with a damper, outdoor air duct, and controls to provide automated outdoor air delivery when conditions are favorable.

Although any of these ventilation cooling approaches can be used whenever outdoor temperatures are lower than indoor temperatures, the primary benefit occurs during summer nights when cooler outdoor air can be used to efficiently reduce indoor air temperatures

below the daytime air conditioner thermostat set point, offsetting or eliminating next-day cooling loads. The key distinction between ventilation cooling and night ventilation cooling is that the latter approach involves cooling beyond the air conditioner set point and using building mass as a thermal storage system. The effectiveness of night ventilation cooling depends upon the climate conditions, thermal envelope, and how much indoor temperature variation the occupant will tolerate.

Figure 4-36: Diurnal Temperature Variation and Ventilation Cooling



Source: California Energy Commission

Figure 4-36 above illustrates how ventilation cooling can offset air-conditioning energy use with a relatively small amount of off-peak fan energy.

4.7.10.1 Whole-House Fans

Traditional whole-house fans have a simple barometric damper (Figure 4-37) and either a belt driven or direct-drive motor driving a prop fan. Figure 4-38 shows the damper open with the fan immediately above.

Figure 4-39 shows a similar product that moves less air but provides an insulated damper with a better leakage seal between the attic and conditioned space. These units are generally designed to fit between standard rafter spacing, simplifying retrofit installations.

Finally, Figure 4-40 shows remote whole-house fan design that removes the fan farther from indoor space, reducing the noise during operation.

Whole-house fans operate most effectively at cooling a space when windows throughout the house are opened to a limited extent to ensure fairly uniform airflow throughout the dwelling. This results in the greatest interaction of the cool air with the interior mass throughout the dwelling, providing the greatest amount of stored cooling. Running the fan all night long is most effective at fully “charging” the thermal mass. Noise can be reduced somewhat through either use of a variable-speed control or installation of a multispeed fan, allowing low-speed nighttime operation. Security concerns and added dust and allergens are other factors to consider with the installation of a whole-house fan.

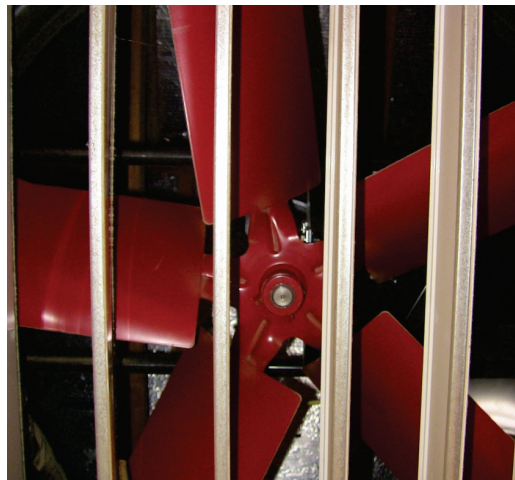
The WHFs used to comply with the Energy Standards must be listed in the Energy Commission’s Appliance Database which can be accessed at: <https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx>.

Figure 4-37: Whole-House Fan Damper



Source: California Energy Commission

Figure 4-38: Open Barometric Damper With Fan Above



Source: California Energy Commission

Figure 4-39: Insulated Whole-House Fan With Damper Actuation



Source: California Energy Commission

Figure 4-40: Ducted Remote Whole House Fan



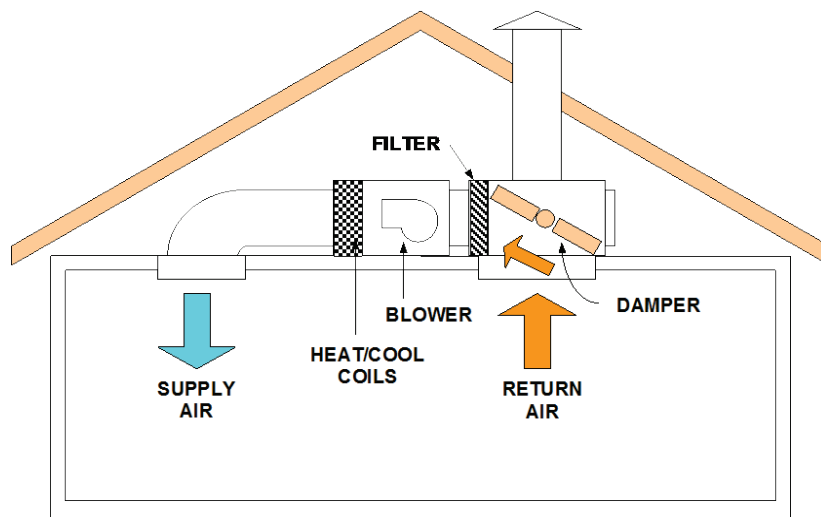
Source: California Energy Commission

4.7.10.2 Central Fan Systems

Central fan ventilation cooling systems use the furnace or air handler fan to deliver outdoor air to conditioned space. By adding an automated damper, outside air duct, and temperature sensors and controls, these systems can automatically deliver filtered outdoor air to occupant-specified comfort levels when outdoor conditions warrant the use of ventilation. This automated operation represents an improvement over WHFs, which rely entirely on the occupant being available to initiate operation and open windows throughout the house. A disadvantage of the central fan systems is that they typically move less air and consume more energy per cfm due to the more restrictive duct systems.

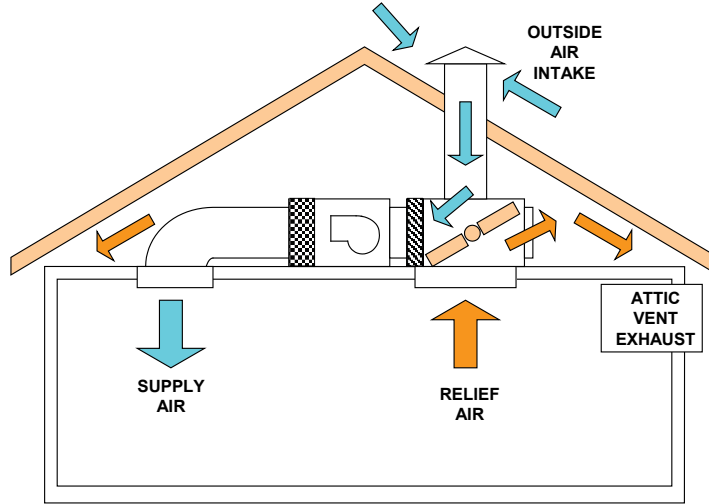
Figure 4-41 and Figure 4-42 show the airflow paths when the systems operate in conventional return air mode or outdoor air mode. In Figure 4-41, the damper is positioned to direct return air to the air handler for normal heating and cooling operation. In Figure 4-42 (ventilation cooling mode), the damper position is reversed so that air entering the air handler is now pulled from the outside air duct and then delivered to the house, with relief air exhausted through the damper to the attic. The air intake shown in these figures can be either a roof penetration inlet as shown in Figure 4-43 or a gable end screen vent as shown in Figure 4-44. A larger diameter duct sized to handle the full ventilation airflow runs from the air inlet to the damper box.

Figure 4-41: Central Fan System (Return Air Mode)



Source: California Energy Commission

Figure 4-42: Central Fan System (Outdoor Air Mode)



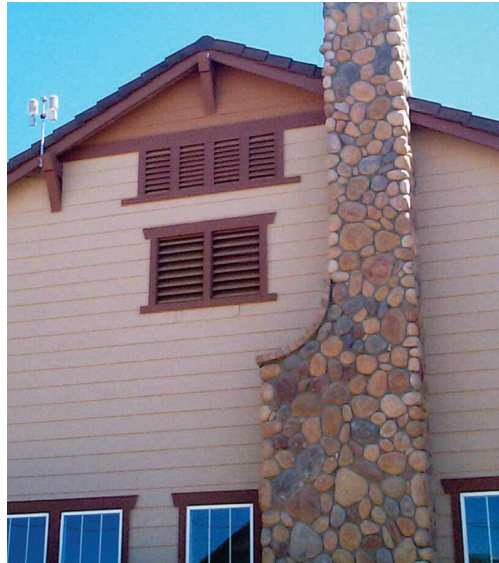
Source: California Energy Commission

Figure 4-43: Sample Rooftop Air Intake



Source: California Energy Commission

Figure 4-44: Sample Gable End Air Intake (lower set of vents)



Several advantages for central fan systems include control integration with the central system thermostat, precise control of ventilation initiation and termination, filtered outdoor air, and increased home security (windows can remain shut). One of the systems currently available also uses a variable-speed motor, promoting fan speed control in response to outdoor conditions and indoor comfort settings. This has been shown to provide energy savings relative to a fixed speed central fan ventilation system.

4.7.10.3 Prescriptive Requirements

Component Package A specifies a whole-house fan as a prescriptive requirement for single-family newly constructed buildings in Climate Zones 8 through 14. The whole-house fan, or central fan system, must meet the eligibility criteria specified below to meet the prescriptive requirement.

Additions of 1,000 ft² or less are exempt from the whole-house fan prescriptive requirements.

A. Eligibility Criteria for Whole-House Fans

§150.1(c)12

1. Whole-house fans must meet combustion air safety requirements related to indoor gas-fired appliances.
2. Whole House Fans modeled for Title 24 credits must be listed in the Energy Commission Appliance Database.
3. To meet the prescriptive requirement, the installed whole-house fan(s) must have a listed airflow of at least 1.5 cfm/ft² of house conditioned floor area. The house must have a minimum attic net free vent area to outdoors of one square foot per 750 cfm of installed whole-house fan(s) rated airflow. See Table 4-20 and Table 4-21 for net free ventilation area based on the square footage of the house.
4. Homeowners who have WHFs installed must be provided with a one page “How to operate your whole house fan” informational sheet.

B. Eligibility Criteria for Central Fan Systems

1. Central fan night ventilation systems will be required to meet Title 24 duct leakage requirements (with system operating in return air mode).
2. Central fan night ventilation systems will be required to meet the fan watt draw requirement that involve HERS verification of airflow and fan power, demonstrating an efficacy of no more than 0.58 watts/cfm.
3. In addition to sensing temperature at the thermostat, the central fan system must have an outdoor temperature sensor (used to initiate and terminate night ventilation operation) and a temperature sensor sensing the air temperature entering the air handling unit (used for damper position verification).
4. Central fan systems will be treated as “fixed-speed” systems, unless the manufacturer can provide documentation to the California Energy Commission that the product demonstrates the criteria listed below. The Commission will review the submittal and determine that the system adequately meets the qualifying criteria:
 - a. The installed fan motor is a variable-speed motor.

- b. The motor is controlled in night ventilation mode to vary in a continuous range between full air flow (100 percent) and a minimum airflow of no more than 25 percent of full airflow.
- c. The manufacturer will provide written documentation on how its control strategy is implemented, how night ventilation fan speed is controlled, and how ventilation cooling rates are determined. The ventilation cooling rate calculation will occur within a 24-hour interval or less to ensure that the system responds in a timely manner to changes in weather patterns.

Table 4–20 shows example conversions for the calculated net free vent area (NFVA) for a range of Energy Commission- listed whole-house fan airflow levels. Instead of using the table, one can calculate the NFVA by dividing the listed cfm by 750.

Table 4–20: Sample NFVA Calculation

CEC Listed Airflow (cfm)	Minimum Attic NFVA (ft2)
2000	2.7
3000	4
4000	5.3
5000	6.7
6000	8
7000	9.3

Source: California Energy Commission

Since attic vents present some level of airflow restriction, use the appropriate screen and louver reduction factor from Table 4–21.

Table 4–21: Attic Vent Airflow Reduction Factors

Vent Type	Reduction Factor
¼" screen (hardware cloth)	0.90
¼" screen with metal louvers	0.75
¼" screen with wood louvers	0.25
Insect screen (mesh under ¼")	0.50
Insect screen with metal louvers	0.50
¼" screen with wood louvers	0.25

Source: California Energy Commission

Example 4-46

Required vent area = Minimum Attic NFVA (Table 4–20) ÷ Reduction Factor

A 3,000 cfm fan is selected from the Energy Commission Appliance Database. The builder plans to use vents with "¼" screen with metal louvers".

Answer

The minimum required vent area is = $4.0 \div 0.90 = 4.4 \text{ ft}^2$

Example 4-47 – Ventilation Cooling**Question:**

I am building a 2,350 ft² house in Climate Zone 8. Do I need to install a whole-house fan or central fan ventilation system?

Answer:

Yes, if you are complying prescriptively.

No, if you are complying using the performance method.

Whole-house fans (or eligible central fan systems) are a prescriptive requirement in Climate Zones 8-14, meaning that they are not mandatory, although they define the prescriptive compliance level. If you decide to install a whole-house fan to meet the prescriptive requirement, you should select a fan from the Energy Commission Appliance Database. The prescriptive requirement specifies a minimum airflow of 1.5 cfm/ft² (3,525 cfm for the proposed house) and 1 ft² of attic net free ventilation area per 750 cfm of airflow (4.7 ft² for a 3525 cfm fan).

Example 4-48**Question:**

Why do I need to provide attic ventilation area for a whole-house fan?

Answer

Whole-house fans move a lot of air, all of which is exhausted to the attic. Without sufficient attic relief to the outdoors, the air velocity will increase (potentially disturbing blown insulation), and the fan will move less air.

Example 4-49**Question:**

What are the advantages and disadvantages of whole-house fans relative to central fan ventilation cooling systems?

Answer:

Whole-house fans are relatively inexpensive; both in first cost and operating cost, and are highly effective if used properly in the right climate. They move much more air than central fan systems, which must deliver air through the existing duct system. Whole-house fans can be noisy, require user operation to open windows, turn on and off, bring dust and allergens indoors from outside, and potentially reduce home security if operated throughout the night. Central fan systems are more expensive and generally move less air, but provide totally automated operation, independent of whether the occupant is home. Windows can remain shut, and all outdoor air is filtered. Some central fan systems may also be configured to provide fresh air ventilation consistent with the mechanical ventilation requirements. Review product literature to determine if available products meet the Energy Commission's fresh air ventilation requirements.

Example 4-50**Question:**

A two-story home with a 2,500 sf of conditioned space and having an attic of 1,500 sf is located in Climate Zone 10. Are whole-house fans required? Does this affect the number of vents in the attic?

Answer:

Yes. §150.1(c) 12 requires whole-house fans (WHF) in single-family houses that are located in Climate Zones 8-14. These are climate zones that have summer cooling needs but where the home can be efficiently cooled on cool summer evenings by the use of a whole-house fan.

§150.1(c)12 also requires that these fans be sized so they provide at least 1.5 cubic feet per minute (cfm) of flow for each square foot of conditioned space in the house. The fans used must be listed in the Energy Commission's Appliance Database (<http://appliances.energy.ca.gov/QuickSearch.aspx>) and the rated cfm listed on the CF2R-Mech 02 form. In addition, the attic must have at least 1 sf of attic vent free area for each 750 cfm of whole-house fan-rated flow.

Thus, for this house with 2,500 sf of conditioned floor area, the minimum total flow rate of whole house fans installed in the house must be at least:

Min WHF flow rate = Conditioned Floor Area x 1.5 CFM/sf = 2,500 sf x 1.5 cfm/sf = 3,750 cfm.

In this case, the builder has selected two 2,000 cfm whole house fans. The minimum amount of vent net free area in the attic is calculated as follows:

Net Free Area = Total WHF cfm / (750 cfm/sf NFA) = (2,000 + 2,000) / 750 = 5.3 sf

4.8 Compliance and Enforcement

This section describes compliance documentation and field verification requirements related to heating and cooling systems.

4.8.1 Design-Phase Documentation

The initial compliance documentation consists of the certificate of compliance (CF1R). It lists the features that the house needs for it to comply with the prescriptive or performance requirements, depending on the compliance path taken.

Mandatory features as required by §150.0 are not documented on any required compliance forms. They are, however, listed in a Mandatory Features Checklist provided in Appendix A that enforcement personnel can use as a compliance tool, if they choose.

For the prescriptive compliance approach, the required features are based on Prescriptive Component Package A, shown in Table 150.1-A.

For the performance compliance approach, the required features are based on a set of features that the designer has documented to result in a level of efficiency at least as good as Prescriptive Component Package A. The calculations for documenting this are done using the approved performance software, the algorithm of which is detailed in the *Alternative Calculation Method (ACM) Manual*.

The performance approach provides maximum design flexibility. It also allows the compliance credit for special, additional features to be quantified.

The CF1R has a section where special modeling features are listed. These are features for which special compliance credit was taken using the performance approach. They required additional visual verification by the enforcement agency to ensure proper installation. Some require field verification and diagnostic testing by a HERS Rater. These will be listed in a separate section.

The following are heating and cooling system features that will be listed in this section if they exist in the proposed design:

Special Features Not Requiring HERS Rater Verification:

1. Ducts in a basement
2. Ducts in a crawlspace
3. Ducts in an attic with a radiant barrier
4. Hydronic heating and system design details
5. Gas-fired absorption cooling
6. Zonal control
7. Ductless wall heaters

Special Features Requiring HERS Rater Verification:

1. Duct sealing
2. Verified duct design – for reduced duct surface area and ducts in conditioned space
3. Low-leakage ducts in conditioned space
4. Low -leakage air handlers
5. Verification of return duct design
6. Verification of air filter device design
7. Verification of bypass duct prohibition
8. Refrigerant charge
9. Installation of a fault indicator display (FID)
10. Verified system airflow
11. Air handler fan watt draw
12. High energy efficiency ratio (EER)
13. Verified seasonal energy efficiency ratio (SEER)
14. Maximum-rated total cooling capacity
15. Evaporative cooled condensers
16. Ice storage air conditioners
17. Continuous whole-building mechanical ventilation airflow
18. Intermittent whole-building mechanical ventilation airflow
19. High-quality insulation installation (QII)

Information summarizing measures requiring field verification and diagnostic testing is presented in Table RA2-1 of the Reference Residential Appendix RA2. The field verification and diagnostic testing protocols that must be followed to qualify for compliance credit are described in RA3 of the Reference Residential Appendix.

Registration of the CF1R with an approved HERS Provider is required. The building owner or the person responsible for the design must submit the CF1R to the HERS Provider Data Registry for retention by following the procedures described in Chapter 2 and in RA2 of the Reference Residential Appendix. Registration ensures that the project follows the

appropriate verification process, provides tracking, and provides instant access to the most current documentation.

4.8.2 Construction-Phase Documentation

During construction, the general contractor or specialty subcontractors must complete all applicable sections of the certificate of installation (CF2R) for any building design special features specified on the certificate of compliance (CF1R). A list of CF2R sections that apply to the HVAC special feature requirements follows:

1. HVAC Systems
2. Duct Leakage Diagnostics
3. Refrigerant Charge Verification
4. Duct Design Verification for the Location and Area Reduction Compliance Measures. The duct design specifications and layout must be included on the building plans submitted to the enforcement agency, and a copy of the duct design layout must be posted or made available with the building permit(s) issued for the building and must be made available to the enforcement agency, installing contractor, and HERS Rater for use during installation and for all applicable inspections.
5. Fan Efficacy Verification
6. System Airflow Verification.
7. High SEER/EER Verification.
8. Whole-Building Ventilation for Indoor Air Quality (IAQ), Local Ventilation Exhaust, and Other IAQ Measures Given in ASHRAE Standard 62.2

Like the CF1R, registration of the CF2R is required. The licensed contractor responsible for the installation must submit the CF2R information that applies to the installation to a HERS Provider Data registry using procedures described in Chapter 2 and in RA2 of the Reference Residential Appendix.

4.8.3 Field Verification and/or Diagnostic Testing

For buildings for which the certificate of compliance (CF1R) requires HERS field verification for compliance with the Energy Standards, a HERS Rater must visit the site to perform field verification and diagnostic testing to complete the applicable heating and cooling system certificates of field verification and diagnostic testing (CF3R). The following measures require field verification and diagnostic testing if they are used in the proposed design for compliance and are listed on the CF1R as special “Features Requiring HERS Rater Verification.”

1. Verified duct leakage. Outside air (OA) ducts for central fan integrated (CFI) ventilation systems shall not be sealed/taped off during duct leakage testing. CFI OA ducts that use controlled motorized dampers, open only when OA ventilation is required to meet ASHRAE Standard 62.2, and closed when OA ventilation is not required may be configured to the closed position during duct leakage testing.
2. Verified duct design – supply duct location, surface area, and R-value (including buried ducts).
3. Low-leakage ducts in conditioned space.
4. Low-leakage air handlers.

5. Refrigerant charge verification
6. Verification of installation of a fault indicator display (FID)
7. Forced air system airflow verification using the installer-provided hole for the placement of a hole for a static pressure probe (HSPP), or a permanently installed static pressure probe (PSPP).
8. Air handler fan watt draw.
9. High-efficiency air conditioner energy efficiency ratio (EER).
10. Evaporatively cooled condensers.
11. Photovoltaic (PV) field verification. To receive PV rebates for photovoltaic installations under the New Solar Home Partnership, the output of the installed system must be measured and shown to comply with the output specified on the rebate application (taking into account variables such as the solar insolation, the time, and the temperature)
12. Central fan-integrated systems for ventilation cooling for air handler fan watt draw.
13. Whole-building ventilation for indoor air quality (IAQ), local ventilation exhaust, and other IAQ measures given in ASHRAE Standard 62.2

Field verification for nonmandatory features is necessary only when performance credit is taken for the measure. For example, maximum cooling capacity need only be HERS-verified if maximum cooling capacity was used to achieve credit in the proposed design. Some field verification is for mandatory measures and will occur in all homes, unless they are exempt from the measure.

Like the CF1R and CF2R, registration of the CF3R is required. The HERS Rater must submit the field verification and diagnostic testing information to the HERS Provider data registry as described in Chapter 2. For additional details describing HERS verification and the registration procedure, refer to RA2 of the Reference Residential Appendix.

4.9 Refrigerant Charge

4.9.1 Refrigerant Charge Verification

This section summarizes the procedures for verifying refrigerant charge for air-conditioning systems as described in Section RA3.2 of the Reference Residential Appendix. Refrigeration technicians and HERS Raters who perform the testing should refer to these and other technical documents. This section is intended to provide an overview and explanation of these procedures.

4.9.1.1 Overview

A split-system air conditioner undergoes the final assembly at installation. The installation must be verified to ensure proper performance. Important factors that affect performance include the amount of refrigerant in the system (the charge) and the proper functioning of the metering device. Air conditioner energy efficiency suffers if the refrigerant charge is either too low or too high and if the metering device (TXV or EXV) is not functioning properly. In addition to a loss of efficiency and capacity, errors in these areas can lead to premature compressor failure.

To help avoid these problems, the prescriptive standards require that systems be correctly installed. The prescriptive standards also require that they be field-verified in Climate Zones

2, and 8 through 15. Refrigerant charge verification is also required in any climate zone when chosen as a compliance feature using the performance approach.

The requirement to verify the refrigerant charge after installation does not apply to new packaged systems where the installer certifies the package system came factory-charged and did not alter the system in any way that would affect the refrigerant level; however, airflow and other requirements must still be verified. The prescriptive standards regarding verification of refrigerant charge do apply to altered package systems in Climate Zones 2 and 8 through 15.

Verification of proper refrigerant charge must occur after the HVAC contractor has installed and charged the system in accordance with the manufacturer's specifications. The procedure requires properly calibrated digital refrigerant gauges, thermocouples, and digital thermometers. When multiple systems in the same home require testing, test each system.

In a typical home cooling system, there are two important performance criteria that are relatively easy to verify that there is neither too much nor too little refrigerant in the system. In systems with a fixed orifice device in the evaporator coil, the number to check is called the *superheat*. In a system with a variable metering device, the number to check is called the *subcooling*.

Superheat refers to the number of degrees the refrigerant is raised after it evaporates into a gas. This occurs inside the evaporator coil (or *indoor coil*). The correct superheat for a system will vary depending on certain operating conditions. The target superheat for a system must be obtained from a table provided in the RA3.2 protocols or the manufacturer's superheat table. There is an allowed range of several degrees between the measured superheat and the target superheat for a system to pass.

Subcooling refers to the number of degrees the refrigerant is lowered after it condenses into a liquid. This occurs inside the condenser coil (or *outdoor coil*). The manufacturer specifies the correct subcooling for a system. It may vary depending on operating conditions. Like superheat, there is an allowed range of several degrees between the measured subcooling and the target subcooling for a system to pass.

The temperature at which a refrigerant condenses or evaporates is called the *saturation temperature*. Above the saturation temperature, a refrigerant is always a gas. Below the saturation temperature, a refrigerant is always a liquid.

Saturation is when a refrigerant exists as both a liquid and a gas. It always occurs at the same temperature, depending on what the pressure of the refrigerant happens to be. At higher pressures, the saturation temperature goes up and vice versa. This convenient property is what makes refrigeration work.

The saturation temperature can be determined by simply measuring the pressure of a refrigerant and referring to a table, known as a *pressure-temperature (PT) table*, for that specific refrigerant. Saturation temperatures are well-documented for all common refrigerants.

Because variable refrigerant metering devices are prone to failure and even more so to improper installation, it is important that the operation of these devices be checked. A metering device maintains a relatively constant superheat over a wide range of operating conditions; therefore, checking the superheat, in addition to the other tests performed, will indicate if the metering device is operating correctly.

Unfortunately, checking superheat and subcooling can be done only under certain indoor and outdoor conditions. This verification procedure, called the Standard Charge Verification Method, is very weather-dependent.

There is another way to verify proper refrigerant charge that is not weather-dependent, and that is by weighing the refrigerant. Called the Weigh-in Charge Verification Method, this approach can be performed only by the installer. It can be verified by the HERS Rater either by simultaneous observation or by using the standard method when conditions permit.

4.9.1.2 Minimum System Airflow Verification for Refrigerant Charge Verification

To have a valid charge test, the system airflow must be verified to be at least 300 cfm/ton for altered systems and 350 cfm/ton for new systems. The procedures for measuring total system airflow are found in RA3.3. They include plenum pressure matching using a fan flow meter, a flow grid, a powered flow hood, and the traditional (nonpowered flow hood). The airflow verification procedures for refrigerant charge verification no longer include the temperature split method.

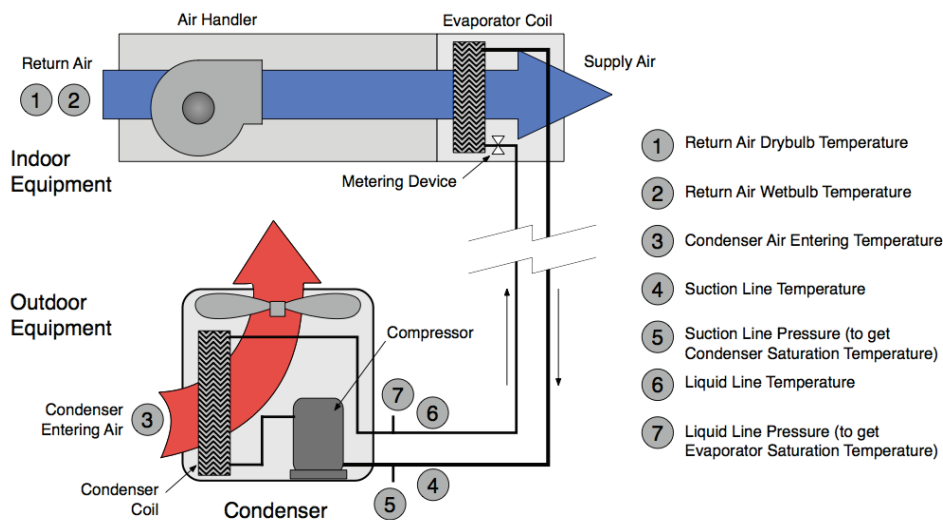
If an altered system does not meet the minimum airflow requirements, remedial steps are required to increase the system airflow. More airflow is generally better for systems with air conditioning. Not only does this allow proper refrigerant charge to be verified, but it improves the overall performance of the system. When able to be performed on a system, regardless of the refrigerant charge verification procedure, minimum system airflow must always be verified.

In some alterations, improving airflow may be cost-prohibitive and there is a process for documenting this (RA3.2.2.7.3). When this option is used, verification by sample groups is not allowed. Minimum airflow is critical to proper air-conditioner operation. Reducing airflow reduces cooling capacity and efficiency. Many systems in California have oversized equipment and undersized ducts. In newly installed duct systems, the minimum airflow requirement is higher because the opportunity exists to design and install a better system. In altered systems, the installer may be required to modify the ducts system to meet the minimum airflow. The minimums of 300 and 350 cfm/ton are far lower than the desired airflow for most systems, which is usually 400 cfm/ton and higher.

4.9.1.3 Standard Charge Verification Procedure (RA3.2.2)

The first step is to turn on the air-conditioning system and let it run for at least 15 minutes to stabilize temperatures and pressures. While the system is stabilizing, the HERS Rater or the installer may attach the instruments needed to take the measurements.

Figure 4-45: Measurements for Refrigerant Charge and Airflow Tests



Source: California Energy Commission

The following measurements shall be taken by the technician or HERS Rater, when applicable.

1. The return air wet bulb and dry bulb temperatures are measured in the return plenum before the blower at the location labeled "Title 24 – Return Plenum Measurement Access Hole." This hole must be provided by the installer, not the rater (See Point 2 in Figure 4-45). See Figure RA 3.2-1 for more information on the placement of the measurement access hole (MAH).
2. Moreover, the outdoor air dry bulb temperature is measured at the point where the air enters the outdoor condensing coil. (See Point 4 in Figure 4-45). It is important that this outdoor temperature sensor be shaded from direct sun during the verification procedure.

In addition to the air temperature measurements, four refrigerant properties need to be measured. Two of these measurements are taken near the suction line service valve before the line enters the outdoor unit and are used to check the superheat.

1. The first measurement is the temperature of the refrigerant in the suction line, which is taken by a clamp-on thermocouple or other suitable device insulated from the outdoor air. (See Point 5 in Figure 4-45.)
2. The second measurement determines the saturation temperature of the refrigerant in the evaporator coil. (See Point 6 in Figure 4-45.) The saturation temperature can be determined from the low-side (suction line) pressure and a saturation temperature table for the applicable refrigerant.

To check the subcooling, two more refrigerant properties are required and may be measured near the liquid line service valve at the point where the line exits the outdoor unit. (See Points 7 in Figure 4-45):

1. The liquid refrigerant temperature in the liquid line is measured by a clamp-on thermocouple insulated from the outdoor air.
2. The condenser saturation temperature can be determined from the liquid line pressure and a saturation temperature table for the applicable refrigerant.

Note: Determination of the condenser saturation temperature and the liquid line temperature is used only for the subcooling verification method on systems with TXV or EXV metering devices.

4.9.1.4 Superheat Charge Verification Method (RA3.2.2.6.1)

The *Superheat Charge Verification Method* is used on units with a fixed refrigerant metering device (not a TXV or EXV).

Airflow verification must be confirmed prior to starting the Superheat Verification Method.

Table 4–22: Structure of Target Superheat

		Return Air Wet-Bulb Temperature (°F) (T Return, wb)									
		50	51	52	53	54	55	--	--	75	76
Condenser Air Dry-Bulb Temperature (°F) (T condenser, db)	55	Target Superheat = Suction Line Temperature minus Evaporator Saturation Temperature See Reference Residential Appendix Table RA3.2-2									
	56										
	57										
	--										
	--										
	93										
	94										
	95										

Source: California Energy Commission

The *Superheat Verification Method* compares the actual (measured) superheat temperature to a target value from a table. The actual superheat temperature is the measured suction line temperature ($T_{\text{Suction, db}}$) minus the evaporator saturation temperature ($T_{\text{Evaporator, Saturation}}$). The target superheat value is read from a table (Table RA3.2-2 of the Reference Residential Appendix or the manufacturer’s superheat table).

For illustration, the structure of Table RA3.2-2 is shown above as Table 4–22.

Only an EPA-certified technician may add or remove refrigerant. Under no circumstances may HERS Raters add or remove refrigerant on systems that they are verifying.

4.9.1.5 Subcooling Verification Method (RA3.2.2.6.2)

The *Subcooling Verification Method* is used on units with a variable refrigerant metering device (a TXV or EXV).

Airflow verification must be confirmed prior to starting the Subcooling Verification Method.

The Subcooling Verification Method compares the actual subcooling temperature to the target value supplied by the manufacturer. The actual subcooling is the condenser saturation temperature ($T_{\text{Condenser, Saturation}}$) minus the liquid line temperature (T_{Liquid}).

4.9.1.6 Weigh-In Charging Procedure

The weigh-in charging procedure charges the system by determining the appropriate weight of refrigerant based on the size of the equipment and refrigerant lines rather than by actual performance of the system. Systems using the weigh-in procedure by the installer for any reason may not be third-party-verified by using sample groups.

The weigh-in procedure does not relieve the installer from having to ensure proper airflow.

There are two installer options for the weigh-in procedure. One involves adjusting the amount of refrigerant in a system by adding or removing a fraction of the refrigerant as specified by the manufacturer (weigh-in charge adjustment). The other involves evacuating the entire system and recharging it with the correct total amount of refrigerant, by weight (weigh-in total charge).

The weigh-in charge adjustment procedure may only be used when a new factory-charged outdoor unit is being installed and the manufacturer provides adjustment specifications based on evaporator coil size and refrigerant line size and length.

The weigh-in total charge may be used for any weigh-in procedure but still requires manufacturer's adjustment specifications. Only the installer/technician may perform any kind of weigh-in procedure.

4.9.1.7 Equipment Limitations

The Energy Standards specifically require verification of refrigerant charge only for air-cooled air conditioners and air-source heat pumps. All other types of systems are not expressly exempt from the refrigerant charge requirements. Certain portions of the requirements may still apply, such as the minimum system airflow requirement. The installer would have to verify with the manufacturer and confirm with the Energy Commission. The installer must adhere strictly to the manufacturer's specifications.

Variable refrigerant flow systems and systems such as minisplits that cannot be verified using the standard approach must demonstrate compliance using the weigh-in method. Verification by the HERS Rater can only be accomplished by simultaneous observation of the installer's weigh-in.

4.9.1.8 HERS Rater Verification Procedures

When required by the certificate of compliance, HERS Raters will perform third-party field verification and diagnostic testing of refrigerant charge. These may include the standard method, simultaneous observation of the weigh-in method, verification of minimum system airflow, and verification of installation of the measurement access hole.

The verification procedures are essentially identical for the Rater and the installer except that the tolerances for passing the superheat and subcooling tests are less stringent for the Rater's test. This is to allow for some variations in measurements due to instrumentation or test conditions (for example, weather).

The following conditions prohibit verification using sample groups:

1. When the weigh-in method is used
2. When the minimum airflow cannot be met despite reasonable remediation attempts. (See RA3.2.2.7.3).

As always, to be eligible for sampling, the installer must first verify and pass the system. If sampling is not being used, the Rater will perform the verification only after the installer has charged the system according to manufacturer's specifications.

4.9.1.9 Winter Setup Procedures

Reference Appendix RA1 provides for the approval of special case refrigerant charge verification procedures when the equipment is specifically approved by the manufacturer for such procedures. One such procedure is found in RA1.2. It provides for a modification to the standard charge procedure when conditions make the standard charge method difficult.

The Standard Charge Verification Procedure (Section RA3.2.2 of the Reference Residential Appendices) calls for the outdoor temperature to be within the manufacturer's specified range. When outdoor temperatures are below 70°F, the setup for the Standard Charge Verification Procedure must be modified to achieve the proper system pressure differential needed for the procedure. (The Standard Charge Verification procedure is generally allowed to be used down to 55°F without the winter setup; however, the 70°F requirement mentioned here is typical of most manufacturers' requirements for the winter setup). The winter setup for the Standard Charge Verification Procedure (winter charge setup) allows both installers and HERS Raters to use the Standard Charge Verification Procedure of RA3.2.2 in the winter. The Weigh-in Charging Procedure specified in Section RA3.2.3 may also be used,

only by the installer, as long as the manufacturer did not certify an alternative refrigerant charge verification protocol that can be used for the system. In the case where the manufacturer has certified to the Energy Commission an “Alternative Refrigerant Charge Verification Protocol” meeting the requirements of RA1.1.1, HERS Rater refrigerant charge verification procedures may adhere to an approved alternative protocol.

The winter charge setup creates the right conditions at the unit being tested for outdoor temperatures above 37°F and below 71°F that allow the system to operate in the same range of pressure differences between the low-side pressure and the high-side pressure as occurs during warm outdoor temperatures. The winter charge setup is used only for units equipped with variable metering devices, which include thermostatic expansion valves (TXV) and electronic expansion valves (EXV) for which the manufacturer specifies subcooling as the means for determining the proper charge for the unit, including units equipped with microchannel heat exchangers. The winter charge setup achieves an appropriate high side-low side pressure differential to conduct the Standard Charge Verification Procedure, by restricting the airflow at the condenser fan outlet by using a condenser outlet air restrictor. Once this pressure differential is achieved, the variable metering device calculations are conducted in the same way as the variable metering device procedures described in Reference Residential Appendix RA 3.2.2.6.2. All other applicable requirements of Section RA3.2.2 remain the same and must be completed when using the winter charge setup.

Though not specifically mentioned in the FID protocols of Residential Appendix RA3.4.2, the winter setup method detailed in RA 1.2 may be used when normally allowed. For FID verification the winter setup method will be treated the same as the subcooling method.

4.9.1.10 Using Weigh-In Charging Procedure at Low Outdoor Temperatures

When a new HVAC system is installed, for enforcement agencies to issue an occupancy permit, the HVAC installer must check the refrigerant charge, and a HERS Rater must verify the correct charge; however, an exception to §150.1(c)7A provides for an alternative third-party HERS verification if the weigh-in method is used when the outdoor temperatures are less than 55 degrees F.

Typically, when the weigh-in method is used by the installing contractor to ensure proper refrigerant charge, a HERS Rater must perform a charge verification in accordance to the procedures outlined in the Reference Residential Appendix RA3.2, which is the standard charge procedure described above in this chapter. However, since the standards charge verification procedures (RA3.2) cannot be performed when the outdoor temperatures are less than 55 degrees, the Energy Standards provide the installer with two choices:

1. Use the “HERS Rater - Observation of Weigh-In Charging Procedure” as prescribed in Reference Residential Appendix RA3.2.3.2, to demonstrate compliance, and install an Occupant Controlled Smart Thermostat (OCST).
2. Wait for warmer temperatures and perform the standard charge verification procedure, which can delay the project. In this case, the installer must include the signatures of the homeowner and HERS Rater on the CF2R - MCH25c form for the local enforcement agency, as part of an agreement that he or she will return to correct refrigerant charge if a HERS Rater determines it is needed later, as per Residential Appendix RA 2.4.4. The installer must also provide written notice to the homeowner that the charge has not yet been verified (RA2.4.4). An example form is provided in Figure 4-46.

As noted above, when the HVAC installer elects this procedure for verification (RA3.2.3.2), the system thermostat must be an occupant controlled smart thermostat (OCST), which conforms to the requirements of Reference Joint Appendix JA5.

Figure 4-46: Example of Notification to Homeowners of Delayed Charged Verification

Note to Homeowner: We're not done yet!

Congratulations on your new Air-Conditioning system! Your new system is much more efficient than older systems, and it has been installed to industry guidelines, ensuring many years of comfort and efficient service.

One thing you need to know, however, is that the installation process is not complete! Because your unit was installed when the outside air temperature was too low to fine tune the air conditioner, the unit must be serviced and verified when the weather is warmer.

This requires your cooperation. You need to allow access to the unit for your Installer and/or HERS Rater (verifier) to verify that the refrigerant charge and airflow are set correctly. Your project is not considered finished until this verification takes place. If it is not done, **your unit may cost more to operate, may not heat and cool as effectively, and may not last as long.**

You will be contacted within the next few months to schedule this service. If you do not hear something after a few months of warmer weather, please contact your Installer. Enjoy your new system!

Source: California Energy Commission

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5. Water Heating Requirements

5.1 Overview

Chapter 5 describes the compliance requirements for domestic water heating for residential dwellings, including single-family, and low-rise (three or fewer habitable floors) multifamily buildings with a dedicated water heater for each dwelling unit or a central system that serves multiple dwellings. This chapter also describes common water heater types, best practices for water heater maintenance, hot water distribution system designs, and examples of commonly asked questions regarding compliance with Energy Standards requirements. For general information about compliance and enforcement please see Chapter 2 of this compliance manual.

5.1.1 What's New for 2016

This section summarizes changes to the requirements for residential water heating for the *2016 Energy Standards*. Please see Sections 5.3 and 5.4 for detailed information on the mandatory and prescriptive water heating requirements in the *2016 Energy Standards*.

5.1.1.1 Mandatory Requirements

1. Isolation valves must be installed on instantaneous water heaters that have an input rating greater than 6.8 kBTU per hour (2 kilowatts [kW]). The valves must be installed on the cold water line leading to the water heater and the hot water line leaving the water heater. As discussed in Section 5.2.3 of this chapter, manufacturers recommend flushing the heat exchanger in instantaneous water heaters. Isolation valves simplify this routine maintenance practice, which reduces the cost and burden of maintaining the water heater.
2. Storage water heaters do not need to have blankets anymore. The *2013 Energy Standards* required storage water heaters with efficiency levels equivalent to the minimum federal efficiency standard to be externally wrapped (such as with a water heater blanket) with insulation of R-12 or greater. This requirement has been deleted. With the amended federal standards that went effect on April 16, 2015, external insulation of water heater storage tanks is no longer cost-effective.
3. For alterations, all newly installed hot water piping and existing accessible piping must be insulated if installing new piping at the time an existing water heater is replaced (that is, replacement water heating systems).

5.1.1.2 Prescriptive Requirements

The prescriptive requirements for new construction and additions for single-family buildings and multifamily buildings with a dedicated water heater for each dwelling unit have been updated. A dwelling unit is defined as a residence with a dedicated water heater. Use of the term pertains to both a single-family home and a unit (such as an apartment) within a multifamily building that has a dedicated water heater.

The 2016 prescriptive requirements for single-family buildings and multifamily buildings with a dedicated water heater in each dwelling unit are as follows:

- Option 1: Install a natural gas or propane instantaneous water heater that meets the minimum requirements in California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f) for federally regulated appliances.

Option 2: Install a natural gas or propane storage water heater with a rated storage volume of 55 gallons or less that meets the minimum requirements in California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f) for federally regulated appliances. In addition, the building must comply with the HERS-verified Quality Insulation Installation (QII) requirements (see Chapter 3 of this compliance manual), as well as one of the following requirements:

1. HERS-verified pipe insulation (see Reference Appendix¹ RA 3.6, RA4.4.1, RA4.4.3, and RA4.4.14 for the requirements of proper installation of pipe insulation and Section 5.6.2.5 of this chapter)
2. HERS-verified compact hot water distribution design (see Reference Appendix RA 3.6 and RA4.4.16 for requirements and Section 5.6.2.4 of this chapter)

Option 3: Install a natural gas or propane storage water heater with a rated storage volume more than 55 gallons and an input rating of 105,000 BTU/hr or less. The water heater must meet the requirements in California's *Title 20 Appliance Efficiency Regulations* Section 1605.1(f) for federally regulated appliances. In addition, the building must comply with one of the following:

1. HERS-verified pipe insulation
2. HERS-verified compact hot water distribution design.

There is no longer a prescriptive option that allows electric water heating. Users that wish to use electric water heating can comply with the Energy Standards using the performance approach.

5.1.1.3 Performance Compliance Options

1. The water heating energy budget is now based on the energy performance of a natural gas instantaneous water heater that meets the minimum requirements in California's *Title 20 Appliance Efficiency Regulations* Section 1605.1(f) for federally regulated appliances.
2. The point-of-use distribution credit no longer requires HERS verification.

¹ The Reference Appendices can be downloaded on the California Energy Commission website for the *2016 Energy Standards*.

5.1.2 At a Glance

Table 5-1 provides an overview of the location of the water heating requirements in the *2016 Energy Standards* by construction and building type.

Table 5-1: Overview of Water Heating Requirements in the Energy Standards and this Chapter

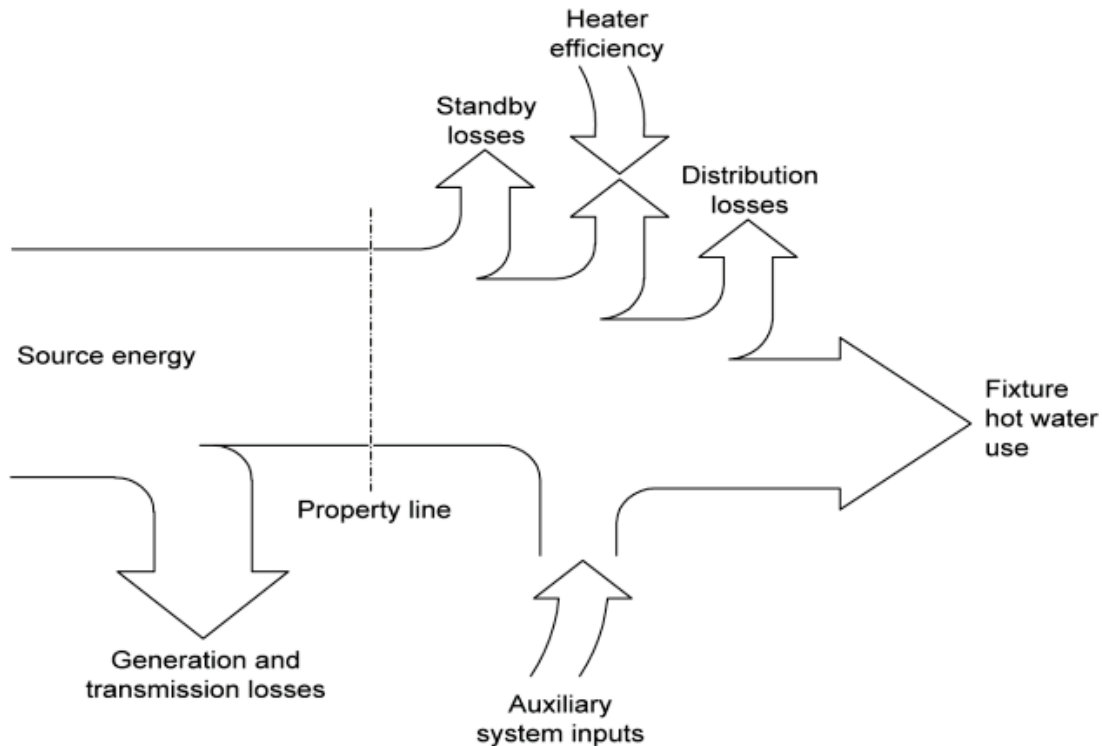
Type	Mandatory Requirements		Prescriptive Requirements		Performance Requirements	
	Standards Section	Manual Section	Standards Section	Manual Section	Standards Section	Manual Section
Single-family home – Newly built	§110.3; §150.0(n)	5.3	§150.1(c)8A i,ii,iii	5.4.1	§150.1(b)	5.5
Single-family home – Addition	§110.3; §150.0(n)	5.3	§150.2(a)1D	5.4.1	§150.2(a)2	5.5
Single-family home – Alteration	§110.3; §150.0(n)	5.3	§150.2(b)1	5.4.1	§150.2(b)2	5.5
Multi-family – Newly built individual dwelling units	§110.3; §150.0(n)	5.3	§150.1(c)8B	5.4.2	§150.1(b)	5.5

5.1.3 Water Heating Energy

Water heating accounts for the largest share of natural gas usage (49 percent) in California homes. Nearly 90 percent of California homes have natural gas water heating, with the common water heater type being a 40- or 50-gallon atmospheric combustion storage water heater. Standby loss associated with the center flue design represents about 25-35 percent of the annual energy use of a typical gas storage water heater system. Roughly 6 percent of households use electricity to heat water, and most of the remaining homes use propane (liquefied petroleum gas or LPG).

Total energy use associated with water heating consists of the end use, heater inefficiencies, standby loss, and distribution system inefficiencies. Figure 5-1 below shows the energy flows that constitute water heating energy usage. Hot water draws at the end use points (for example, faucets, showers, and so forth) represent the useful energy consumed. In most cases, hot water that is actually used represents the largest fraction of water heating energy use, although in situations when there are very few hot water draws, standby losses from the water heater and the hot water distribution system can exceed the quantity of useful energy consumed at the end point. Energy impacts associated with the hot water distribution system vary widely based on the type of system, quality of insulation and installation, building and plumbing design, and hot water use patterns. Distribution losses in a typical single-family home may be as much as 30 percent of the total energy used for water heating. Distribution losses in single-family homes with compact hot water distribution systems may be lower than 10 percent of total water heating energy use. In a typical multifamily building, distribution losses can account for more than 30 percent of total water heating energy use. An important consideration for any water heating system is the recovery load (that is, end use plus distribution losses) of the water heating unit minus any contribution from auxiliary heat inputs, such as a solar thermal system.

Figure 5-1: Water Heating Energy Flow Representation



5.2 Residential Water Heating Equipment

Residential water heaters primarily provide hot water for direct use (e.g., in showers and faucets) and for appliances such as dishwashers and clothes washers. There are several types of residential water heaters described below. The most common water heaters in single-family homes are small storage or instantaneous water heaters. For multifamily buildings, two options are commonly used: either one or more commercial storage water heaters or one or more boilers coupled with a storage tank to serve the entire building. Alternatively, water heaters are installed in each dwelling unit (similar to single-family).

When using the prescriptive approach to comply with the Energy Standards, the user has the option of installing a natural gas or propane water heater. If complying via the performance approach, the user can install any water heater that meets the minimum *Title 20 Appliance Efficiency Regulations* in Section 1605.1(f).

5.2.1 Instantaneous Water Heaters

Instantaneous water heaters, commonly referred to as *tankless* or *on-demand*, heat water using natural gas, electricity, or propane. These units do not have a tank for storing heated water but instead use a sensor that detects the flow of water over the heat exchanger that initiates the heating element (typical volumes around 0.5 gallons). Instantaneous units are capable of delivering water at a controlled temperature of less than 180°F. The input rating for gas instantaneous water heaters ranges between 50,000 and 200,000 BTU per hour (at least 4,000 BTU per hour per gallon of stored water) with a storage capacity of less than 2 gallons.

Instantaneous water heaters require an electrical connection for controls and the combustion air blower, a direct or power venting system, and a larger gas line (typical input ratings of 140 to

200 kBTU/hr). The installation of all these design components have been required for newly constructed residential buildings since the *2013 Energy Standards*.

Electric instantaneous water heaters are not generally designed for use with solar water heating systems or as heat sources for indirect-fired water heaters. They are also typically inappropriate for use with recirculation systems. Consult manufacturer's literature when considering these applications. Electric instantaneous water heaters are not allowed through the prescriptive approach to compliance but can be installed using the performance approach as long as the total energy budget is not exceeded.

To comply prescriptively with the *Energy Standards*, a user can choose to install a gas or propane instantaneous water heater that meets the minimum efficiency requirements of California's *Title 20 Appliance Efficiency Regulations* Section 1605.1(f) for federally regulated appliances.

5.2.2 Storage Water Heater

5.2.2.1 Federally Regulated Residential Storage Water Heaters

Storage water heaters use gas (natural gas or propane), electricity or oil to heat and store water at a thermostatically controlled temperature (less than 180° F) for delivery on demand. Federal appliance efficiency standards differentiate storage water heaters based on whether the rated storage volume is greater than 55 gallons or less than or equal to 55 gallons.

The U.S. Department of Energy (DOE) classifies residential gas water heaters as having an input of 75,000 BTU per hour or less and has a storage capacity ranging between 20 and 100 gallons. A basic gas storage water heater is composed of a standing pilot ignition system, a burner, a combustion chamber, a flue baffle, a flue, an insulated water tank, a cold water inlet and hot water outlet, a sacrificial anode, a gas valve, a temperature and pressure relief valve, a thermostat, heat traps, and an outer case.

The DOE classifies residential electric storage water heaters as having an input of 12 kW or less and have a storage capacity ranging between 20 and 120 gallons. A basic electric storage residential water heater differs from gas water heaters by using an electric resistance heating element. As noted in this chapter, electric storage water heaters are not allowed through the prescriptive approach to compliance but can be installed using the performance approach as long as the water heating energy budget is not exceeded.

The DOE classifies residential oil storage water heaters as having an input of 105,000 BTU per hour or less and a storage capacity of 50 gallons or less. A basic oil storage residential water heater consists of a combustion chamber, a flue baffle, a flue, an insulated water tank, a cold water inlet and hot water outlet, a sacrificial anode, a power burner system, a thermostat, a temperature and pressure relief valve, and an outer case. Oil storage water heaters are not allowed through the prescriptive approach to compliance but can be installed using the performance approach as long as the water heating energy budget is not exceeded.

Recently DOE added a new category of water heaters called *grid-enabled water heaters* and is defined as an electric resistance water heater that has a rated storage tank volume of more than 75 gallons and is manufactured on or after April 16, 2015. The water heater must have an activation lock at the point of manufacture and is intended for use only as part of an electric thermal storage or demand response program.

5.2.2.2 Federally Regulated Residential-Duty Commercial Water Heater

This appliance is essentially a commercial water heater that can be legally installed in a residential building. It is defined in the Federal Code of Regulations (10 CFR 431.102) as any gas-fired, electric, or oil storage or instantaneous commercial water heater that meets the following conditions:

1. Uses a single-phase external power supply for models that require electricity.
2. Is not designed to provide outlet hot water at temperatures greater than 180°F.
3. Is not excluded by the specified limitations regarding rated input and storage capacity as described in Table 5-2 below. In other words, a residential-duty commercial water heater must have rate input and rated storage volume below the value listed in Table 5-2.

Table 5-2: Capacity Criteria for Defining Nonresidential Water Heaters

<i>Water Heater Type</i>	<i>Indicator of Nonresidential Application</i>
Gas-Fired Storage	Rated input >105 kBTU/h; Rated storage volume >120 gallons.
Oil-Fired Storage	Rated input >140 kBTU/h; Rated storage volume >120 gallons.
Electric Storage	Rated input >12 kW; Rated storage volume >120 gallons.
Heat Pump With Storage	Rated input >15 kW; Rated current >24 A at a rated voltage of not greater than 250 V; Rated storage volume >120 gallons.
Gas-Fired Instantaneous	Rated input >200 kBTU/h; Rated storage volume >2 gallons.
Electric Instantaneous	Rated input >58.6 kW; Rated storage volume >2 gallons.
Oil-Fired Instantaneous	Rated input >210 kBTU/h; Rated storage volume >2 gallons.

Source: U.S. Department of Energy (2014). "Energy Conservation Program for Consumer Products and Certain Commercial and Industrial Equipment: Test Procedures for Residential and Commercial Water Heaters; Final Rule."
<http://www.regulations.gov/#/documentDetail:D=EERE-2011-BT-TP-0042-0082>

Residential-duty commercial water heaters are rated in uniform energy factor (UEF) and are allowed through the prescriptive approach to compliance but can also be installed using the performance approach as long as the total energy budget is not exceeded.

5.2.2.3 Storage Heat Pump Water Heater

A *storage heat pump water heater* is an electric water heater that uses a compressor to transfer thermal energy from one temperature level to a higher temperature level for heating water. It includes all necessary auxiliary equipment such as fans, storage tanks, pumps, or controls. DOE classifies heat pump water heater under the category of electric storage water heater, and it must meet the federal minimum efficiency standards, depending on tank size. Heat pump water heaters are not allowed through the prescriptive approach to compliance but can be installed using the performance approach as long as the water heating energy budget is not exceeded. (See Section 5.5 for more information on the energy budget and performance path to compliance.)

5.2.2.4 Hot Water Supply Boiler

A *hot water supply boiler* is industrial water heating equipment with a heat input rate from 300 to 12,500 kBTU per hour and at least 4,000 BTU per hour per gallon of stored water. A hot water boiler should have either the temperature or pressure control necessary for heating potable water for purposes other than space heating, or the boiler manufacturer's literature should indicate that the intended uses of the boiler include heating potable water for purposes other than space heating. A hot water boiler could be fueled by oil or gas, and it must adhere to

the minimum thermal efficiency and maximum standby loss as described in California's *Title 20 Appliance Efficiency Regulations*.

Boilers are typically used for doing both space heating and water heating. Use of a boiler will typically require one or more unfired storage tanks to be installed as part of the system. Careful attention should be given to the layout of these systems due to the potential for high energy losses between the boiler and storage tanks. Boilers are not allowed through the prescriptive approach to compliance but can be installed using the performance approach as long as the water heating energy budget is not exceeded.

5.2.3 Water Heater Maintenance

Water heaters should be maintained according to manufacturer recommendations to ensure proper water heater performance, prolonged useful life, and warranty coverage. If water heaters are not maintained, the useful life of the unit can be shortened and failures that may result may not be covered under the warranty. This section presents the best practices for maintaining the life and efficiency of water heaters. Table 5-3 lists the primary maintenance activities for storage and instantaneous water heaters based on manufacturer and plumber recommendations. Some manufacturers recommend additional maintenance than those listed in Table 5-3. For example, a leading water heater manufacturer recommends draining one gallon of water from the bottom of storage water heaters monthly to remove sediment in the tank. As noted in Table 5-3, both storage water heaters and instantaneous water heaters have recommended regular maintenance procedures.

Table 5-3: Key Maintenance Activities for Water Heaters

<i>Water Heater Type</i>	<i>Maintenance Activity</i>	<i>Frequency</i>
Instantaneous	Draining and flushing heat exchanger	Typically recommended every 2 to 4 years (will vary depending on local water quality conditions)
	Inspection of burner, temperature & pressure relief valve, air intake filter, water filter, and venting system	Typically recommended annually
Storage	Draining and flushing storage tank	Typically recommended every 6 months to annually (will vary depending on local water quality conditions)
	Inspection of burner, thermostat (operation of), venting system, temperature & pressure relief valve	Typically recommended every 3 months to annually
	Inspection of the anode rod	Typically recommended every 1 to 2 years or more frequently in areas with soft water

5.2.3.1 Maintenance of Instantaneous Water Heaters

The primary maintenance activities for instantaneous water heaters are flushing the heat exchanger to remove scale buildup and inspecting and cleaning the inlet water filter screen, which helps minimize the amount of debris or sediment that enters the water heater.

Some manufacturers recommend a maintenance schedule, but the maintenance schedule users deploy may vary based on water quality. In areas with hard water, more frequent maintenance (every two years) is recommended. In areas where the water quality is relatively good, water heater maintenance is recommended every three to four years. Frequent inspection of the inlet water filter screen will enable a user to monitor the amount of sediment entering the water heater. If the filter tends to fill with sediment regularly, then more frequent flushing may be required. Users can also reference local water quality data to determine the level of water quality in their area to help guide maintenance schedules.

To assist in flushing the heat exchanger, manufacturers and plumbers recommend the installation of a drain kit (that is, isolation valves). (See Figure 5-2 below.) The installation of isolation valves on instantaneous units is mandatory in the *2016 Energy Standards* (§110.3(c)7 and §150.0 (n)4). Isolation valves enable the unit to be isolated from both the inlet cold water and the outlet hot water lines, thereby allowing the heat exchanger to be flushed using a simple procedure. Integral to the kit are hose bibs that allow the flushing hoses to be attached.

Manufacturers recommend that a licensed professional flush the heat exchanger to avoid potentially damaging the water heater, though some manufacturers sell flush kits so that homeowners can conduct their own maintenance on the water heater. Flush kits consist of a submersible pump, two short hoses, hose connections, and a 5-gallon bucket. These components can be purchased separately or as a preassembled kit. A solution of white vinegar is widely recommended for flushing the heat exchanger as it is food-grade and very effective at removing scale.

In addition to flushing the heat exchanger, manufacturers recommend periodically inspecting and cleaning the inlet water filter screen, which helps minimize the amount of debris or sediment that enters the water heater. This can be done by running the filter screen under hot water and using a brush to remove debris. Replacement of the inlet water filter screen is not necessary unless it is damaged.

Figure 5-2: Isolation Valves



Source: <http://www.brasscraft.com/products.aspx?id=266>

5.2.3.2 Maintenance of Storage Water Heaters

For storage water heaters, the primary maintenance activities consist of draining the tank, inspecting the anode rod, and replacing the anode rod, if necessary. The recommended frequency of regular maintenance varies by manufacturer. Like instantaneous water heaters, the frequency of maintenance depends on water quality. Most manufacturers recommend draining the tank every six months to once per year to remove sediment that has accumulated in the bottom of the tank. Periodic inspections (every six months to once a year) of the burner, venting system, and temperature and pressure relief valves are also recommended by manufacturers.

Manufacturers typically recommend inspecting the anode rod every two years and replacing it when necessary to prolong tank life, but the frequency of inspection depends on local water conditions. If water is soft or a water softener is used, more frequent inspection of the anode is needed as softened water will corrode the sacrificial anode rod at a much faster rate than unsoftened water. If the setup of the water heater prevents an easy removal of the corroded anode rod, then it might be necessary to completely move the tank from the location to replace the anode rod.

5.3 Mandatory Requirements for Water Heating

5.3.1 Equipment Certification

§110.3(a)

Manufacturers must certify that their products comply with California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f) at the time of manufacture. Regulated equipment that applies to all of the aforementioned system types in Section 5.2 must be listed in the California Energy Commission Appliance Efficiency Database.

5.3.2 Equipment Efficiency

§110.3(b), §110.1

Residential water heaters are regulated under California's *Title 20 Appliance Efficiency Regulations*, Section 1605.1(f). These regulations align with the federal efficiency standards for residential water heaters. The efficiency requirements are given in Table 5-4 below.

Table 5-4: Minimum Federal Energy Factor Requirements for Residential Water Heaters (Effective April 16, 2015)

<i>Product Class</i>	<i>Rated Storage Volume</i>	<i>Energy Factor</i>
Gas-fired Water Heater	≈ 20 gal and ≈ 55 gal	0.675 – (0.0015*V _s)
	> 55 gal and ≈ 100 gal	0.8012 – (0.00078* V _s)
Oil-fired Water Heater	≈ 50 gal	0.68 – (0.0019*V _s)
Electric Water Heater	≈ 20 gal and ≈ 55 gal	0.960 – (0.0003*V _s)
	> 55 gal and ≈ 120 gal	2.057 – (0.00113*V _s)
Tabletop Water Heater	≈ 20 gal and ≈ 100 gal	0.93 – (0.00132*V _s)
Instantaneous Gas-fired Water Heater	< 2 gal	0.82 – (0.0019*V _s)
Instantaneous Electric Water Heater	< 2 gal	0.93 – (0.00132*V _s)
Grid-Enabled Water Heaters	>75 gal	1.061-(0.00168* V _s)

V_s: Rated Storage Volume – the water storage capacity of a water heater (in gallons).

Source: U.S. Department of Energy

http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/27

Storage water heating equipment that have rated storage volumes of 19 gallons or less or rated storage volumes larger than 101 gallons (in other words, the products not specified in Table 5-4 above), and commercial water heaters are regulated by the *California Appliance Efficiency Regulations*. Energy factor is not applicable for this equipment, but rather minimums are specified for thermal efficiency and standby loss, as shown in Table 5-5 below.

Table 5-5: Minimum Energy Factor Requirements – California Appliance Efficiency Regulations for Water Heaters Not Covered by the Federal Residential Water Heater Standards

<i>Appliance</i>	<i>Input-to-Volume Ratio</i>	<i>Size (Volume)</i>	<i>Minimum Thermal Efficiency (%)</i>	<i>Maximum Standby Loss^{1,2}</i>
Gas storage water heaters	< 4,000 BTU/hr/gal	any	80	$Q/800 + 110(Vr)1/2$ BTU/hr
Gas instantaneous water heaters	$\geq 4,000$ BTU/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(Vr)1/2$ BTU/hr
Gas hot water supply boilers	$\geq 4,000$ BTU/hr/gal	< 10 gal	80	–
		≥ 10 gal	80	$Q/800 + 110(Vr)1/2$ BTU/hr
Oil storage water heaters	< 4,000 BTU/hr/gal	any	78	$Q/800 + 110(Vr)1/2$ BTU/hr
Oil instantaneous water heaters	$\geq 4,000$ BTU/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(Vr)1/2$ BTU/hr
Oil hot water supply boilers	$\geq 4,000$ BTU/hr/gal	< 10 gal	80	–
		≥ 10 gal	78	$Q/800 + 110(Vr)1/2$ BTU/hr
Electric storage water heaters	< 4,000 BTU/hr/gal	any	–	$0.3 + 27/Vm$ %/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.

Source: California Energy Commission, *Title 20 Appliance Efficiency Regulations (2014)*
<http://www.energy.ca.gov/2014publications/CEC-400-2014-009/CEC-400-2014-009-CMF.pdf>

5.3.3 Isolation Valves

§110.3(c)7

All newly installed instantaneous water heaters (minimum input of 6.8 kBTU/hr) shall have isolation valves on both the incoming cold water supply and the hot water pipe leaving the water heater. Isolation valves assist in the flushing of the heat exchanger and help prolong the life of instantaneous water heaters.

5.3.4 High-Efficiency Water Heater Ready

§150.0(n)

To facilitate future installations of high-efficiency equipment, the Energy Standards contain the following mandatory requirements for systems using gas or propane water heaters that serve individual dwelling units.

These requirements are for new construction and additions (if a water heater is installed in the added floor area), and they are not applicable to alterations.

1. A 120-volt (V) electrical receptacle that is within three feet of the water heater and accessible to the water heater with no obstructions.
2. A Category III or IV vent or a Type B vent with straight pipe between the outside termination and the space where the water heater is installed
3. A condensate drain that is no more than 2 inches higher than the base of the installed water heater and allows natural draining without pump assistance
4. A gas supply line with a capacity to provide at least 200,000 BTU/hr to the water heater.

These requirements make it easier for someone to retrofit high efficiency gas water heaters in the future. Virtually all high efficiency gas water heaters require an electrical connection and wiring during initial construction stage is much less costly than trying to retrofit it later.

5.3.4.1 Venting

Table 5-6 below summarizes venting requirements for different types of water heaters. Higher efficiency water heaters often require different vent materials due to the presence of acidic condensation from flue gases. The standard Type B vent installed for conventional atmospheric gas water heaters is made of steel and would soon be destroyed by the condensate. As a result, the Energy Standards require that a Type B vent for the water heater can be installed only when there is a straight shot between the water heater and where the vent leaves the building. There should be no bends along the path of the Type B vent, except the portion of the Type B vent outside the building and in the space where the water heater is installed. The installation shall meet all code and manufacturers' guidelines. Because Category III and IV pipes are usually smaller than those for Type B vents, a straight Type B vent can be easily modified into a Category III or IV vent by simply inserting a new vent pipe through the existing Type B vent pipe. A flue pipe that makes bends through the building structure is not easy to retrofit, and, thus, these flues must be either Category III or IV vent pipes. Only stainless steel Category III and IV vents are compatible with typical atmospheric combustion storage water heaters.

Table 5-6: Summary of Acceptable Vent Material by Appliance Category

<i>Appliance Venting Category</i>	<i>Vent Pressure</i>	<i>Condensing or Non-Condensing</i>	<i>Common Vent Pipe Material</i>
Category I: An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent	Nonpositive; atmospheric-vented; gravity-vented; most common category of gas-fired water heaters.	Noncondensing (typically less than 82% efficiency)	Metal double wall "B" vent
Category II: An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that may cause excessive condensate production in the vent	Nonpositive	Condensing	Special venting material per the product manufacturer
Category III: An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent	Positive (usually created by a blower motor); generally cannot be adjoined to gravity-vented water heater.	Noncondensing (typically less than 82% efficiency)	Stainless steel; these usually require 3" clearance to combustibles and the joints must be sealed air tight.
Category IV: An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent	Positive (usually created by a blower motor); generally cannot be adjoined to gravity-vented water heater.	Condensing	Plastic pipe (PVC, CPVC, ABS, etc.)

5.3.4.2 Condensate Drain

The requirement for the condensate drain being placed near the water heater and no higher than the base of the tank allows the condensate to be removed without relying on a sump pump.

5.3.4.3 Gas Line

Designing the gas line to provide 200,000 BTU per hour gas supply capacity to the water heater is required to accommodate future retrofit to a gas instantaneous water heater, which usually has a heat input capacity of 199,000 BTU/hr or higher. Similar to the electrical requirement, installing a larger gas line during new construction is inexpensive relative to a future gas line retrofit.

Gas pipe sizing for the building needs to consider piping layout and gas supply requirements for other gas appliances, such as gas clothes dryers, gas furnaces, gas ranges and ovens, and gas fireplace burners. The traditional practice of using a ½-inch gas pipe in a single-family house to serve a storage water heater is **not** in compliance with the mandatory requirement. The minimum gas pipe size for water heaters is ¾-inch. The exact gas piping system should be designed following the California Plumbing Code.

5.3.5 Mandatory Requirements for Hot Water Distribution Systems

5.3.5.1 Pipe Insulation for All Buildings

§150.0(j)2

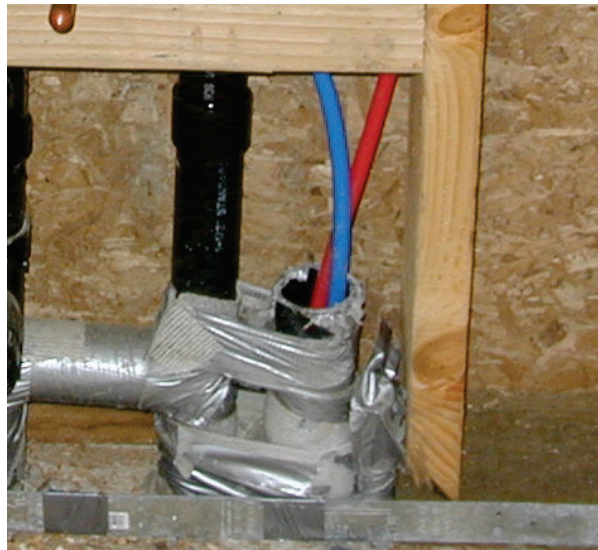
A. Pipe Insulation Is Mandatory in the Following Cases:

1. The first 5 feet of hot and cold water pipes from the storage tank or water heater.
2. All piping with a nominal diameter of ¾ inch or larger.

3. All piping associated within a domestic hot water recirculation system regardless of the pipe diameter. This excludes branches off of the recirculation loop that are less than $\frac{3}{4}$ inch diameter or do not serve the kitchen.
4. Piping from the heating source to a storage tank or between tanks.
5. Piping buried below grade.
6. All hot water pipes from the heating source to the kitchen fixtures.

In addition to insulation requirements, all domestic hot water pipes that are buried below grade must be installed in a waterproof and noncrushable casing or sleeve. The installation shown in Figure 5-3 below would not meet the installation requirements since they are not insulated. In addition, in Figure 5-3 the hot and cold water lines are not separated. Heat transfer will occur, resulting in energy loss and causing condensation on the cold water line.

Figure 5-3: Noncompliant Below-Grade Piping and Hot and Cold Water Lines Separation



B. Piping exempt From the Mandatory Insulation Includes:

1. Factory-installed piping within space conditioning equipment.
2. Piping that serves process loads, gas piping, cold domestic water piping (other than within five feet of the water heater), condensate drains, roof drains, vents, or waste piping.
3. Piping that penetrates framing members. This piping is not required to have insulation where it penetrates the framing. However, if the framing is metal, then some insulating material must prevent contact between the pipe and the metal framing.
4. Piping located within exterior walls that are installed so that piping is placed inside wall insulation. This piping does not need to be insulated if all the requirements for Insulation Installation Quality are met (see Reference Appendix RA4.4.1).
5. Piping in the attic does not need pipe insulation if it is continuously buried by at least 4 inches of blown ceiling insulation. Piping may not be placed directly in contact with sheetrock and then covered with insulation to meet this requirement.

C. Other installation information:

1. No insulation should be installed closer than 6 inches from the flue. If possible, bend the pipe away from the flue. Otherwise, it may be necessary to stop pipe insulation short of the storage tank. (See the current version of the California Mechanical Code.)
2. All pipe insulation seams should be sealed.
3. Installed piping may not be located in supply or return air plenums. (See the current version of the California Mechanical Code.)
4. Hot and cold water piping, when installed in parallel runs, should be at least 2 inches apart. (See Reference Appendix RA4.)
5. If a fire wall interrupts the first 5 feet of pipe, the insulation may be interrupted at the wall and continued on the other side.
6. Insulation for pipe elbows should be mitered and insulation for tees should be notched. (See Reference Appendix RA4.)

Figure 5-4: Pipe Insulation Requirements First Five Feet From Water Heater

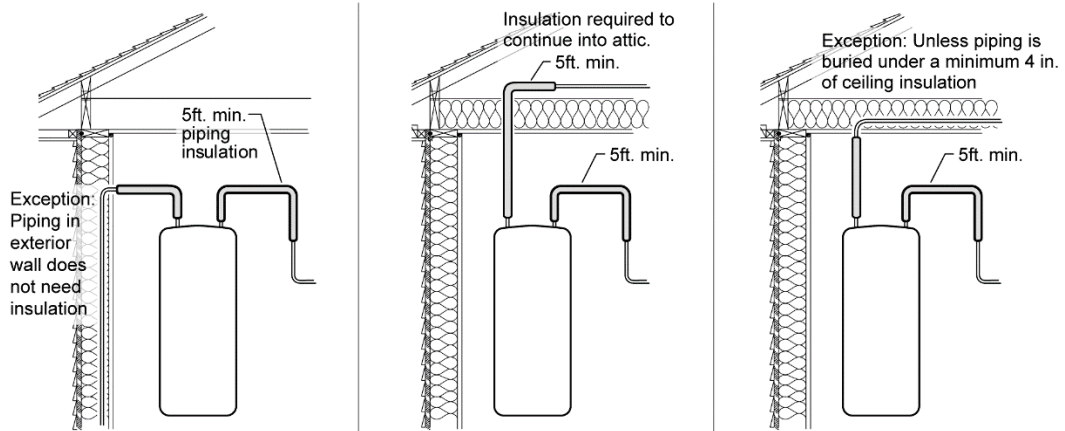


Table 5-7: Pipe Insulation Thickness Requirement (Excerpt From Table 120.3-A of the Energy Standards)

FLUID TEMPERATURE RANGE (°F)	CONDUCTIVITY RANGE (in Btu-inch per hour per square foot per °F)	INSULATION MEAN RATING TEMPERATURE (°F)	NOMINAL PIPE DIAMETER (in inches)				
			< 1	1 to <1.5	1.5 to < 4	4 to < 8	8 and larger
			INSULATION THICKNESS REQUIRED (in inches)				
Above 350	0.32-0.34	250	4.5	5.0	5.0	5.0	5.0
251-350	0.29-0.32	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

Where insulation is required as described above, 1 inch of insulation is typically required. This requirement applies to domestic hot water pipe (above 105° F) when the pipe diameter is 1 inch or smaller, the water temperature is between 105°F and 140°F, and the insulation conductivity between 0.22 and 0.28 BTU-in/hr-ft²-°F (typical of cellular foam pipe insulation material). One and one half inch insulation is required on pipes greater than 1 inch. For other situations refer to Table 120.3-A.

5.3.5.2 Insulation Protection

§150.0(j)3

If hot water piping insulation is exposed to weather, it must be protected from physical damage, UV deterioration, and moisture. Insulation is typically protected by aluminum, sheet metal, painted canvas, plastic cover, or a water-retardant coating that shields from solar radiation. Adhesive tape should not be used as insulation cover because removal of the tape will damage the integrity of the original insulation during preventive maintenance.

5.3.5.3 Distribution Systems Serving Multiple Dwelling Units – With Recirculation Loops

§110.3(c)5

Multifamily buildings may have water heaters for each dwelling unit but are more likely to have a central water heating system with a recirculation loop that supplies each of the units. This recirculation loop consists of a supply portion of larger diameter pipe connected to smaller diameter branches that serve multiple dwelling units, guest rooms, or common area fixtures and a return portion that completes the loop back to the water heating equipment. The large volume of water that is recirculated during periods of high use creates situations that require the installation of certain controls and servicing mechanisms to optimize performance and allow for lower cost of maintenance. The following paragraphs cover the requirements for system serving multiple dwelling units and with recirculation loops; the corresponding compliance form is CF2R-PLB-01-E.

A. Air Release Valves

§110.3(c)5A

The constant supply of new water in combination with the continuous operation of pumps creates the possibility of the pump cavitation due to the presence of air in the water. Cavitation is the formation of bubbles in the low-pressure liquid on the suction side of the pump. The cavities or bubbles will collapse when they pass into the higher regions of pressure, causing noise and vibration that may lead to damage to many of the components. In addition, there is a loss in capacity, and the pump can no longer build the same head (pressure). This ultimately affects the efficiency and life expectancy of the pump.

Cavitation shall be minimized either by installing an air release valve or by mounting the pump vertically. The air release valve must be located no more than 4 feet from the inlet of the pump. The air release valve must also be mounted on a vertical riser with a length of at least 12 inches.

B. Backflow Prevention

§110.3(c)5B

Temperature and pressure differences in the water throughout a recirculation system can create 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 backward toward the hot water load and reducing the delivered water temperature.

To prevent this from occurring, the Energy Standards require that a check valve or similar device be located between the recirculation pump and the water heating equipment.

C. Equipment for Pump Priming/Pump Isolation Valves

§110.3(c)5C&D

A large number of systems are allowed to operate until complete failure simply because of the difficulty of repair or servicing. Repair labor costs can be reduced significantly by planning ahead and designing for easy pump replacement when the pump fails. Provision for pump priming and pump isolation valves helps reduce maintenance costs.

To meet the pump priming equipment requirement, a hose bib must be installed between the pump and the water heater. In addition, an isolation valve shall be installed between the hose bib and the water heating equipment. This configuration will allow the flow from the water heater to be shut off, allowing the hose bib to be used for bleeding air out of the pump after pump replacement.

The requirement for the pump isolation valves will allow replacement of the pump without draining a large portion of the system. The isolation valves shall be installed on both sides of the pump. These valves may be part of the flange that attaches the pump to the pipe. One of the isolation valves may be the same isolation valve as in Item C.

D. Connection of Recirculation Lines

§110.3(c)5E

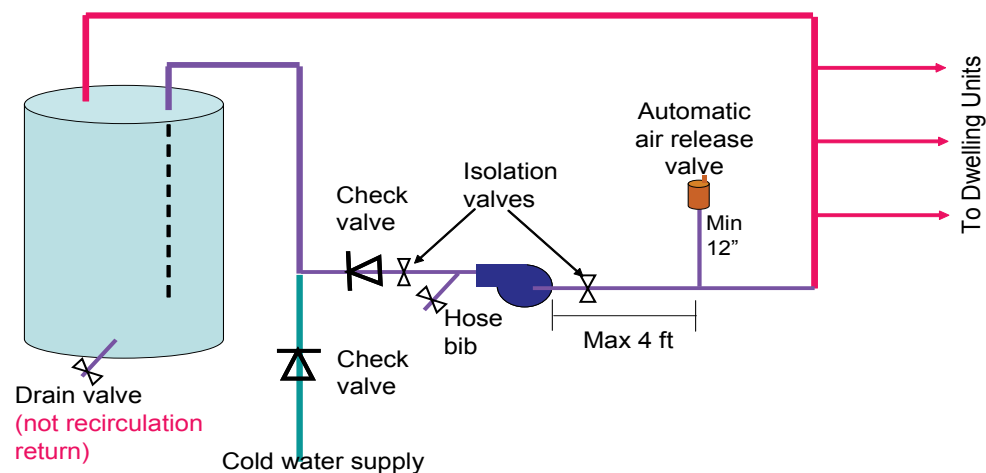
Manufacturer's specifications should always be followed to assure optimal performance of the system. The cold water piping and the recirculation loop piping should never be connected to the hot water storage tank drain port.

E. Backflow Prevention in Cold Water Supply

§110.3(c)5F

The dynamic between the water in the heater and the cold water supply are similar to those in the recirculation loop. Thermosyphoning can occur on this side of this loop just as it does on the recirculation side of the system. To prevent this, the Energy Standards require a check valve to be installed on the cold water supply line. The valve should be located between the hot water system and the next closest tee on the cold water supply line. The system shall comply with the expansion tank requirements as described in the California Plumbing Code.

Figure 5-5: Mandatory Central System Installation Requirements



Example 5-1 – Distribution Systems**Question:**

When I'm insulating the pipes for a recirculating water heating system, I understand that I must insulate the entire length of hot water pipes that are part of the recirculation loop. Do I also need to insulate the runouts?

Answer:

No, other than the pipe to the kitchen fixture as it is a mandatory requirement. Since the water in runouts does not recirculate, other runouts do not need to be insulated.

Example 5-2 – Recirculation system insulation**Question:**

Can I get pipe insulation credit for a recirculating water heating system?

Answer:

Not for systems serving a single dwelling unit. Recirculating water heating systems have a mandatory insulation requirement for the recirculating section of the hot water pipes; pipes less than 1 inch must be insulated to 1 inch of insulation. For systems serving multiple dwelling units, using thicker-than-required insulation results in credit within the performance approach. All the circulation loop pipes in one location type (for example, inside, outside, underground) must be insulated to the higher level to qualify.

Example 5-3 – Pipe Insulation**Question:**

I thought I was supposed to insulate hot and cold water piping from the water heater for either the first 5 feet or the length of piping before coming to a wall, whichever is less. Did I misunderstand?

Answer:

Yes. The requirement is that you must insulate the entire length of the first 5 ft, regardless of whether there is a wall (§150.0(j)2). You have two options: (1) interrupt insulation for a fire wall and continue it on the other side of the wall or (2) run the pipe through an insulated wall, making sure that the wall insulation completely surrounds the pipe. The reason for insulating the cold line is that when heated, the water inside the water heater expands and pushes hot water out the cold water line. The first several feet of the cold water pipe near the water heater can be warm and insulation reduces the heat loss from the first 5 feet of the cold water piping

5.4 Prescriptive Requirements for Water Heating

5.4.1 Single Dwelling Units

§150.1(c)8

There are three options to comply with the prescriptive water heating requirements for newly constructed single dwelling units. For all three options, the water heater must comply with the mandatory requirements for water heaters. (See Section 5.3.) If a recirculation distribution system is installed, only demand recirculation systems with manual control pumps are allowed. The three options are described below.

- Option 1: Install a natural gas or propane instantaneous water heater with an input rating of 200,000 BTU per hour or less.

Option 2: Install a natural gas or propane storage water heater with a rated storage volume 55 gallons or less and an input rating of 105,000 BTU per hour or less. The dwelling unit must meet all of the requirements for Quality Insulation Installation (QII), which requires that a HERS Rater verify QII has been designed and installed in accordance with Energy Standards. The user must also do one of the following:

1. Use a compact hot water distribution design, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards (See Reference Appendix RA4.4.16.)
2. Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.

Option 3: Install a natural gas or propane storage water heater with a rated storage volume greater than 55 gallons and an input rating of 105,000 BTU per hour or less. The user must also do one of the following:

1. Insulate all domestic hot water pipes which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.

If Option 2 is pursued, in which a gas storage water heater that is 55 gallons or less is installed instead of a gas instantaneous water heater, then QII will need to be considered at the start of the design process, and it must be coordinated with several players including the designer, the general and/or insulation contractor, and the HERS Rater. QII will be included as part of the first building inspection, typically well in advance of the actual water heater being installed.

For more information on QII compliance requirements see Chapter 3 (Building Envelope) of this compliance manual and RA3.5 of the Reference Appendix. QII is required for Option 2 but not for Option 3. That is, if a natural gas or propane water heater less than 55 gallons is installed, the building must also comply with the QII requirements.

The minimum federal efficiency requirement for storage water heaters greater than 55 gallons is more stringent than storage water heaters that are 55 gallons or less.

For more information on HERS-verified domestic hot water pipe insulation requirements, see Section 5.6.2.5 of this chapter. The Reference Appendix contains the requirements for the proper installation of pipe insulation (see RA4.4.1, RA4.4.3 and RA4.4.14). The compliance requirements in Reference Appendix RA4.4.3 state that all the piping in a hot water distribution system must be insulated from the water heater to each fixture or appliance following the proper installation provisions in Reference Appendix RA4.4.1. RA 4.4.14 states that HERS inspection is needed to verify that all hot water piping in nonrecirculating systems is insulated correctly. A summary of the mandatory pipe insulation requirements is described in Section 5.3.5.1. HERS-verified pipe insulation is included in Options 2 and 3 described above. If a user does not want to insulate pipes, he or she can choose to use a compact hot water distribution design instead.

For more information on HERS-verified compact hot water distribution design, see Section 5.6.2.4. HERS-verified compact hot water distribution designs are included in Options 2 and 3 described above. If a user does not use a compact design, he or she can comply with HERS-verified pipe insulation requirements instead.

Any other water heating system that differs from the three options described in this section does not meet the prescriptive requirements. Other systems can be installed if using the performance approach as described in Section 5.5.

For additions, the prescriptive requirements described above apply only if a water heater is being installed as part of the addition. The prescriptive requirements apply only to the space that is added, not the entire building.

For alterations where an existing water heater is being replaced, the water heater must meet the mandatory equipment efficiency requirements. Pipe insulation requirements do not apply to alteration for portion of the pipes that are inaccessible. See Chapter 9 for more detailed explanation for the water heating alteration requirements.

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As mentioned, there are three options for users to comply prescriptively with the water heating requirements for newly constructed single dwelling units, including additions. All options must also comply with the applicable mandatory requirements in §110.3 and §150.0 (j and n).

1. A system with a single natural gas or propane instantaneous water heater:
 - a. A gas input rating less than or equal to 200,000 BTU/h.
 - b. No supplemental storage tank is installed.
 - c. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.
2. A system with a single gas or propane storage water heater with a rated storage volume of 55 gallons or less must have:
 - a. A gas input rating of 105,000 BTU/h or less.
 - b. The dwelling unit must meet all of the requirements for QII as specified in the Reference Appendix RA3.5, and either
 - i. Have HERS-verified insulation on all domestic hot water piping (see RA4.4.1, RA4.4.3 and RA4.4.14)
 - ii. Have a HERS-verified compact distribution system design (see RA4.4.16).
 - c. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.
3. A system with a single gas or propane storage type water heater with a rated storage volume of greater than 55 gallons must have:
 - a. A gas input rating 105,000 BTU/h or less, and either
 - i. Have HERS-verified insulation on all domestic hot water piping (see RA4.4.1, RA4.4.3 and RA4.4.14)
 - ii. Have a HERS-verified compact distribution system design (see RA4.4.16).
 - b. If using a recirculation distribution system, only demand recirculation systems with manual control pumps are allowed.

Example 5-4 – Single-family home with multiple water heaters

Question:

A newly built 6,000-ft² single-family residence has three gas storage water heaters (40-gallon, 30-gallon, and a 100-gallon unit with 80,000 BTU/h input). Does it comply?

Answer:

In most cases, multiple water heaters will result in greater energy consumption than the standard design case (one water heater for a new single-family home). As such, a performance calculation is required since the system does not meet the standard requirements and must be shown to meet the water heating energy budget. The energy budget for the standard design building is determined by applying the mandatory and prescriptive requirements to the proposed design building. See §150.1(b)1 for more details on energy budgets and performance standards.

Example 5-5 – Single-family home with a point-of-use distribution system**Question:**

A newly built 1,800 ft² single-family residence has two identical 30-gallon gas storage water heaters and a distribution system that meets the point-of-use criteria. Does this system comply?

Answer:

Because there are two water heaters, this system does not meet the standard prescriptive water heating systems requirements of §150.1(f)8, regardless of the distribution system. To evaluate this design, it must be modeled using the performance approach.

Example 5-6 – Alterations**Question:**

If my house has an electric-resistance water heater and I plan to upgrade my water heater, do I need to install a gas instantaneous or gas storage water heater?

Answer

No, if natural gas is not already connected to the building, then an electric water heater that meets the requirements of California's Appliance Efficiency Regulations can replace the existing water heater. If installing new piping to the water heater then you will need to comply with the mandatory pipe insulation requirements. See Section 5.3.5.1 for more information on pipe insulation requirement and Chapter 9 for more information on alterations.

Example 5-7– Additions**Question:**

I am building an addition to my home that will be a self-contained apartment. Do I need to comply with the prescriptive requirements?

Answer:

If the addition will include a water heater, or if it will be connected to the existing hot water distribution system to supply hot water to the apartment, then you must comply with the standards either through the prescriptive or performance path. If taking the prescriptive approach, please note that if you install a gas storage water heater, you must also comply with the QII and pipe insulation or compact design requirements (that is, HERS verification). If taking the performance approach, you can install any type of water heater as long as it 1) meets the requirements of California's *Appliance Efficiency Regulations* and 2) does not exceed the water heating energy budget for the self-contained building. If you were adding only an additional room with hot water and not a self-contained dwelling, then the water heating budget would be based on the existing building plus addition. (See Section 5.5.)

Example 5-8 – Storage Water Heaters**Question:**

Can I install a gas storage water heater that is more than 55 gallons instead of a gas instantaneous one?

Answer:

Yes. To comply prescriptively, you can install a gas storage water heater that holds more than 55 gallons. You must also install either HERS-verified insulation on all hot water piping OR a HERS-verified compact hot water distribution system in addition to the condensing storage water heater. You can also take the performance approach to install a gas storage water heater of any size as long as it 1) meets the requirements of California's *Title 20 Appliance Efficiency Regulations* and 2) does not exceed the total energy budget for the building. (See Section 5.5.)

5.4.2 Multiple Dwelling Units: Multifamily, Motel/Hotels, and High-Rise Residential

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There are two options for using the prescriptive approach to compliance for multifamily buildings:

1. A water heater must be installed in each unit that meets the requirements for a single-family building.
2. A central gas or propane-fired water heater or boiler.

The water heater must have an efficiency that meets the requirements in §110.1 and §110.3 (as listed in Table 5-5). In addition, if a central recirculation system is installed, it shall be installed with demand recirculation controls and a distribution layout with at least two recirculation loops. These prescriptive rules were developed based on studies that found that recirculation pipe heat loss is a major component of energy loss within a central hot water system. Pipe heat loss is affected by the pipe surface area, pipe insulation level, and the temperature difference between the hot water and ambient air. The motivation behind having two loops is to reduce recirculation pipe sizes, thus pipe surface area. This measure reduces energy use and piping materials associated with recirculation systems. Central water heating systems with eight or fewer dwelling units are exempted from needing two recirculation loops.

5.4.2.1 Dual-Loop Recirculation System Design

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A dual-loop design is illustrated in Figure 5-6. In a dual loop design, each loop serves half of the dwelling units. According to plumbing code requirements, the pipe diameters can be downsized compared to a loop serving all dwelling units. The total pipe surface area is effectively reduced, even though total pipe length is about the same as or somewhat greater than that of a single-loop design. For appropriate pipe sizing guidelines, please refer to the Universal Plumbing Code.

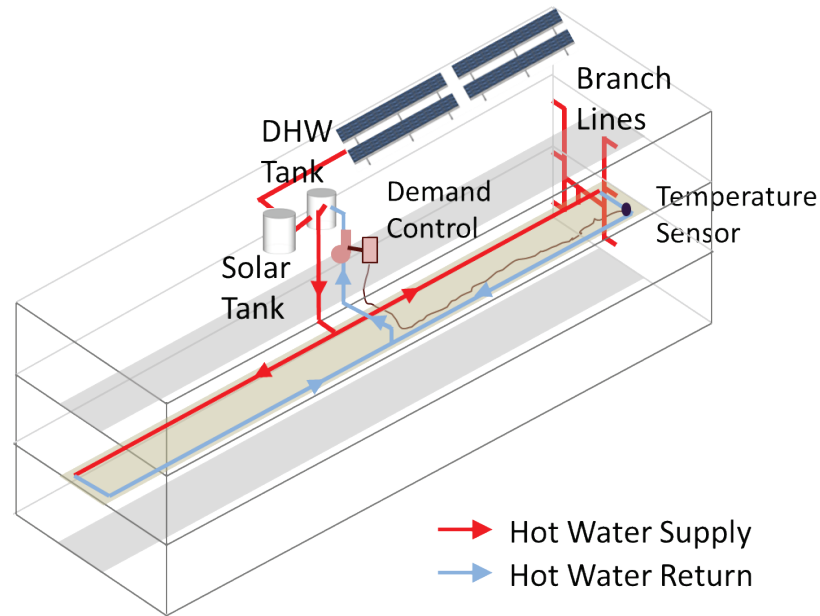
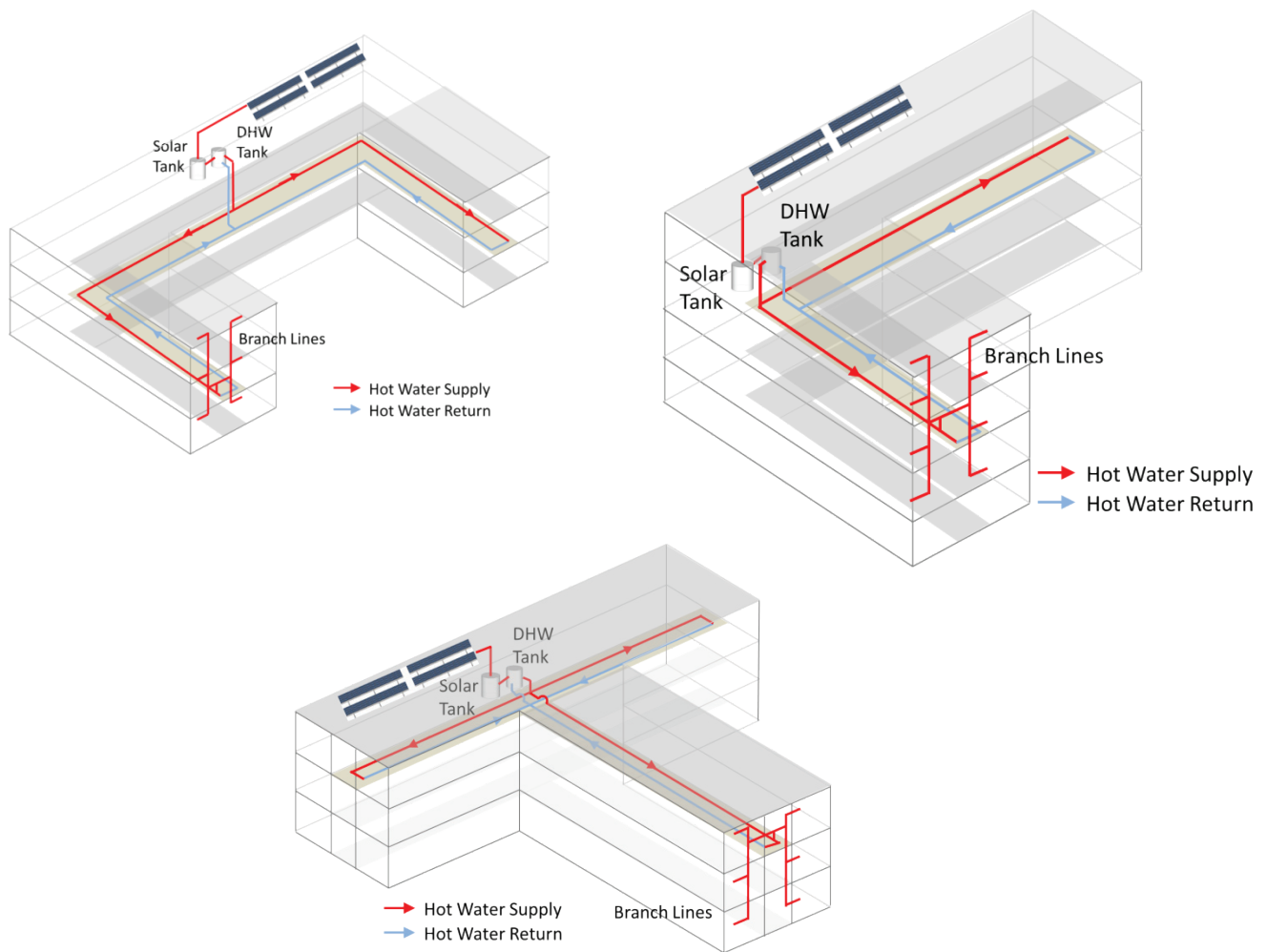
Figure 5-6: Example of a Dual-Loop Recirculation System

Figure 5-6 provides an example of how to implement dual loop design in a low-rise multifamily building with a simple layout. In this example, the water heating equipment is 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 dwelling unit. The figure also illustrates how the solar water heating system and demand control are integrated.

For buildings with complicated layouts, how to create and locate recirculation loops heavily depends on building geometry. In general, the system should be designed to have each loop serve an equal number of dwelling units to minimize pipe sizes. For systems serving buildings with distinct sections, for example, two wings in an L-shaped building, it is better to dedicate a separate recirculation loop to each of the sections. Very large buildings and buildings with more than two sections should consider using separate central water heating systems for each section. In all cases, simple routing of recirculation loops should be used to keep recirculation pipes and runouts as short as possible. Figure 5-7 provides dual-loop recirculation system designs in buildings with complicated shapes.

Figure 5-7: Examples of dual-loop recirculation system designs in buildings of complicated shapes



Location of water heating equipment in the building also needs to be carefully considered to properly implement the dual-loop design. The goal is to keep overall pipe length as short as possible. As an example, for buildings in regular shapes, locating the water heating equipment at the center of the building footprint rather than at one end of the building helps minimize the pipe length needed to connect the water heating equipment to the two loops. If a water heating system serves several building sections, the water heating equipment would preferably nest between these sections.

With the new prescriptive solar water heating requirement this cycle, 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 configured only as a preheater of 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 based mostly on the building layout and are relatively independent of the solar water heating system. On the other hand, gas water heating equipment and solar tanks should be located close to each other to avoid heat loss from pipes connecting the two systems. The preferred configuration is to place both the gas water heating equipment and solar tanks on the top floor

near the solar collector so that the total system pipe length can be reduced. As noted before, minimizing pipe length helps reduce domestic hot water system energy use as well as system plumbing cost.

5.4.2.2 Demand Recirculation Control

The prescriptive requirement for domestic hot water systems serving multiple dwelling units requires the installation of a demand recirculation control to minimize pump operation and heat loss from pipes. Please note that they are different from the demand controls used in single dwelling units. Demand controls for central recirculation systems operate by sensing hot water demand and recirculation return temperatures. The temperature sensor should be installed at the farthest end of the recirculation loop close to the last branch pipe.

Any system not meeting these prescriptive requirements must instead meet the standard design building energy budget that is established by the energy efficiency performance of a gas instantaneous water heater that meets the requirements of California's *Title 20 Appliance Efficiency Regulations* or must follow the performance compliance method for the building as a whole.

Example 5-9 - Multifamily with individual water heater

Question:

A 10-unit multifamily building has separate gas water heaters for each dwelling unit. Five units have 30-gallon water heaters, and 5 units have 50-gallon water heaters. Does this comply?

Answer:

The Energy Standards provide two prescriptive compliance paths for domestic hot water heating systems in multifamily buildings. One is to use a central water heating system. The other is to use separate gas waters for each dwelling unit, as in this example. To use this compliance method, all dwelling units must use residential water heaters or residential-duty commercial water heaters (heat input of less than 105,000 BTU/hr) with EF ratings equal or higher than corresponding Title 20 appliance standard requirements. Other requirements also pertain. See the three options in §150.1(c)8.

Example 5-10 – Multifamily recirculation system

Question:

We are building an 8-unit, 7,800 ft² multifamily building with a 200-gallon storage gas water heater with a time- and temperature-controlled recirculation system that has 1 inch of insulation on all the piping. The system serves all the units. Do I have to perform calculations to show compliance?

Answer:

Water-heating calculations are required since the standard design assumption uses demand recirculation for the control strategy for central recirculation. Furthermore, solar water heating is a prescriptive requirement for all multifamily buildings with central recirculation systems.

Example 5-11 – Multifamily large water heater

Question:

We are building a 10-unit apartment building with a single large water heater. We do not plan to install a recirculation pump and loop. Does this meet the prescriptive requirements?

Answer:

No. Since it is unlikely that a nonrecirculating system will satisfactorily supply hot water to meet the tenants' needs, either a recirculating system or individual water heaters must be installed to meet the prescriptive requirements. There is an exception for multifamily buildings of eight units or fewer.

5.5 Performance Approach Compliance for Water Heating

5.5.1 Energy Budget Calculation

The computer performance approach allows for the modeling of water heating system performance by taking into account building floor area, climate, system type, efficiency, and fuel type. The standard design water heating budget is defined by the corresponding prescriptive requirements. The performance method allows for modeling alternative water heater and distribution system combinations. Some of these options will offer compliance credits, and others will result in penalties.

5.5.2 Systems Serving Single Dwelling Unit

In the case of single dwelling units, any type or number of water heaters can theoretically be installed. The calculated energy use of the proposed design is compared to the standard design energy budget based on a single natural gas instantaneous water heater with a standard distribution system. Adding multiple water heaters to a single-family design will generally result in an energy penalty in the water heating budget that must be offset elsewhere in the total energy budget.

A standard distribution system serving a single dwelling unit does not incorporate a pump for hot water recirculation and does not take credit for any additional DHW design features. As per the prescriptive requirements, all mandatory pipe insulation requirements must be met, such as insulating all pipes running to the kitchen. Alternative distribution systems are compared to the standard design case by using distribution system multipliers (DSMs), which effectively rate alternative options.

Table 5-8 lists all the recognized distribution systems that can be used in the performance approach with the assigned distribution multiplier. The standard distribution system has a multiplier of 1.0. Distribution systems with a multiplier less than 1 represent an energy credit, while distribution systems with a multiplier greater than 1 are counted as an energy penalty. For example, pipe Insulation with HERS Inspection Required (PIC-H) has a multiplier of 0.8. That means that it is modeled at 20 percent less distribution loss than the standard distribution system. For more information or installation requirements on any of the systems, refer to Section 5.6.

Table 5-8: Applicability of Distribution Systems Options Within a Dwelling Unit

<i>Distribution System Types</i>	<i>Assigned Distribution System Multiplier</i>	<i>Systems Serving a Single Dwelling Unit</i>	<i>Multifamily With Central Recirculation Systems</i>
No HERS Inspection Required			
Trunk and Branch -Standard (STD)	1.0	Yes	Yes
Pipe Insulation (PIA)	0.9	Yes	Yes
Parallel Piping (PP)	1.05	Yes	--
Point of Use (POU-H)	0.3	Yes	--
Recirculation: Non-Demand Control Options (R-ND)	9.0	Yes	--
Recirculation with Manual Demand Control (R-Dman)	1.6	Yes	Yes
Recirculation with Motion Sensor Demand Control (R-DAuto)	2.4	Yes	--
HERS Inspection Required			
Pipe Insulation (PIC-H)	0.8	Yes	Yes
Parallel Piping with 5' maximum length (PP-H)	0.95	Yes	--
Compact Design (CHWDS-H)	0.7	Yes	--
Recirculation with Manual Demand Control (R-Drmc-H)	1.45	Yes	--
Recirculation with Motion Sensor Demand Control (RDRsc-H)	2.2	Yes	--
Non-Compliant Installation Distribution Multiplier	1.2	Yes	Yes
<i>Note: Any system that does not meet the installation requirements listed in RA3 and RA4 for the specific system type in any way must have either the installation corrected or the compliance run redone using the noncompliance installation distribution multiplier.</i>			

5.5.3 Systems Serving Multiple Dwelling Units

For systems serving multiple dwelling units with a recirculating pump, the standard distribution system design is based on a central recirculation system with two recirculation loops that are controlled by a demand control technology. Systems designed with other options are allowed, but they require compliance verification through performance calculation.

Central recirculation systems using only one recirculation loop are expected to have larger pipe surface areas than those of dual-loop designs, according to plumbing code requirements for pipe sizing. For large buildings, it may be better to use more than one recirculation loop with each serving a small portion of the building, even though additional credit for designs with more than two recirculation loops is not provided.

If demand control is not used, temperature modulation controls and/or continuous monitoring should be used as an alternative compliance method. Recirculation timer controls are not given any control credits because field studies revealed that they are usually not properly configured to achieve the intended purposes. Buildings with uncontrolled recirculation systems will have to

install other efficiency measures to meet compliance requirements through the performance method.

Systems with all pipes insulated can claim compliance credit. The amount of credit is increased if the insulation is verified by a HERS Rater. Increasing recirculation pipe insulation by 0.5 inch above the mandatory requirements can also result in compliance credit through performance calculation.

5.5.4 Treatment of Water Heater Efficiency

For information on how water heater efficiency is considered in terms of modeling energy performance using the compliance software tool, please refer to the *Residential Alternative Calculation Method (ACM) Reference Manual*.

5.5.5 Compliance Issues

Water heating is becoming more important to overall building compliance as building envelope performance and mechanical efficiency improve. When the performance approach is used, a high-efficiency water heater and an efficient distribution system can significantly affect the overall performance margin of a building, especially in the milder climates like Climate Zones 4 through 9, where water heating typically represents a larger fraction of the overall energy budget.

Asking for a cut sheet on the installed equipment to verify efficiency is a simple shortcut to checking compliance. When used in a combined hydronic system, it is important to check the capacity of the system to verify that both space and water heating loads can both be met.

5.6 Distribution Systems

5.6.1 Types of Water Heating Distribution Systems

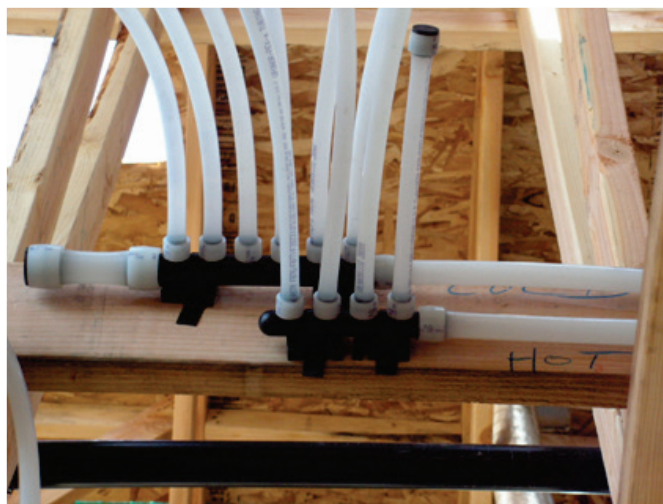
The water heating distribution system is the configuration of piping (and pumps and controls in the case of recirculating systems) that delivers hot water from the water heater to the end-use points within the building. For systems designed for single-family buildings or individual dwelling units in a multifamily building, the system will resemble one of the system types described below under dwelling unit distribution systems. In multifamily buildings, the use of a central water heater and central recirculation distribution system that brings hot water close to all the dwelling units is also common. A description of the recognized systems for serving single and multiple dwelling units are listed in the following two sections. The installation of a hot water distribution system that does not meet all of the installation guidelines discussed in this compliance manual and in the Reference Appendix RA3 and RA4 must have either the deficiencies corrected or compliance calculations using the performance approach assuming that the installed distribution system is substandard. In all cases, the locations of the water heaters and fixtures should be given consideration at the beginning of building design. By minimizing the length of distribution piping, energy use, water waste, wait time for hot water and construction cost can all be reduced.

5.6.2 Systems Serving Single Dwelling Unit

5.6.2.1 Standard Distribution System (Trunk-and-Branch and Mini-manifold Configurations)

The most basic plumbing layout, and assumed as the reference design in the performance approach, is represented by the conventional trunk-and-branch layout. This layout of a trunk-and-branch system may include one or more trunks each serving a portion of the building. The trunks are subdivided by branches that serve specific rooms, and these are in turn divided into twigs that serve a particular point of use. This distribution system class includes mini-manifold layouts (see Figure 5-8), which incorporate trunk lines that feed remote manifolds that then distribute water via twigs to the end-use points. A standard distribution system may not incorporate a pump for hot water recirculation. Piping cannot be run up to the attic and then down to points of use on the first floor.

Figure 5-8: Mini-manifold Configuration



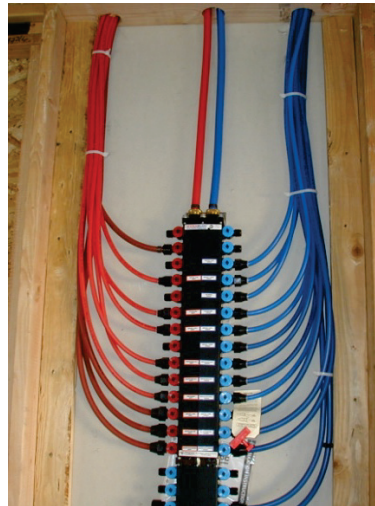
Installation Criteria and Guidelines

No pumps may be used to recirculate hot water with the standard distribution system. All applicable mandatory features must be met. When designing a trunk-and-branch system, the concern is keeping all segments of the system as short and as small a diameter as possible. Even an insulated pipe will lose most of the stored heat within 30 minutes. The other issue to consider is that if hot water gets into a cold water line, all the water in the pipe must be discharged, and up to an additional third of the volume of hot water will be needed to heat the pipe so that the water arriving at the point of use will be the desirable temperature. The requirements and guidelines for the installation of the standard distribution system are included in Reference Appendix RA3 - Residential Field Verification and Diagnostic Testing Protocols and RA4 - Eligibility Criteria for Energy Efficiency Measures.

5.6.2.2 Central Parallel Piping System

The primary design concept in a central parallel piping system is an insulated main trunk line that runs from the water heater to one or more manifolds, which then feeds use points with $\frac{1}{2}$ " or smaller plastic piping. The traditional central system with a single manifold (Figure 5-9) must have a maximum pipe run length of 15 feet between the water heater and the manifold. With the advent of mini-manifolds, the central parallel piping system can now accommodate multiple mini-manifolds in lieu of the single central manifold, provided that a) the sum of the piping length from the water heater to all the mini-manifolds is less than 15 feet and b) all piping downstream of the mini-manifolds is nominally $\frac{1}{2}$ inch or smaller.

Figure 5-9: Central Manifold System



Installation Criteria and Guidelines

All applicable mandatory measures must be met. Piping from the manifold cannot be run up to the attic and then down to points of use on the first floor. The intent of a good parallel piping design is to minimize the volume of water entrained in piping between the water heater and the end-use points, with a focus on reducing the length of the $\frac{3}{8}$ -inch or 1-inch line from the water heater to the manifold(s). To encourage reducing the pipe length between the water heater and manifold, there is a distribution system compliance credit for installations that are HERS-verified to have no more than 5 feet of piping between the water heater and the manifold(s). The manifold feeds hot water use points with $\frac{3}{8}$ or $\frac{1}{2}$ inch PEX tubing. (Check with enforcement agencies on the use of $\frac{3}{8}$ -inch piping in the event that it is prohibited without engineering approval.) The adopted requirements for installation guidelines are included in RA3 and RA4.

5.6.2.3 Point of Use

A *point-of-use distribution system design* significantly reduces the volume of water between the water heater and the hot water use points. Use of this type of system requires a combination of good architectural design (that is, water heater location adjacent to hot water use points), an indoor mechanical closet, or the use of multiple water heaters. Figure 5-10 provides an example of the latter approach where three water heaters are installed close to the use points. For compliance with this credit, field verification is required. This system is not applicable to systems serving multiple dwelling units.

Installation Criteria and Guidelines

All applicable mandatory features must be met, and the distance between the water heater and any fixture using hot water cannot exceed the length specified in Table 5-9 below. The adopted requirements for installation guidelines are included in RA3 and RA4. All water heaters and hot water fixtures must be shown on plans submitted for a local building department plan check.

Figure 5-10: Point-of-Use Distribution System

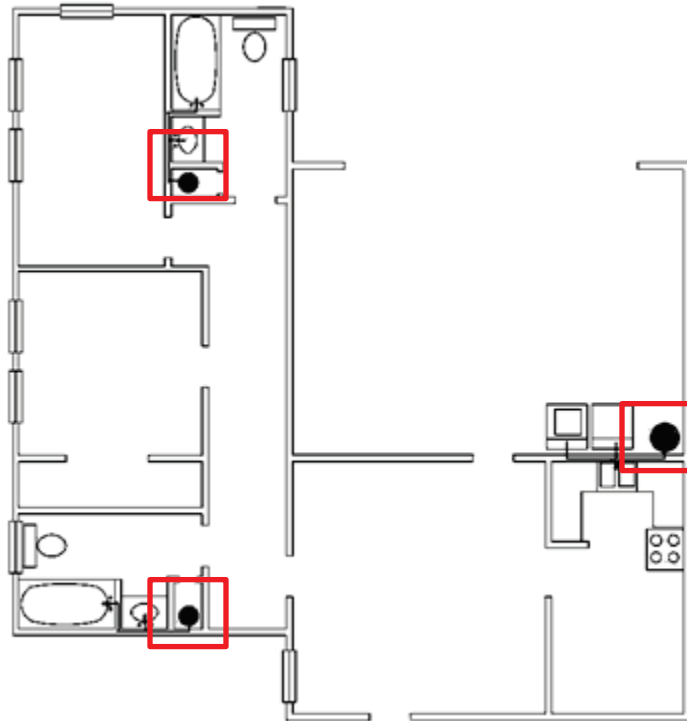


Table 5-9: Point-of-Use Distribution System

Size Nominal, Inch	Length of Pipe (feet)
3/8"	15
1/2"	10
3/4"	5

5.6.2.4 HERS-Verified Compact Design

A *compact distribution system design* means that all the hot water use points in a non-recirculating distribution system are within a specified length of piping to the water heater that serves those fixtures.

If the user is complying with the Energy Standards using the prescriptive approach, there is the option of using compact hot water distribution design in combination with a propane or natural gas storage water heater (and Quality Insulation Installation, if installing a gas storage water heater that is 55 gallons or less). Compact hot water distribution design can also be used to help achieve the required energy budget (in other words, as a compliance credit) if the user is

complying with the Energy Standards using the performance approach. To use the compact hot water distribution design to comply with Energy Standards, the design and installation must be HERS-verified and meet the Reference Appendix RA4.4.16 requirements.

Table 5-10 below specifies the maximum pipe run length that meets the compact design criteria based on floor area served (floor area served = building conditioned floor area divided by the number of water heaters), which recognizes that multiple water heaters may be beneficial in achieving a more compact distribution system.

Typical hot water distribution systems are often designed to be much larger than needed in terms of pipe length. A design consideration that often is overlooked is the location of the water heater relative to hot water use points. Figure 5-11 below shows a common production home layout with the water heater located in the corner of the garage and hot water use points in each corner of the house.

A more effective hot water distribution system design is shown in Figure 5-12. In the figure, the location of the water heater is near the kitchen and bathrooms and laundry area. The location of hot water use points plays an integral role in achieving the benefits associated with a compact distribution system design.

Figure 5-11: “Common” Production Home House Layout

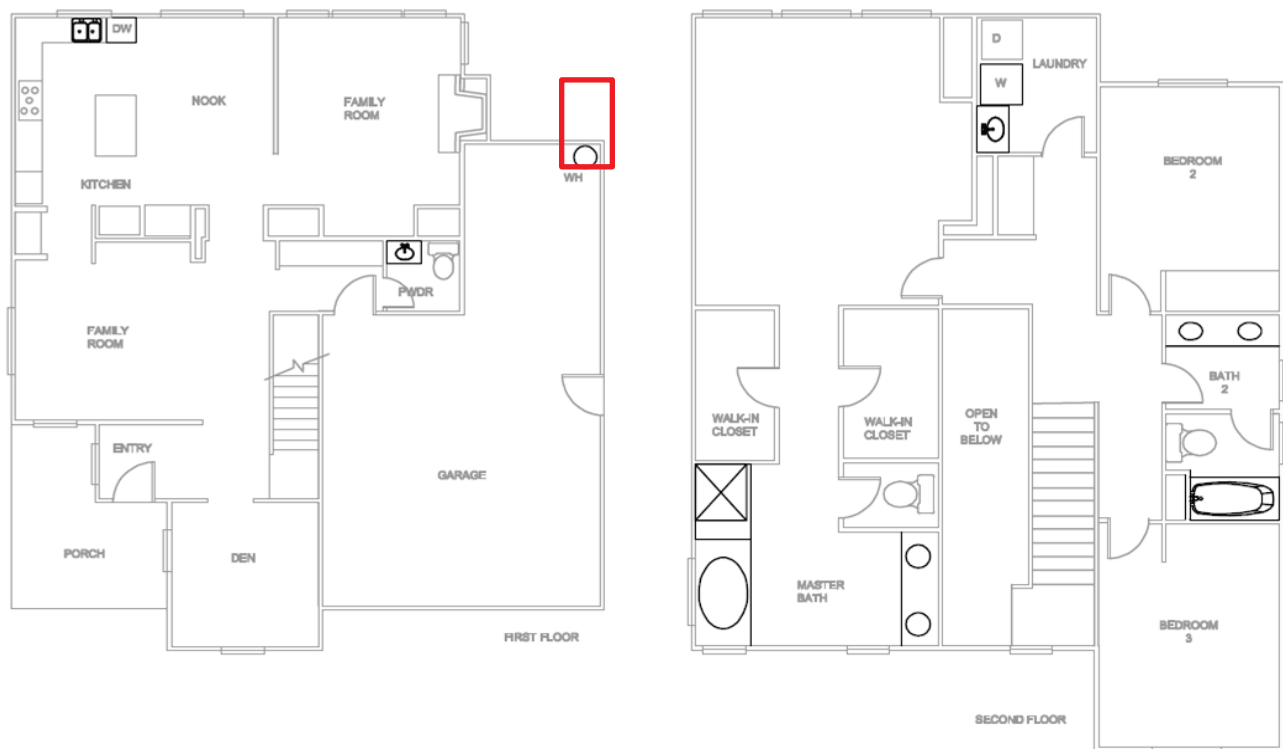


Figure 5-12: Compact Design Distribution System

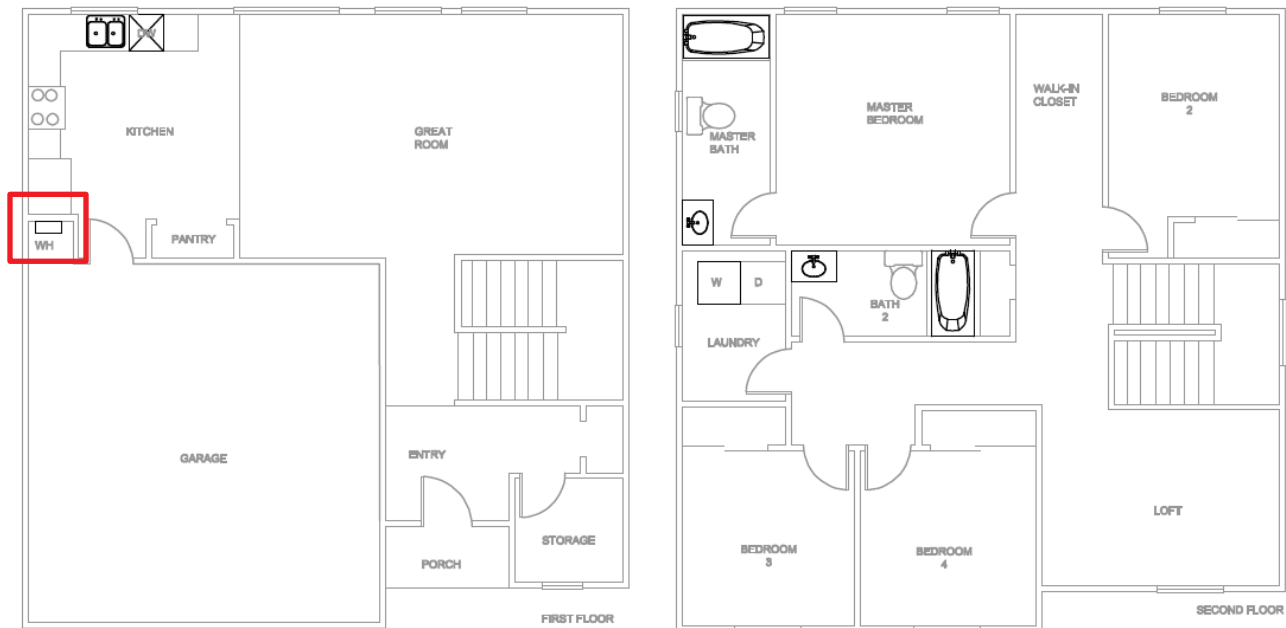


Table 5-10: Compact Distribution System

<i>Floor Area Served (ft²)</i>	<i>Maximum Water Heater To Use Point Distance (ft)</i>
< 1000	28'
1001 – 1600	43'
1601 – 2200	53'
2201 – 2800	62'
>2800	68'

5.6.2.5 Pipe Insulation Credit

Compliance credit is available in the performance compliance approach if all piping in the hot water distribution system is insulated from the water heater to each fixture or appliance. In addition to the mandatory pipe insulation requirements described in Section 5.3.5.1, pipe insulation should be checked to ensure all elbows and tees are fully insulated and fit tightly to the pipe. No piping should be visible due to insulation voids with the exception of the last segment of pipe that penetrates walls and connects to the fixture or appliance. Additional credit is available if the insulation is verified by a HERS inspection.

5.6.2.6 Recirculation System – Non-Demand Control Options

This type of distribution system encompasses all recirculation strategies that do not incorporate a demand control to minimize recirculating pump operation. Under this category, recirculation system types include uncontrolled continuous recirculation, timer control, temperature control, and time/temperature controls. The intent is to clearly distinguish between recirculation system control options that result in very little daily pump operating time (demand control strategies) and the other strategies where pump runs continuously or run time is much more uncertain. Recirculation systems are known to save water, but the energy impact can be very high in a poorly designed and/or controlled system.

Installation Criteria

All piping used to recirculate hot water must be insulated to meet the mandatory requirements. Since the standards require pipe insulation for recirculating systems, these systems are not eligible for the pipe insulation credit. For systems serving a single dwelling unit, the recirculating loop within a dwelling unit must be laid out to be within 8 feet of all hot water fixtures served by the recirculating loop. As with all recirculation systems, an intelligent loop layout (loop in-board of hot water use points) and proper insulation installation are essential in obtaining desired performance. Piping in a recirculation system cannot be run up to the attic and then down to points of use on the first floor. The adopted requirements for installation guidelines are included in Reference Appendices RA3 and RA4.

5.6.2.7 Recirculation System – Demand Control

A *demand-control recirculation system* uses brief pump operation in response to a hot water demand “signal” to circulate hot water through the recirculation loop. The system must have a temperature sensor, typically located at the most remote point of the recirculation loop. Some water heaters have temperature sensors located within the water heater. The sensor provides input to the controller to terminate pump operation when the sensed temperature rises. Typical control options include manual push button controls or occupancy sensor controls installed at key use areas (bathrooms and/or kitchen). Push button control is preferred from a performance perspective, since it eliminates “false signals” for pump operation that an occupancy sensor could generate. The adopted requirements for installation guidelines are included in Reference Appendices RA3 and RA4.

Installation Criteria

All criteria listed for continuous recirculation systems apply. Piping in a recirculation system cannot be run up to the attic and then down to points of use on the first floor.

Pump start-up must be provided by a push button, flow switch, or occupancy sensor. Pump shut-off must be provided by a combination of a temperature sensing device that shuts off the pump when the temperature sensor detects no more than 10 degree rise above the initial temperature of water in the pipe or when the temperature reaches 102 degree F. Moreover, the controls shall limit the maximum pump run time to five minutes or less.

For a system serving a single dwelling, push buttons and sensors must be installed in all locations with a sink, shower, or tub, with the exception of the laundry room.

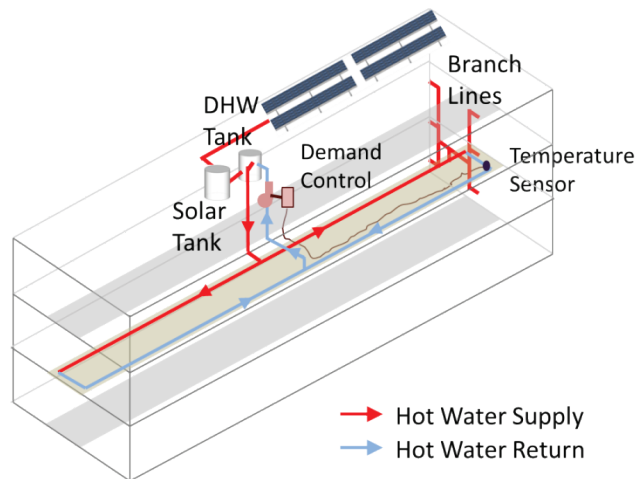
Plans must include a wiring/circuit diagram for the pump and timer/temperature sensing device and specify whether the control system is manual (push button or flow switch) or other control means, such as an occupancy sensor.

5.6.3 Systems Serving Multiple Dwelling Units

5.6.3.1 Multiple Dwelling Units: Central Demand Recirculation System (Standard Distribution System)

The standard distribution system for water heaters serving multiple dwelling units incorporates recirculation loops, which bring hot water to different parts of the building, and a demand control, which automatically shuts off the recirculation pump when the recirculation flow is not needed. In summary, central recirculation systems include three components, recirculation loops, branch pipes, and pipes within dwelling units. Recirculation loops are used to bring hot water close to all dwelling units but are not expected to go through each dwelling unit. Branch pipes are used to connect pipes within dwelling units and the recirculation loops. This concept is illustrated in Figure 5-13. Designs of distribution systems within dwelling units are similar to those serving single dwelling units, described in Section 5.6.2.

Figure 5-13: Standard Multifamily Central Distribution System



Demand controls for central recirculation systems are automatic control systems that control the recirculation pump operation based on measurement of hot water demand and hot water return temperatures.

5.6.3.2 Multiple Dwelling Units: Recirculation Temperature Modulation Control

A recirculation temperature modulation control shall reduce the hot water supply temperature when hot water demand is determined to be low by the control system. The control system may use a fixed control schedule or dynamic control schedules based measurements of hot water demand. The daily hot water supply temperature reduction, which is defined as the sum of temperature reduction by the control in each hour within a 24-hour period, shall be more than 50 degrees Fahrenheit to qualify for the energy savings credit. Qualifying equipment shall be listed with the Commission.

Recirculation systems shall also meet the requirements of §110.3.

5.6.3.3 Multiple Dwelling Units: Recirculation Continuous Monitoring Systems

Systems that qualify as a recirculation continuous monitoring systems for domestic hot water systems serving multiple dwelling units shall record no less frequently than hourly measurements of key system operation parameters, including hot water supply temperatures, hot water return temperatures, and status of gas valve relays for water-heating equipment. The continuous monitoring system shall automatically alert building operators of abnormalities identified from monitoring results. Qualifying equipment or services shall be listed with the Commission.

Recirculation systems shall also meet the requirements of §110.3.

5.6.3.4 Non-recirculating Water Heater System

Multiunit buildings may also use systems without a recirculation system, if the served dwelling units are closely located so that the branch pipes between the water-heating equipment and dwelling units are relatively short. Long branch lines will lead to excessive energy and water waste.

5.7 Combined Hydronic System

5.7.1 Combined Hydronic

Combined hydronic space heating systems use a single heat source to provide both space heating and domestic hot water. The current modeling of these system types is fairly simplistic, treating water heating performance separately from the space-heating function.

5.8 Shower Heads

5.8.1 Certification of Showerheads and Faucets

Maximum flow rates have historically been set by the *Appliance Efficiency Regulations*, and all faucets and showerheads sold in California must meet these standards. California's *Title 20 Appliance Efficiency Regulations* contain the maximum flow rate for showerheads and lavatory and kitchen faucets. Current flow requirements contained in the Title 24 part 11 CALGreen Code set more efficiency levels. Installations of showerheads and faucets are mandatory under the CALGreen Code and must be met.

5.9 Solar Water Heating

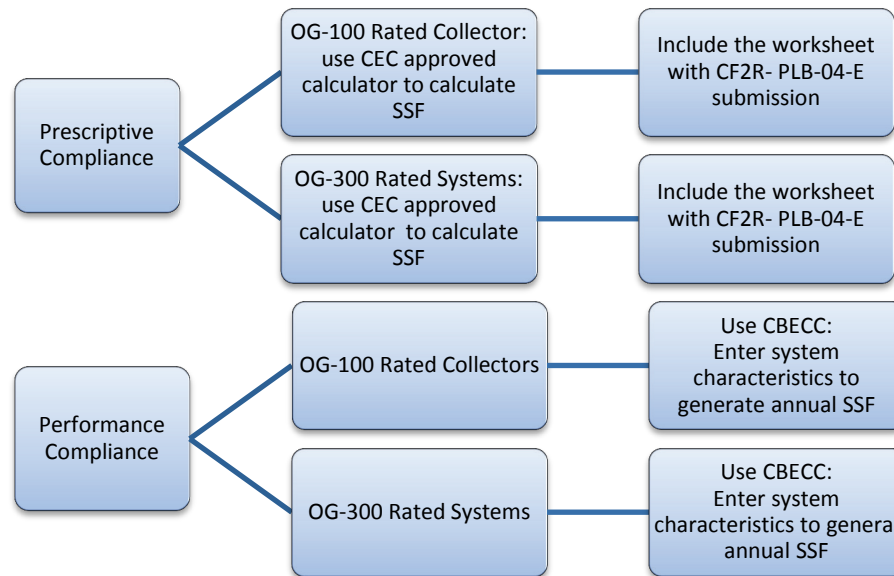
The water heating calculation method allows water heating credits for solar water heaters. Solar thermal systems save energy by using renewable resources to offset the use of conventional energy sources.

For single-dwelling solar thermal systems, systems must be Solar Rating and Certification Corporation (SRCC) approved. Accepted testing procedures include either a fully approved system with OG-300 test results or a built up system that uses the collector (OG-100) rating. For multifamily buildings, only systems with OG-100 collectors can be installed. For more detailed instructions on installation of solar water heaters, refer to Reference Appendix RA4.4.21. The sortable database of SRCC-certified equipment is located on the SRCC website at the following link:

<https://secure.solar-rating.org/Certification/Ratings/RatingsSummaryPage.aspx>

Figure 5-14 summarizes the process flow for demonstrating compliance via the prescriptive and performance approaches for solar thermal systems.

Figure 5-14: Compliance Process for Solar Thermal System



Regardless of the system type installed and compliance method chosen, mandatory requirements for pipe insulation apply as described in Section 5.3.5.1.

5.9.1 Solar or Recovered Energy in State Buildings

§110.3(c)6

Low-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 physically infeasible. See the Compliance Options section below for more information about solar water heating systems.

5.9.1.1 Solar-Ready Buildings Requirements

§150.0(r) §110.1

There are mandatory requirements for all buildings to be “solar ready.” The motivation behind having solar-ready requirements is to encourage more future installations of both photovoltaic and solar water-heating systems, even if these systems are not installed during the time of new construction. Details on these solar ready requirements are in Chapter 7 – “Solar Ready Requirements” of this compliance manual. In summary, the elements to being solar-ready include:

1. A designated solar zone.
2. Designated conduit and plumbing paths.
3. Documentation for solar zone and paths on construction plans.
4. Adequate electric busbar and panel capacity.

5.9.2 Prescriptive Requirements for Solar Water Heating

This section discusses when solar water heating is required prescriptively for systems serving multiple-dwelling units.

5.9.2.1 Multifamily, Motel/Hotels, and High-Rise Nonresidential

§150.1(c)8Ciii

Solar water heating is prescriptively required for water heating systems serving multiple dwelling units, whether they are multifamily, motel/hotels, or high-rise nonresidential buildings. The minimum solar fraction depends on the climate zone (CZ): 0.20 for CZ 1 through 9 and 0.35 for CZ 10 through 16. See Table 5-11 below.

Table 5-11: Required Performance of Solar Systems Installed in Multifamily Buildings with Central Distribution Systems

<i>Climate Zone</i>	<i>Minimum Solar Fraction</i>
1-9	0.20
10-16	0.35

The regulations 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 Reference Appendix RA4.4. Installation of a solar water heating system exempts multifamily buildings from needing to set aside solar zone for future solar PV and solar water heating installation as specified in §110.10(b)1B. The following paragraphs offer some high-level design considerations for multifamily building solar water heating systems.

A high-priority factor for solar water heating system design is component sizing. Proper sizing of the solar collectors and solar tank ensures that the system takes 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 serious as it should be, especially for climate conditions with relatively high solar insolation level such as California. This is especially critical for multifamily-sized systems, due to load variability.

The solar water heating sizing requirements for the standards are conservative. For example, the highest solar fraction requirement in the *2013 Energy Standards* was at 50 percent. Stakeholders further suggested that industry standard sizing for an active system is 1.5 square feet of collector area per gallon capacity of the solar storage tank. For more detailed guidance and best practices, there are many publicly available industry design guidelines. Two such resources developed by/in association with government agencies are:

1. *Building America Best Practices Series: Solar Thermal and Photovoltaic Systems*
http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/41085.pdf
2. *California Solar Initiative – Thermal: Program Handbook*
http://www.cpuc.ca.gov/NR/rdonlyres/CB11B92E-DFFF-477B-BFA9-F1F04906F9F9/0/CSIThermal_Handbook201209.pdf

Because of the solar water heating requirements and the prevalence of recirculation hot water systems in multifamily buildings, it is essential to emphasize the importance of proper integration between the hot water recirculation system and the solar water heating system. Industry stakeholders recommended 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.

Another design consideration is the layout and placement of collectors and solar tank. The idea here, similar to the discussions on recirculation system design in Section 5.6, is to minimize the length of plumbing, thus reducing pipe surface areas susceptible to heat loss and piping materials needed. This calls for the shortest feasible distance between the collectors themselves; furthermore, since solar tanks are typically plumbed in series just upstream of the conventional/auxiliary water heating equipment, the distance between collectors and solar tank should also be as short as possible.

5.9.3 Performance Approach Compliance for Solar Water Heating

Solar water heating systems with a solar fraction higher than the specified prescriptive minimum can be used as a tradeoff under the performance approach. Figure 5-14 shows the compliance process needed for demonstrating compliance with solar water heating modeling. The CBECC-Res API integrates the capability of calculating an annual solar fraction. Users now input collector and system component specifications to calculate a corresponding solar fraction for the proposed system.

5.10 Swimming Pool and Spa Heating

5.10.1 Swimming Pool and Spa Types

The Energy Standards include many additional requirements for residential swimming pool filtration equipment, which affect pump selection and flow rate, piping and fittings, and filter selection. These standards are designed to reduce the energy used to filter and maintain the clarity and sanitation of pool water.

5.10.2 Mandatory Requirements for Pools and Spas

Before any pool or spa heating system or equipment may be installed, the manufacturer must certify to the Energy Commission that the system or equipment complies with §110.4 and §110.5. The requirements include minimum heating efficiency according to the *Appliance Efficiency Regulations*, an on-off switch outside the heater, permanent and weatherproof operating instructions, no continuous pilot light, and no electric resistance heating. (See exceptions below.)

§110.5

Pool and spa heaters may not have continuously burning pilot lights.

§110.4

Outdoor pools and spas with gas or electric heaters shall have a cover installed. The cover should be fitted and installed during the final inspection.

There are two exceptions for electric heaters, which may be installed for:

1. Listed package units with fully insulated enclosures (for example, hot tubs), and with tight-fitting covers, insulated to at least R-6.
2. Pools or spas getting 60 percent or more of the annual heating from site solar energy or recovered energy.

5.10.2.1 Pool Pump Requirements

For maximum energy efficiency, pool filtration should be operated at the lowest possible flow rate for a period that provides sufficient water turnover for clarity and sanitation. Auxiliary pool loads that require high flow rates, such as spas, pool cleaners, and water features, should be operated separately from the filtration to allow the filtration flow rate to be kept to a minimum.

§150.0(p)1

All pumps and pump motors shall comply with the specifications of the *Appliance Efficiency Regulations*.

The pool filtration flow rate may not be greater than the rate needed to turn over the pool water volume in 6 hours or 36 gallon per minute (gpm), whichever is greater. This means that for pools of less than 13,000 gallons, the pump must be sized to have a flow rate of less than 36 gpm, and for pools of greater than 13,000 gallons, the pump must be sized using the following equation:

$$\text{Max Flow Rate (gpm)} = \frac{\text{Pool Volume (gallons)}}{360\text{min.}}$$

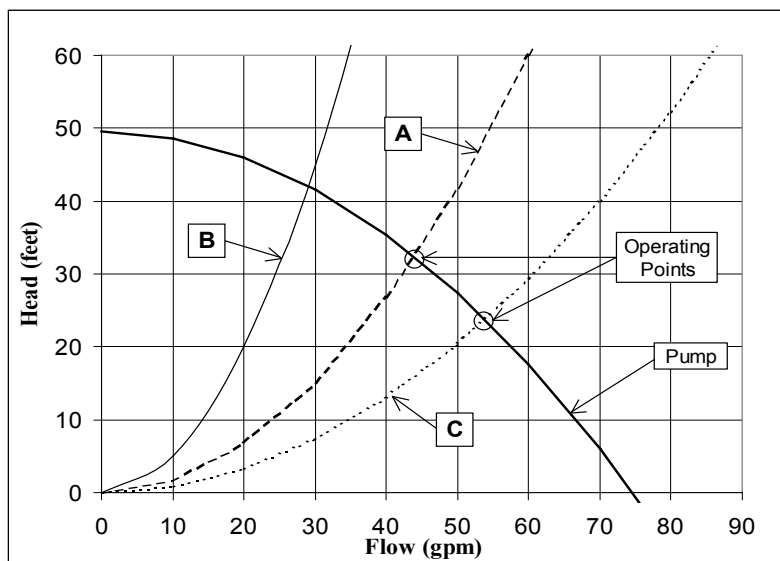
These are maximum flow rates. Lower flow rates and longer filtration times are encouraged and will result in added energy savings.

Pools with auxiliary pool loads must use either a multispeed pump or a separate pump for each auxiliary pool load. For example, if a spa shares the pool filtration system, either a multispeed pump must be used or a separate pump must be provided to operate the spa. If the pool system can be served by one pump of less than 1 total horsepower (hp) in capacity, the pump may be single-speed.

Filtration pump motors with a capacity of 1 total-hp or more must be multispeed.

All pool pumps sold in California must be tested and listed with the Energy Commission according to the *Appliance Efficiency Regulations*. Pump manufacturers must list flow rate, power, and energy factor at each of three system curves. (See Figure 5-15.) For pools equal to or less than 17,000 gallons, a pump must be chosen such that the flow rate listed for Curve A is less than the 6-hour turnover rate. For pools greater than 17,000 gallons, a pump must be chosen such that the listed flow rate at Curve C is less than the 6-hour turnover rate.

Figure 5-15: System Test Curves



5.10.2.2 Pool Pump Controls

Pool controls are a critical element of energy efficient pool design. Modern pool controls allow for auxiliary loads such as cleaning systems, solar heating, and temporary water features without compromising energy savings.

§110.4(b)

A time switch or similar control mechanism must be installed as part of the pool water circulation control system that will allow all pumps to be set or programmed to run only during the off-peak electric demand period and for the minimum time necessary to maintain the water in the condition required by applicable public health standards.

§150.0 (p)1

Multispeed pumps must have controls that default to the filtration flow rate when no auxiliary pool loads are operating. The controls must also default to the filtration flow rate setting within 24 hours and must have a temporary override capability for servicing.

5.10.2.3 Pool Pipe, Filter, and Valve Requirements

Correct sizing of piping, filters, and valves reduces overall system head, reduces noise and wear, and increases energy efficiency. Other mandatory requirements include leading straight pipe into the pump, directional inlets for mixing, and piping to allow for future solar installations.

§110.4(b) and §150(p)2

Pool piping must be sized according to the maximum flow rate needed for all auxiliary loads. The maximum velocity allowed is 8 fps in the return line and 6 fps in the suction line. Table 5-12 shows the minimum pipe sizes required by pool volume based on a 6-hour turnover filtration flow rate. These pipe sizes would need to be increased if there are auxiliary loads that operate at greater than the filtration flow rate. Conversely, they could be reduced if the pump is sized for greater than a 6-hour turnover filtration flow rate.

Table 5-12: Hour Turnover Pipe Sizing

<i>Pool Volume (gallons)</i>		<i>Minimum Pipe Diameter (in)</i>	
Min	Max	Return	Suction
-	13,000	1.5	1.5
13,000	17,000	1.5	2.0
17,000	21,000	2.0	2.0
21,000	30,000	2.0	2.5
30,000	42,000	2.5	3.0
42,000	48,000	3.0	3.0
48,000	65,000	3.0	3.5

There must be a length of straight pipe that is greater than or equal to at least 4 inches pipe diameters installed before the pump. That is, for a 2-inch suction pump, there must be at least 8 inches of straight pipe before the pump strainer basket.

Traditional hard 90° elbows are not allowed. All elbows must be sweep elbows or a type of elbow that has a pressure drop less than the pressure drop of straight pipe with a length of 30 pipe diameters. For example, a 2-inch elbow must have a pressure drop less than a 5-foot length of a 2-inch straight pipe.

Field verification of sweep elbows may be performed by checking that the distance “w” of the installed sweep elbow is greater than that for a hard 90 elbow. (Refer to Figure 5-16.) The difference in measurement between the radial edge of one sleeve to the perpendicular side of the elbow is found to be distinct between sweep elbows and hard 90s. There is sufficient difference in distance “w” such that all sweep elbows exceed the minimum values listed in Table 5-13.

Figure 5-16 below illustrates “w” the dimension between the elbow sleeves, and Table 5-13 shows the minimum distances “w” for an acceptable sweep elbow.

Figure 5-16: Measuring “w” at the Pool Site

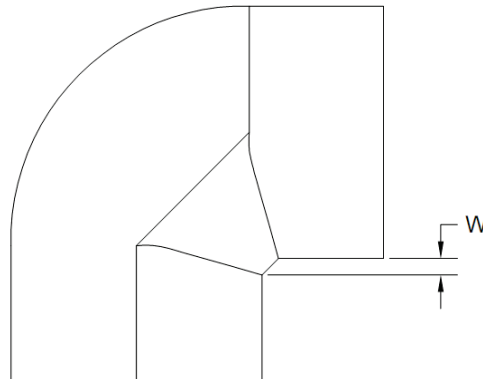


Table 5-13: Pool Site Measurement for Sweep Elbows

<i>Pipe Diameter</i>	<i>Minimum W (inch)</i>
1.5	3/8
2	1/2
2.5	5/8
3	3/4
4	1

Filters shall be sized using NSF/ANSI 50 based on the maximum flow rate through the filter. The filter factors that must be used are in ft²/gpm:

- a. Cartridge 0.375
- b. Sand 15
- c. Diatomaceous Earth 2

Backwash valves must be sized to the diameter of the return pipe or two inches, whichever is greater. Multiport backwash valves have a high-pressure drop and are discouraged. Low-loss slide and multiple 3-way valves can provide significant savings.

The pool must have directional inlets to adequately mix the pool water.

If a pool does not use solar water heating, 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. Provide at least 36 inches of pipe between the filter and the heater to allow for the future addition of solar heating equipment.
2. Plumb separate suction and return lines to the pool dedicated to future solar heating.
3. Install built-up or built-in connections for future piping to solar water heating. An example of this would be a capped off tee fitting.

Example 5-12 – Pool covers**Question:**

My pool has both a solar heater and a gas heater. Do I need to install a pool cover?

Answer:

Yes. A cover is required for all pools with gas or electric heaters, regardless of whether they also have a solar heater.

Example 5-13 – Pool pump**Question:**

I have a 25,000 gallon pool and want to use a two-speed pump with a Curve C flow rate of 79 gpm on high-speed and 39 gpm on low-speed. Is this okay, and what size piping must I installed?

Answer:

The maximum filtration flow rate for a 25,000-gallon pool is 69 gpm by using equation [Max Flow Rate (gpm) = Pool Volume (gallons) / 360 minutes], so the pump is adequately sized, as long as a control is installed to operate the pump on low-speed for filtration. The maximum pipe size must be based on the maximum flow rate of 79 gpm. Referencing Table 5-9, you must use 2.5-inch suction and 2-inch return piping.

5.11 Compliance and Enforcement

Chapter 2 of this compliance manual addresses the compliance and enforcement process generally and discusses the roles and responsibilities of each of the major parties, the compliance forms, and the process for field verification and/or diagnostic testing. This section highlights compliance enforcement issues for water heating systems.

5.11.1 Design Review

The design review verifies that the certificate of compliance matches the plans and specifications for the proposed building. The certificate of compliance has a section where special features are listed. The following are water heating features that should be listed in this section of the certificate of compliance:

1. Any system type other than one water heater per dwelling unit
2. Non-NAECA large water heater performance
3. Indirect water heater performance
4. Instantaneous gas water heater performance
5. Distribution system type and controls
6. Solar system
7. Combined hydronic system

If any of these measures are called out on the certificate of compliance, special attention should be given to make sure that identical information is located on the plan set. Highlighting key concerns or adding notes will allow field inspectors to quickly catch any measures that should be installed that made a significant difference in compliance.

5.11.2 Field Inspection

During construction, the contractor and/or the specialty contractors complete the necessary sections of the certificate of installation. For water heating, there is only one section to be completed where information about the installed water heating system is entered if complying prescriptively with the installation of a gas instantaneous water heater. However, if complying prescriptively with a gas storage water heater, the completion of additional documents will be needed. (See Appendix A.)

Inspectors should check that the number and types of water heating systems indicated on the installation certificates match the approved certificate of compliance. The distribution system is also significant and must correspond to plan specifications.

5.11.3 HERS Field Verification and/or Diagnostic Testing

5.11.3.1 Single Family

HERS verification is required for all hot water distribution types that include options for field verification. The first type is alternative designs to conventional distribution systems that include parallel piping, demand recirculation, and automatic and manual on-demand recirculation. The second type is for compact distribution systems, which can be used only when verified by field verification. In addition, HERS-verified QII is also required for users that comply prescriptively by installing a minimally compliant gas storage water heater that is 55 gallons or less; QII is not required if prescriptive compliance is pursued by installing a minimally compliant gas instantaneous water heater or gas storage water heater larger than 55 gallons. For all of the cases where HERS verification is required, the HERS Rater must verify that the eligibility requirements for the specific system are met.

In addition, HERS-verified pipe insulation is an option for prescriptive compliance and as a compliance credit for the performance approach. This credit applies if all pipes in a non-recirculating distribution system are insulated. HERS verification is required if this credit is taken in combination with the installation credit. Uninsulated hot water pipes in insulated walls or buried in the attic insulation would comply with the requirements. In this case a HERS Rater must verify that the eligibility requirements for pipe insulation have been met.

As previously described in this chapter, if a user wishes to comply prescriptively with the Energy Standards and installs a minimally compliant gas storage water heater (55 gallons or less) plus HERS-verified QII or a minimally compliant gas storage water heater with a storage volume greater than 55 gallons, then either the compact distribution design or insulation on all domestic hot water piping must be installed, both of which require HERS verification.

5.11.3.2 Multifamily

The only HERS verification for water heating that applies to central domestic hot water recirculation systems in multifamily buildings is the verification of multiple distribution lines for central recirculation systems.

5.12 Glossary/Reference

5.12.1 General Glossary/Reference for Water Heating

Relevant terms are defined in Reference Joint Appendix JA1.

The following are terms that are either not defined in JA1 or expansions to the Appendix I definitions.

- A. **External tank insulation** can be applied to the exterior of storage type water heater tanks. When installed, water heater insulation should be applied to completely cover the exterior of the water heater, but should not conceal controls or access ports to burners, obstruct combustion air openings, or interfere in any way with safe water heater operation. Insulation of top and bottom surfaces is not necessary.
- B. **Recovery energy** is the energy used to heat water.
- C. **Recovery load** is the load on the water heater due to hot water end uses and distribution losses.
- D. **Single dwelling unit** is a residence with a dedicated water heater. Single dwelling units can be a single-family home or an individual dwelling unit in a multifamily building, as long as each unit has a dedicated water heater.
- E. **Thermal efficiency** is defined in the *Appliance Efficiency Regulations* as a measure of the percentage of heat from the combustion of gas or oil that is transferred to the hot water as determined using the applicable test methods.
- F. **Uniform energy factor (UEF)** of water heater is the uniform energy descriptor used to describe the overall water heater efficiency as determined using the applicable test method in the *Appliance Efficiency Regulations*. Typical gas storage water heaters have typical UEFs of about 0.60-0.76, electric storage water heaters approximately 0.90, and gas instantaneous units approximately 0.80-0.94. It replaced the “energy factor” metric previously used for residential water heaters.

5.12.2 General Glossary/Reference for Swimming Pool and Spa

- A. **Flow rate** is the volume of water flowing through the filtration system in a given time, usually measured in gallons per minute.
- B. **Nameplate power** is the motor horsepower (hp) listed on the nameplate and the horsepower by which a pump is typically sold.
- C. **Pool pumps** usually come with a leaf strainer before the impeller. The pumps contain an impeller to accelerate the water through the housing. The motors for residential pumps are included in the pump purchase but can be replaced separately. The pumps increase the “head” and “flow” of the water. Head is necessary to move fluid through pipes, drains, and inlets, push water through filters and heaters, and project it through fountains and jets. Flow is the movement of the water used to maintain efficient filtering, heating, and sanitation for the pool.
- D. **Return** refers to the water in the filtration system returning to the pool. The return lines or return side, relative to the pump, can also be defined as the pressure lines or the pressure side of the pump. Water in the returns is delivered back to the pool at the pool inlets.
- E. **Service factor**. The service factor rating indicates the percentage above nameplate horsepower at which a pump motor may operate continuously when full-rated voltage is applied and ambient temperature does not exceed the motor rating. Full-rated pool motor

service factors can be as high as 1.65. A 1.5 hp pump with a 1.65 service factor produces 2.475 hp (total hp) at the maximum service factor point.

- F. **Suction** created by the pump is how the pool water gets from the skimmers and drains to the filtration system. The suction side and suction lines refer to the vacuum side of the pump. It is at negative atmospheric pressure relative to the pool surface.
- G. **Total dynamic head (TDH)** refers to the sum of all the friction losses and pressure drops in the filtration system from the pools drains and skimmers to the returns. It is a measure of the system's total pressure drop and is given in units of either psi or feet of water column (sometimes referred to as "feet" or "feet of head").
- H. **Total motor power** or T-hp, refers to the product of the nameplate power and the service factor of a motor used on a pool pump.
- I. **Turnover** is the act of filtering one volume of the pool.
- J. **Turnover time** (also called *turnover rate*) is the time required to circulate the entire volume of water in the pool or spa through the filter. For example, a turnover time of 6 hours means an entire volume of water equal to that of the pool will be passed through a filter system in six hours.

$$\text{Turnover Time} = \frac{\text{Volume of the pool}}{\text{Flow rate}}$$

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6. Residential Lighting

This chapter covers the Title 24 California Code of Regulations, Part 6 (the Energy Standards), requirements for lighting in low-rise buildings and the dwelling units in high-rise buildings. It is addressed primarily to lighting designers, electrical engineers, and enforcement agency personnel responsible for residential lighting.

6.1 Overview

For residential buildings and spaces, all of the lighting requirements are mandatory measures. There are no tradeoffs between lighting and other building features and lighting is not part of any component package under the prescriptive method.

The residential lighting Energy Standards apply only to permanently installed luminaires, including luminaires with easily interchangeable lamps, but do not apply to portable luminaires such as table lamps or freestanding floor lamps.

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.

6.1.1 Significant Changes in the 2016 Energy Standards

The 2016 Energy Standards have simplified the residential lighting requirements through the following important changes:

1. All luminaires installed in residential construction must qualify as “high efficacy luminaires.” This eliminates varying requirements by room and type of controls. This also eliminates the need to calculate the wattage of low versus high efficacy luminaires in the kitchen.
2. The definition of “high efficacy luminaires” has been expanded. It includes the light sources identified as efficient in 2013 (linear fluorescent, pin based compact fluorescent, GU-24 base CFL, HID, and induction lighting), and now also includes any luminaire that contains a JA8 compliant lamp or other light source that is appropriately marked. JA8 contains requirements that ensure that light sources, including lamps and luminaires, provide sufficient color quality, life, and energy efficiency. Table 150.0-A of §150.0 contains the definition.
3. All permanently installed luminaires with interchangeable lamps must contain lamps that comply with the requirements of Joint Appendix 8 (JA8) and be appropriately marked to be considered “high efficacy luminaires.”
4. The marking “JA8-2016” is required for compliance and shall only be used on lamps that meet the requirements of Joint Appendix 8 and are listed in the Energy Commission JA8 database.
5. The marking “JA8-2016-E” indicates that in addition to the requirements above for a JA8-2016 light source, the light source has been tested to provide long life at elevated temperatures. Light sources must be marked “JA 8-2016-E” if they are to be used in enclosed or recessed luminaires.
6. Recessed downlight luminaires and enclosed luminaires are required to contain a JA8 compliant lamp that meets the elevated temperature requirement. Recessed downlight luminaires with screw based sockets are no longer permitted to be installed.

7. The builder must provide the new homeowner with a luminaire schedule (as required in Title 24 California Code of Regulations, Part 1, §10-103(b)) that includes a list of lamps installed in the luminaries so that the homeowner knows what light sources they are entitled to when they take possession of the new home.
8. Inspections for lighting are more straightforward as all luminaries have a high efficacy light source and there is a completed luminaire schedule for the inspector to review.

In addition to these changes, the 2016 Energy Standards include minor modifications to the lighting controls requirements to maintain consistency with the requirements for dimmers and/or vacancy sensors.

6.1.2 Scope and Application

The residential lighting requirements in the Energy Standards, apply to more than just single-family homes. Space types covered include:

- Single-family buildings, indoor and outdoor lighting
- Low-rise multifamily buildings (three stories or less), indoor and outdoor lighting
- High-rise multifamily residential units
- Hotel and motel guest rooms
- Outdoor lighting controlled from the inside of a high-rise multifamily unit or hotel/motel guest room
- Fire station dwelling accommodations
- Dormitory and senior housing dwelling accommodations
- Accessory buildings such as sheds or garages (U occupancy type) on residential sites

The following subchapters provide a brief introduction to how the residential lighting requirements apply in these various space types. Specific requirements are discussed in greater detail throughout this chapter.

6.1.2.1 Single-family and Low-rise Multifamily

The residential lighting requirements apply to all indoor lighting of and outdoor lighting attached to single-family buildings.

The residential lighting requirements apply to lighting within dwelling units in multifamily buildings. In addition to the residential lighting requirements, if the interior common area of a low-rise multifamily building is greater than 20 percent of the total floor area, the lighting in the common areas must comply with the nonresidential lighting standards.

A low-rise residential building is defined in §100.1(b) as a building, other than a hotel/motel, in one of the following Occupancy Groups:

- R-2, multifamily, with three stories or less; or
- R-3, single-family; or
- U-building, located on a residential site.

6.1.2.2 High-rise Multifamily

Lighting within residential units in high-rise multifamily or high-rise residential buildings is required to comply with the residential lighting requirements. Common areas in all high-rise multifamily buildings must meet all applicable nonresidential lighting requirements. In addition, any outdoor lighting attached to a high-rise residential building controlled from

within a residential unit must also meet the residential lighting requirements of the Energy Standards.

6.1.2.3 Residential Spaces in Nonresidential Buildings

In addition to typical residential units, the residential lighting requirements apply to residential spaces in nonresidential buildings. As defined in §130.0(b), the following spaces are required to comply with the residential lighting standards:

- Hotel and motel guest rooms (Note that hotel and motel guest rooms are also required to comply with the requirements in §130.1(c)8, which require captive card key or other occupant sensing controls.)
- Outdoor lighting attached to a hotel or motel that is controlled from inside the guest room.
- Fire station dwelling accommodations.
- Dormitory and senior housing dwelling accommodations.

The space types listed above are in buildings which are classified as nonresidential. All of the other space types in these nonresidential buildings are required to comply with the applicable nonresidential lighting requirements.

6.1.2.4 Outdoor

Outdoor residential lighting is sometimes subject to the residential lighting requirements, and sometimes subject to the nonresidential lighting requirements.

For example, in low-rise multifamily buildings any private patios, entrances, balconies, porches, and any parking lots or carports for fewer than eight vehicles can comply with either the residential or nonresidential Standards.

6.1.2.5 Additions and Alterations

“Additions” are treated the same as newly constructed buildings, so they must meet the applicable residential lighting requirements of §150.0(k).

For alterations, existing luminaires may stay in place but any new permanently installed luminaires shall meet the applicable requirements of §150.0(k).

6.1.3 Related Resources

There are educational resources prepared by the California Energy Commission and others that provide additional information about residential lighting. The Energy Commission educational resources webpage can be found at:

http://www.energy.ca.gov/efficiency/educational_resources.html.

The Residential Lighting Guide, which discusses best practices and lighting designs to help buildings comply with California’s Title 24 Energy Standards, is prepared by the UC Davis California Lighting Technology Center, and is available at:

<http://cltc.ucdavis.edu/title24>.

6.2 Indoor Luminaire Requirements – All High Efficacy

A “luminaire” is the lighting industry’s term for a light fixture, and is defined by §100.1 as a complete lighting unit consisting of a light source such as a lamp or lamps, together with the parts that distribute the light, position and protect the light source and connect it to the power supply. A “lamp” is the lighting industry’s term for a light bulb or similar separable lighting component, and is defined by §100.1 as an electrical appliance that produces optical radiation for the purpose of visual illumination, designed with a base to provide an electrical connection between the lamp and a luminaire, and designed to be installed into a luminaire by means of a lamp-holder integral to the luminaire.

The 2016 Energy Standards require all permanently installed luminaires to be “high efficacy,” as specified in §150.0(k). Permanently installed lighting is defined in §100.1 and examples of permanently installed lighting include:

- Lighting attached to walls, ceilings, or columns.
- Track and flexible lighting systems.
- Lighting inside permanently installed cabinets.
- Lighting attached to the top or bottom of permanently installed cabinets.
- Lighting attached to ceiling fans.
- Lighting integral to exhaust fans.
- Lighting that is integral to garage door openers if it is designed to be used as general lighting, is switched independently from the garage door opener, and does not automatically turn off after a pre-determined amount of time.

The following are examples of what are not considered to be permanently installed lighting:

- Portable lighting as defined by §100.1 (including, but not limited to, table and freestanding floor lamps with plug-in connections).
- Lighting installed by the manufacturer in refrigerators, stoves, microwave ovens, exhaust hoods for cooking equipment, refrigerated cases, vending machines, food preparation equipment, and scientific and industrial equipment.
- Lighting in garage door openers which consists of no more than two screw-based sockets integrated into the garage door opener by the manufacturer, where the lights automatically turn on when the garage door is activated, and automatically turn off after a pre-determined amount of time.

6.2.1 High Efficacy Luminaires

“Efficacy” is a term used in the lighting industry to describe the overall effectiveness of a lamp or luminaire, including its energy efficiency (expressed as lumens/Watt). In order to simplify the residential lighting requirements, the Energy Standards define certain luminaire types as “high efficacy,” meaning that they possess a high lumens per watt efficiency and do not have any attributes that would make the light less effective or less suitable for residential illumination.

As noted above, the 2016 Energy Standards require that all permanently installed residential luminaires must be high efficacy. However, the types of luminaires that can be considered high efficacy have also been redefined.

6.2.1.1 High Efficacy Luminaires

Certain types of light sources are automatically classified as high efficacy, unless they are in recessed downlight luminaires. Luminaires in any of the following categories are automatically classified as high efficacy:

- Pin-based linear fluorescent luminaires using electronic ballasts.
- Pin-based compact fluorescent luminaires using electronic ballasts.
- Pulse-start metal halide luminaires.
- High pressure sodium luminaires.
- Luminaires with GU-24 sockets other than LEDs.
- Luminaires with hardwired high frequency generator and induction lamp.
- Inseparable SSL luminaires installed outdoors.
- Inseparable SSL luminaries with colored light sources for decorative lighting purpose.

The luminaire types listed here are the only types that are automatically classified as high efficacy. All other luminaire types must have a light source or lamp installed in them at the time of inspection that meets the requirements of Reference Joint Appendix JA8.

Note: Luminaires do not need to be shipped by manufacturers with a JA8 source installed.

6.2.1.2 High Efficacy Lighting

Luminaires not listed in the previous section must have an integral light source or removable lamp that meets the performance requirements of Reference Joint Appendix JA8. The requirements in JA8 are designed to ensure that new lighting technologies like LED provide energy efficient light, while also maintaining performance characteristics that residential customers expect. In addition to setting minimum efficacy requirements, JA8 establishes performance requirements that ensure accurate color rendition, dimmability, and reduced noise and flicker during operation.

Luminaires with integral sources, such as LED luminaires, must be certified by the Energy Commission as meeting the requirements of JA8. Luminaires that have changeable lamps (such as screw base luminaires) must be installed with lamps that have been certified by the Energy Commission as meeting the requirements of JA8. Luminaires and lamps that have been certified by the Energy Commission must be marked with "JA8-2016" or "JA8-2016-E" on the product itself. The "JA8-2016-E" marking indicates that the product meets the elevated temperature requirement of Reference Joint Appendix JA8 and is suitable for elevated temperature applications such as enclosed and recessed fixtures.

Examples of luminaires that can be classified as high efficacy by meeting the requirements of JA8 include:

- LED luminaires with integral light sources that are certified to the Energy Commission
- Screw-based luminaires with JA8-certified lamps
- Low-voltage pin-based luminaires with JA8-certified lamps

In short, almost any luminaire can be classified as high efficacy, as long as the luminaire is installed with a JA8 compliant lamp. The exception is recessed downlight luminaires in ceilings, which must meet additional requirements.

The Energy Commission maintains a database of JA8 compliant luminaires and lamps. The database can be accessed using a Quick Search Tool (<https://cacertappliances.energy.ca.gov/Pages/ApplianceSearch.aspx>) or an Advanced Search (<https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx>).

Table 6-1 summarizes the requirements for residential high efficacy lighting types. As the table shows, there are three categories: luminaires automatically classified as high efficacy; luminaires that must use JA8-certified light sources or lamps; and recessed downlight luminaires in ceilings, which must meet additional requirements.

Table 6-1: Summary of Compliant Luminaire Types

High Efficacy Luminaires*	JA8 High Efficacy Lighting – Lamps and Light Sources that must be JA8-certified	*Recessed Downlight Luminaires in Ceilings
<ul style="list-style-type: none"> • Pin-based linear fluorescent • Pin-based compact fluorescent • Pulse-start metal halide • High pressure sodium • GU-24 other than LEDs • Inseparable SSL luminaires installed outdoors • Inseparable SSL luminaires with colored light sources for decorative lighting purpose 	<ul style="list-style-type: none"> • Light sources in ceiling recessed downlight luminaires.* • LED luminaires with integral sources • Screw-based LED lamps (A-lamps, PAR lamps, etc.) • Pin-based LED lamps (MR-16, AR-111, etc.) • GU-24 based LED light source • Any source or luminaire not listed elsewhere on this table 	<ul style="list-style-type: none"> • Shall not have screw based sockets • Shall contain JA8-certified light sources • Shall meet all performance requirements in §150.0(k)1C

6.2.2 Recessed Downlight Luminaires in Ceilings

In addition to the high efficacy requirements described above, there are several additional requirements for residential downlight luminaires that are recessed in ceilings.

The first set of requirements limit the light sources and lamp types that can be used in recessed downlight luminaires. Recessed downlights:

1. Shall contain light sources that are JA8-certified.
2. Shall not contain screw based lamps.
3. Shall not contain light sources that are labeled “not for use in enclosed fixtures” or “not for use in recessed fixtures.”

In other words, all recessed downlight luminaires must contain a light source or lamp that is JA8-certified, such as an integral LED source, or LED lamp. However, screw-based lamps such as LED A-lamps or LED PAR lamps are not allowed. Pin-based lamps such as LED MR-16 lamps are allowed in recessed fixtures as long as they are JA8-certified.

In addition to the light source and lamp requirements listed above, recessed downlight luminaires in ceilings must also meet all of the following performance requirements:

1. Be listed for zero clearance insulation contact (IC) by Underwriters Laboratories or another nationally recognized testing/rating laboratory.
2. Have a label that certifies the luminaire is airtight with air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283 (exhaust fan housings are not required to be airtight).

3. Be sealed with a gasket or caulk between the luminaire housing and ceiling, and have all air leak paths between conditioned and unconditioned spaces sealed with a gasket or caulk.
4. For luminaires with hardwired ballasts or drivers, allow ballast or driver maintenance and replacement to be readily accessible to building occupants from below the ceiling without requiring the cutting of holes in the ceiling.

Luminaires that meet the first two performance attributes will typically list this information on luminaire cut sheets or packaging. Contractors are responsible for ensuring that luminaires are properly sealed, and that any ballasts or drivers are accessible.

Recessed downlight luminaires that do not meet all of these requirements cannot be used for residential lighting.

Example 6-1: Recessed downlight luminaires: fire-rated housings

Question

If a factory manufactured fire rated luminaire housing is placed over a recessed luminaire in a multifamily residential dwelling unit, is the luminaire still required to comply with the insulation contact (IC) requirements?

Answer

There are limited applications where a non-IC luminaire may be used in conjunction with a manufactured fire-rated luminaire housing in a multifamily residential dwelling unit. However, the luminaire shall still comply with all of the airtight requirements.

A non-IC luminaire may be used in a ceiling in conjunction with a fire-rated housing only if all three of the following conditions are met:

1. The multifamily dwelling unit is an occupancy type R1 or R2; and
2. The luminaire is recessed between different dwelling units that are regulated by California Building Code §712.4.1.2; and
3. The manufactured fire-rated housing is rated for a minimum of 1 hour fire in accordance with UL 263.

6.2.3 Electronic Ballasts in Luminaires

Fluorescent lamps with a power rating of 13 watts or more shall have electronic ballasts that operate the lamp at a frequency of 20 kHz or more. Most commonly available electronic ballasts meet this requirement.

If in doubt, look at the number of pins protruding from the compact fluorescent lamp base. Pin-based compact fluorescent lamps operated with electronic ballasts typically have four-pin lamp holders. Pin-based compact fluorescent lamps with two-pin lamp holders typically indicate that the ballast is magnetic. Be careful not to confuse pin-based CFL sockets with GU-24 sockets.

High intensity discharge (HID) lamps (like pulse-start metal halide or high-pressure sodium) are not required to have electronic ballasts. This requirement does not apply to HID luminaires.

6.2.4 Blank Electrical Boxes

The number of blank electrical boxes installed more than five feet above the finished floor shall not be greater than the number of bedrooms. These electrical boxes shall be served by a dimmer, a vacancy sensor, or fan speed control.

Example 6-2: Blank Electrical Boxes**Question**

Where in the house can the blank electrical boxes as specified in §150.0(k)1B be permitted to be installed?

Answer

The blank electrical boxes as specified in §150.0(k)1B can be installed anywhere within single-family buildings or dwelling units of multifamily buildings. The number of blank electrical boxes cannot be greater than the number of bedrooms.

6.2.5 Night Lights

Permanently installed night lights and night lights integral to an installed luminaire or exhaust fan shall be rated to consume no more than 5W of power per luminaire or exhaust fan, as determined by §130.0(c).

Night lights are not required to be controlled by vacancy sensors, regardless of the type of room they are located in, as specified by §150.0(k)1E.

Example 6-3: Night Lights**Question**

Where in a residential building are night lights permitted to be installed?

Answer

Since there are no location restrictions in the Energy Standards, permanently installed night lights and night lights integral to installed luminaires can be installed anywhere within single family buildings or within dwelling units of multi-family buildings.

6.2.6 Recommendations for Luminaire Specifications

It is important that luminaires are described fully in the specifications and on drawings so that contractors and subcontractors provide and install residential lighting systems that comply with the residential lighting requirements. The specifications should be clear and complete so that contractors understand what is required to comply with the Standards.

Following are a few suggestions to reduce the chance of costly change orders required to bring a non-complying building into compliance.

1. Include all applicable residential lighting requirements in the general notes on the drawings and other bid documents.
2. Include the residential lighting requirements with each luminaire listed in the lighting schedule text and details, as demonstrated in Table 6-2 below.

Table 6-2: Sample Luminaire Specifications

Luminaire Type	Recommended Type of Notes for Luminaire Schedule
Bath Bar	Bath bar, GU-24 sockets rated for use with only LED lamps.
Ceiling fixture (i.e., for a bathroom application)	Fluorescent surface-mounted ceiling luminaire, with one F32-T8 fluorescent lamp and electronic ballast, meeting the requirements of §150.0(k).
LED Recessed Can (i.e., for a kitchen application)	LED recessed can certified by the manufacturer to the Energy Commission, housing rated only for use with LED and not containing incandescent sockets of any kind, meeting the IC, and airtight requirements of §150.0(k).
Ceiling fixture	Surface-mounted screw-base fixture, to be installed with JA8 compliant LED lamps.
Chandelier	Chandelier, installed with JA8 compliant lamps, and controlled by a dimmer switch meeting the requirements of §150.0(k) where the dimmer is certified to the Energy Commission by the manufacturer.
Vacancy Sensor (Manual-on Occupant Sensor)	Vacancy sensor certified to the Energy Commission by the manufacturer.

6.2.7 Examples for Luminaire Requirements

Example 6-4: Kitchen Alterations

Question

I am designing a residential kitchen lighting system where I plan to install six 12W LED recessed downlights, and four 24W linear fluorescent under cabinet luminaires. How many watts of incandescent lighting can I install?

Answer

None. Low efficacy luminaires are no longer allowed for residential lighting. All luminaires must meet the definitions of high efficacy luminaires as established in Table 150.0-A of the Energy Standards.

Example 6-5: Definition of high efficacy lighting

Question

I am using a screw-based luminaire that is rated to take a 60W lamp for lighting over a sink, but I plan to install a 10W LED lamp. Does this qualify as a high efficacy luminaire?

Answer

If the LED bulb is JA8-certified, and is marked “JA8-2016,” or “JA8-2016-E” then yes, that luminaire would qualify as high efficacy.

Example 6-6: Kitchens: Extraction hood lighting

Question

I am installing an extraction hood over my stove, it has lamps within it. Do these lamps have to be high efficacy?

Answer

This lighting is part of an appliance, and therefore does not have to meet the residential lighting requirements for permanently installed lighting.

Example 6-7: Fade-in lighting**Question**

I would like to use lighting with an aesthetic fade-in feature in my design. I noticed that JA8 has a start time requirement. Are fade-in lights able to qualify as high efficacy?

Answer

Yes, aesthetic fade-in is acceptable under Title 24. The test procedure for start time measures “[t]he time between the application of power to the device and the point where the light output reaches 98% of the lamp’s initial plateau.” The “initial plateau” is “[t]he point at which the average increase in the light output over time levels out (reduces in slope).”

For light sources with a fade-in feature, the light output is intentionally following a programmed fade-in curve in order to increase light output gradually. Because the light output must “level out”, the Initial Plateau for these light sources is the point in time at which there is perceived light output and the perceived light increase begins to follow the programmed fade-in curve. (Note that the programmed fade-in curve is expected to be continuously increasing as a function of time.)

This allows fade-in lighting to qualify as high efficacy.

Example 6-8: Ceiling fans with integrated lighting**Question**

Can a ceiling fan with integrated lighting be a high efficacy luminaire?

Answer

Yes. Ceiling fan light kits with integral CFL ballasts are available. Ceiling fans and light kits with screw base sockets can also be considered high efficacy if they are installed with JA8-certified light sources or lamps.

Example 6-9: Best practice for high efficacy spotlights**Question**

Are high-efficacy spotlights available, to replace halogen MR16s?

Answer

Some CFLs resemble spotlights, and manufacturers may describe them as spotlights, but they produce the same diffuse light as regular CFLs.

Metal halide spotlights with 35W T-6 high efficacy lamps are available.

MR16 LEDs can be used as spotlights but must be JA8-certified and labeled before it can be classified as high efficacy.

6.3 Indoor Lighting Controls Requirements

The use of lighting controls is an important component of the Energy Standards.

6.3.1 Requirements of Controls Devices

Manual-on/automatic-off occupant sensors (also known as vacancy sensors), motion sensors, photo-control astronomical time clock controls (used for outdoor lighting), and dimmers installed to comply with §150.0(k) must have been certified to the Energy Commission by their manufacturer, pursuant to the provisions of the Title 20 Appliance Efficiency Regulations (Title 20 California Code of Regulations, §1606), as required by §110.9.

6.3.1.1 Requirements for Dimmers

In addition to meeting the applicable requirements of the Appliance Standards, all forward phase cut dimmers must comply with NEMA SSL 7A. This designation is typically noted on equipment cut sheets or dimmer packaging and ensures compatibility with solid state lighting (including LEDs).

6.3.2 General Controls Requirements

Following are general control requirements that apply in all room types and for all luminaire types:

A. Readily Accessible Manual Controls

All permanently installed luminaires shall have readily accessible controls that permit the luminaires to be manually switched on and off.

B. Exhaust Fans

There are two options for the lighting associated with exhaust fans:

1. All lighting shall be switched separately from exhaust fans.
2. For an exhaust fan with an integral lighting system, it shall be possible for the lighting system to be manually turned on and off while allowing the fan to continue to operate for an extended period of time.

C. Manufacturer Instructions

All lighting controls and equipment shall be installed in accordance with the manufacturer's instructions.

D. Multiple Switches

This requirement applies to all 3-way, 4-way, and other lighting circuits controlled by more than one switch. A lighting circuit controlled by more than one switch where a dimmer or vacancy sensor has been installed to comply with §150.0(k) shall meet all of the following conditions:

1. No controls shall bypass the dimmer or vacancy sensor function.
2. The dimmer or vacancy sensor shall be certified to the Energy Commission that it complies with the applicable requirements of §110.9.

E. Lighting Control Systems and Energy Management Control Systems (EMCS)

Lighting controls may be either individual devices or systems consisting of two or more components. Lighting control systems and EMCS must meet the requirements of §110.9. There is no need for lighting control systems to be certified to the Commission. However, when installing a lighting control system, a licensee of record must sign a lighting control Certificate of Installation.

6.3.3 Spaces Required to Have Vacancy Sensors

Manual-on/automatic-off occupant sensors, also known as vacancy sensors, automatically turn lights off if an occupant forgets to turn them off when a room is unoccupied. Additionally, these sensors are required to provide the occupant with the ability to manually turn the lights:

1. Off upon leaving the room.
2. Off while still occupying a room.
3. On upon entering the room.

The manual-off feature is critical because it provides the occupants with the flexibility to control the lighting environment to their satisfaction, and results in greater energy savings by allowing the occupants to turn off the lights when they are not needed.

The Energy Standards require vacancy sensors to control at least one luminaire in the following room types:

1. Bathrooms.
2. Utility rooms.
3. Laundry rooms.
4. Garages.

If there are rooms or areas where there are safety concerns regarding the use of vacancy sensors, then the use of “dual technology” (infra-red plus ultrasonic) may be desirable, or the vacancy sensor may be staged to partially shut off the lighting before switching it off completely.

6.3.3.1 **Choosing Vacancy Sensors**

Vacancy sensors commonly on the market are wired in two different ways:

1. Where sensor operating current uses the load connection (two-wire connection).
2. Where sensor operating current uses a neutral connection (three-wire connection).

Some vacancy sensors using the load connection for operating current have minimum load requirements.

For example, a vacancy sensor may require that bulbs rated over 25W be installed before the sensor will work. However, if an occupant later installs a screw-in compact fluorescent lamp that is rated less than 25W, the sensor may no longer work.

Therefore, it is critical to select a sensor that has a low enough minimum load requirement to accommodate however small a load the occupant may install into the socket, or one that does not have a minimum load requirement. Sensors that have a minimum load requirement are typically designed to operate without a neutral wire in the switch box, which is a common wiring scheme in older residential units. Vacancy sensors that are designed to take advantage of the neutral wire in the switch box typically do not have a minimum load requirement and are the preferred choice for residential units.

Using vacancy sensors that use the ground wire for the operating current is not recommended. There are potential safety concerns with using the ground to carry current in residential applications.

If you are trying to control a lighting fixture from two different switches you may want to use a ceiling mounted sensor rather than a wall switch occupant sensor, or use 3-way vacancy sensors at both switch locations.

Example 6-10: Bathroom vacancy sensors--Manual off

Question

Must the vacancy sensor in a bathroom provide the occupant the option of turning the light off manually?

Answer

Yes. The vacancy sensor must provide the occupant with the option to turn the lights off manually.

If an occupant forgets to turn the lights off when a room is left unoccupied, then the vacancy sensor must turn the lights off automatically within 20 Minutes. However, the occupant must also have the ability to turn the lights off upon leaving the room.

This provides occupants with the flexibility to control the lighting environment to their satisfaction, and results in greater energy savings by allowing occupants to turn off the lights when they are not needed.

Example 6-11: Can auto-on occupancy sensors be used?

Question

What are the options for using an automatic-on occupant sensor in a bathroom, garage, laundry room, or utility room?

Answer

Automatic-on occupant sensors are not allowed under the residential lighting requirements.

Example 6-12: Usage of Energy Management Control System (EMCS) for controls

Question

What is permitted for the use of Energy Management Control System (EMCS) in the controls of under-cabinet lighting?

Answer

It is allowed to use an EMCS to control under-cabinet lighting provided that the under-cabinet lighting is switched separately from other lighting systems as specified in §150.0(k)2L.

6.3.4 Luminaires Required to Have Dimmers or Vacancy Sensors

All luminaires that are installed with JA8-certified light sources are required to be controlled by either a dimmer or vacancy sensor. In addition, all blank electrical boxes more than five feet above the floor must be controlled by a dimmer, vacancy sensor, or fan speed control.

Dimmers or vacancy sensors are not required on any luminaires located in closets less than 70 square feet, or in hallways.

Although not required for all luminaires or space types, the use of dimmers and/or vacancy sensors is recommended for any application where they can provide additional energy savings or additional amenity for the homeowner or occupant.

6.3.4.1 Choosing Dimmers

It is important to correctly match the dimmer with the type of lighting load that is being dimmed. Failure to do so may result in early equipment failure, including the dimmer, transformer, ballast, or lamp.

This is especially important with LED lighting; a dimmer with the appropriate power range should be chosen to match the total wattage of lighting it controls.

As noted, all forward phase cut dimmers must comply with NEMA SSL 7A for usage with LED light source. This is to ensure compatibility between the forward phase cut dimmers and the LED light sources.

Example 6-13: Using dimmers on three-way lighting circuits

Question

In stairwells and some corridors, 3-way circuits are a common way to allow control of the lighting from either end of the space. How can I use dimmers to give a similar level of control?

Answer

In this case, the lighting must be controlled by at least one dimmer. It is functionally preferable, but not required, to have dimmers at every point. One of the switches must be a dimmer but the other may be a regular toggle switch. Alternatively, more advanced controls are available that allow dimming from both ends of the circuit.

Note that the toggles switch(es) must not allow the lighting to come on at a higher level than is set by the dimmer.

6.4 Multifamily Common Area Lighting Requirements

Common areas in multi-family buildings include areas like interior hallways, lobbies, entertainment rooms, pool houses, club houses, and laundry facilities. Lighting requirements for these spaces depend on the characteristics of the buildings, as described below. Buildings three stories or less are classified as low-rise, and buildings four stories or more are classified as high-rise.

6.4.1 Low-Rise Multifamily

Lighting requirements in common areas of low-rise multifamily buildings depend on the percentage of the total interior common area in each building. Buildings where interior common area equals 20 percent or less to the floor area have one set of requirements, and buildings where the total interior common area is greater than 20 percent of the total floor area have different requirements.

A. If the common area equals 20 percent or less of the total building floor area

In low-rise multifamily buildings where the total interior common area in a single building is 20 percent or less of the total floor area, all permanently installed lighting in interior common areas must be high efficacy and controlled by occupancy sensors.

B. If the common area is greater than 20 percent of the total building floor area

In low-rise multifamily buildings where the total interior common area in a single building is greater than 20 percent of the total floor area, permanently installed lighting in common areas must meet the applicable nonresidential lighting requirements, and corridor and stairwell lighting must be controlled by occupant sensors.

The relevant nonresidential lighting requirements that apply in these cases are:

1. §110.9 – Mandatory Requirement for Lighting Control Devices and Systems, Ballasts, and Luminaires
2. §130.0 – Lighting Systems and Equipment, and Electrical Power Distribution Systems – General
3. §130.1 – Mandatory Indoor Lighting Controls
4. §140.6 – Prescriptive Requirements for Indoor Lighting
5. §141.0 – Additions, Alterations, and Repairs to Existing Nonresidential, High-Rise Residential, and Hotel/Motel Buildings, to Existing Outdoor Lighting, and to Internally and Externally Illuminated Signs

These sections cover allowable equipment, controls requirements for various space types, allowable lighting power densities for various space types, and requirements for additions and alterations to existing buildings. More information about the nonresidential lighting requirements that apply in these scenarios can be found in Chapter 5 of the Nonresidential Compliance Manual.

In addition to meeting the applicable nonresidential lighting requirements listed above, lighting in corridors and stairwells in these buildings must meet the following occupancy control requirements:

1. Occupancy controls must reduce stairway and corridor lighting power by at least 50 percent when the spaces are unoccupied.
2. Occupancy controls must be capable of turning stairwell and corridor lighting fully On and Off from all designated paths of ingress and egress.

The lighting of staircases and stairwells is a significant safety concern; the best way to light stairs is with directional light from above, to maximize the contrast between treads and risers.

Example 6-14: Multifamily common areas: Low rise**Question**

Does the lighting for an interior common-area hallway of a low-rise residential building with a total common area of 10% of the total building area have to comply with the Residential or Nonresidential Lighting requirements?

Answer

Residential requirements only. The lighting of an interior common-area hallway of any low-rise residential building with total common area of 20% or less of the total building area must comply with only the residential lighting requirements.

Example 6-15: Egress Lighting for Common Areas in Low-rise Multifamily Buildings**Question**

What is the egress lighting requirement for interior common areas in low-rise multi-family buildings?

Answer

The only requirement of the Energy Standards for egress lighting system in the interior common areas of a low-rise multi-family residential building is that all luminaires must be high efficacy. Refer to California Code of Regulations, Title 24, Part 2, Chapter 10, for emergency egress lighting requirements.

6.4.2 High-Rise Multifamily

Common areas in all high-rise multifamily buildings (four stories or greater) must meet all applicable nonresidential lighting requirements in the following sections:

1. §110.9 – Mandatory Requirement for Lighting Control Devices and Systems, Ballasts, and Luminaires.
2. §130.0 – Lighting Systems and Equipment, and Electrical Power Distribution Systems – General.
3. §130.1 – Mandatory Indoor Lighting Controls.
4. §130.4 – Lighting Control Acceptance and Installation Certificate Requirements.
5. §140.6 – Prescriptive Requirements for Indoor Lighting.
6. §141.0 – Additions, Alterations, and Repairs to Existing Nonresidential, High-Rise Residential, and Hotel/Motel Buildings, to Existing Outdoor Lighting, and to internally and Externally Illuminated Signs.

These sections cover allowable equipment, controls requirements for various space types, allowable lighting power densities for various space types, and requirements for additions and alterations to existing buildings. More information about the nonresidential lighting requirements that apply in these scenarios can be found in Chapter 5 of the Nonresidential Compliance Manual.

Dwelling units within high-rise multifamily buildings must comply with the residential lighting requirements.

Example 6-16: Multifamily common areas: High rise

Question

Does the lighting for an interior common-area hallway of a high rise residential building have to comply with the Residential or Nonresidential Lighting requirements?

Answer

The lighting of an interior common-area hallway of a high rise residential building must comply with the Nonresidential Lighting Standards. All the lighting in common areas must comply with the Nonresidential Standards; lighting inside the dwelling units must comply with the residential lighting requirements.

Hallways and stairwells are required to have partial off occupancy sensors that switch off at least half the lighting load when the hallway or stairwell is unoccupied.

6.5 Outdoor Lighting Requirements

Outdoor residential lighting is sometimes subject to the residential lighting requirements, and sometimes subject to the nonresidential lighting requirements.

6.5.1 Outdoor Luminaires

All lighting attached to the residence or to other buildings on the same lot must be high efficacy. Table 150.0-A lists all qualifying high efficacy light sources. Note that solid state lighting (SSL) luminaires installed outdoors are exempted from the general residential lighting requirement that all SSL luminaires for residential lighting must meet the requirements of Joint Appendix JA8.

6.5.2 Single-Family Outdoor Lighting

All lighting attached to the residence or to other buildings on the same lot must be high efficacy, and must be controlled by a manual ON and OFF switch and one of the following automatic control types:

1. Photocontrol and motion sensor.
2. Photocontrol and automatic time switch control.
3. Astronomical time clock control that automatically turns the outdoor lighting off during daylight hours.
4. EMCS that provides the functionality of an astronomical time clock, does not have an override or bypass switch that allows the luminaire to be always ON, and is programmed to automatically turn the outdoor lighting off during daylight hours.

Manual ON and OFF switches must not override the automatic control functions listed above, and any control that overrides the automatic controls to ON must automatically reactivate those controls within six hours.

Lighting that is not permanently attached to a building on a single-family site, such as decorative landscape lighting, is not regulated by the residential lighting requirements. However, providing high efficacy lighting and controls such as a time clock or photocontrol will help save energy and ensure that the lighting is not accidentally left on during daylight hours.

Table 6-3: Outdoor Lighting Standards for Single Family Buildings

Outdoor Lighting Requirements Res is short for Residential Standards; Nonres is short for Nonresidential Standards	
Spaces or Areas with Outdoor Lighting	Single Family Buildings
Outdoor lighting mounted to building.	Res
Private patios, entrances, balconies, and porches.	Res
Residential parking lots and carports with 8 or more vehicles per site.	Nonres
Parking garages with 8 or more vehicles.	Nonres

6.5.3 Low-Rise Multifamily Outdoor Lighting

Low-rise multifamily buildings have the option of complying with either the residential or nonresidential lighting standards for the following applications:

1. Private patios
2. Entrances
3. Balconies
4. Porches

For all other outdoor lighting applications, low-rise buildings with three units or less must comply with the residential lighting requirements, and buildings with four units or more must comply with the applicable nonresidential requirements.

Table 6-4: Outdoor Lighting Standards for Low-Rise Multifamily Buildings

Outdoor Lighting Requirements Res is short for Residential Standards; Nonres is short for Nonresidential Standards		
Spaces or Areas with Outdoor Lighting	Low-rise Multifamily Buildings	
	1-3 Dwelling Units	4 or more Dwelling Units
Private patios, entrances, balconies, and porches.	Res or Nonres (builder's option)	Res or Nonres (builder's option)
Residential parking lots and carports with less than 8 vehicles per site.	Res or Nonres (builder's option)	Res or Nonres (builder's option)
Outdoor lighting not regulated by Section 3B or 3D.	Not applicable	Nonres
Residential parking lots and carports with 8 or more vehicles per site.	Nonres	Nonres
Parking garages with 8 or more vehicles.	Nonres	Nonres

6.5.4 High-Rise Multifamily Outdoor Lighting

Any outdoor lighting attached to the building, which is controlled from within the dwelling unit, must comply with the residential requirements.

Outdoor lighting attached to the building that is not controlled from within the dwelling unit must comply with the following nonresidential requirements:

1. §110.9 – Mandatory Requirement for Lighting Control Devices and Systems, Ballasts, and Luminaires
2. §130.0 – Lighting Systems and Equipment, and Electrical Power Distribution Systems – General
3. §130.2 - Outdoor Lighting Controls and Equipment
4. §130.4 - Lighting Control Acceptance and Installation Certificate Requirements
5. §140.7 - Requirements for Outdoor Lighting
6. §141.0 – Additions, Alterations, and Repairs to Existing Nonresidential, High-Rise Residential, and Hotel/Motel Buildings, to Existing Outdoor Lighting, and to internally and Externally Illuminated Signs

For information on the nonresidential lighting requirements, see Chapter 5 of the Nonresidential Compliance Manual.

Table 6-5: Outdoor Lighting Standards for High-Rise Multifamily Buildings

Outdoor Lighting Requirements Nonres is short for Nonresidential Standards	
Spaces or areas with outdoor lighting	High-rise Multifamily Buildings (See footnote 1.)
Residential parking lots and carports with 8 or more vehicles per site.	Nonres
Parking garages with 8 or more vehicles.	Nonres
1. Residential Lighting Standards applies to the dwelling units; Nonresidential Lighting Standards applies to areas outside dwelling units.	

6.5.5 Internally Illuminated Signs

Internally illuminated signs shall consume no more than 5 watts of power as determined according to §130.0, or shall comply the with nonresidential sign lighting requirements in §140.8.

Example 6-17: Outdoor lighting: Glare control

Question

Are there any “cutoff” requirements for residential outdoor luminaires?

Answer

There are no “cutoff” requirements for typical residential outdoor lighting. However, residential parking lots for eight or more vehicles are required to meet the Nonresidential Standards, which do include cutoff requirements for luminaries greater than 150W. The requirement uses the Backlight, Uplight and Glare (BUG) ratings developed by the IES to define acceptable amounts of uplight and glare (there are no limits on “backlight.”) Even though not required for most residential outdoor lighting, luminaires that limit uplight are usually more efficient at providing light in the required area, so a lower wattage lamp and ballast can be used. The BUG requirements also reduce stray light and glare problems which can cause visual discomfort.

Example 6-18: Outdoor lighting: Landscape lighting

Question

I would like to install low-voltage landscape lighting in my yard. Are these required to be on a motion sensor and photocontrol?

Answer

No. Although the lighting requirements only apply to lighting that is attached to the building, it is advisable to use photocontrols or astronomical time clock controls for landscape lighting so that the lighting is not left on during daylight hours.

Example 6-19: Outdoor lighting: Patios

Question

Does outdoor lighting on the patio of a high-rise residential building have to comply with the Residential or Nonresidential Lighting Standards?

Answer

If the patio outdoor lighting is controlled from inside of the dwelling unit, it must comply with the Residential Outdoor Lighting Standards. If the patio outdoor lighting is controlled from outside of the dwelling unit, it must comply with the Nonresidential Outdoor Lighting Standards. For example, if the outdoor patio lighting is controlled by a building-wide EMCS outside of the dwelling units, it must comply with the Nonresidential Outdoor Lighting Standards.

6.6 Residential Parking Garage and Parking Lot Lighting

Residential parking garages are treated as indoor spaces, whereas residential parking lots and carports are treated as outdoor spaces. All three types of parking facilities are required to meet either the residential or the nonresidential requirements, depending on what type of building they are associated with (see the tables above for a summary of requirements.)

Private garages and carport buildings are considered to be low-rise residential buildings and have to comply with requirements of §150.0.

Regardless of the classification of the associated building, any garage, parking lot, or carport for eight or more cars must comply with all applicable nonresidential lighting requirements in §110.9, §130.0, §130.1, §130.2, §130.4, §140.6, §140.7, and §141.0.

6.6.1 Single-Family

Garages on single-family sites with space for seven cars or less must comply with the residential lighting requirements in §150.0(k), which require all luminaires to be high efficacy and that at least one luminaire in each garage to be controlled by a vacancy sensor.

Parking lots and carports on single-family sites with space for seven cars or less must comply with residential outdoor lighting requirements.

6.6.2 Low-Rise Multifamily

Parking garage lighting Standards in low-rise multifamily buildings are determined in the same manner as common area lighting Standards. Buildings where interior common area is 20 percent or less of the total building area must use the residential Standards for parking garages. Multifamily buildings with three or less stories where interior common area is greater than 20 percent of the total building area must use the nonresidential lighting requirements for parking garages.

Parking lots and carports for low-rise multifamily buildings with space for seven cars or less must install all high efficacy luminaires per §150.0(k)1A, and must additionally comply with either the residential or nonresidential lighting requirements (§150.0(k)3B).

6.6.3 High-Rise Multifamily

Garages and parking lots for high-rise multifamily buildings must comply with all applicable nonresidential lighting requirements in §110.9, §130.0, §130.1, §130.2, §130.4, §140.6, §140.7, and §141.0.

Example 6-20: Parking spaces

Question

I have a low-rise multi-family complex with a total of 20 parking spaces. However, the parking spaces are arranged throughout the site in groups of only four spaces each. Are these parking spaces required to comply with the nonresidential outdoor lighting requirements?

Answer

Yes, these spaces are required to comply with the Nonresidential Outdoor Lighting Standards. Parking lots and carports for a total of eight or more cars per site must meet the nonresidential outdoor lighting requirements, regardless of how the spaces are arranged on the site.

6.7 Additions and Alterations

Residential building additions are required to meet all mandatory requirements in §150.0. Because the residential lighting requirements are mandatory requirements, lighting in all residential building additions must meet all the applicable requirements outlined in this chapter.

For residential building alterations, any new or altered lighting systems must also meet all of the applicable requirements indicated in this chapter. Existing luminaires and lighting systems that are not altered may stay as-is.

6.8 Compliance Documentation

This section covers residential lighting compliance documentation (compliance forms) that builders must submit to the responsible code enforcement agency for compliance with the residential lighting requirements.

Because the compliance documentation for residential lighting consists primarily of a Certificate of Installation, it is not to be submitted until after the lighting project has been completed.

All of the residential lighting requirements are mandatory measures. There are no tradeoffs between lighting and other building features.

6.8.1 Certificate of Installation (CF2R-LTG)

Lighting control systems are required to comply with the Certificate of Installation (form CF2R-LTG) requirements in §130.4.

Even though the Certificate of Installation for lighting control systems is designed primarily for use as a nonresidential compliance document, it is also required whenever a lighting control system is used to comply with the residential lighting requirements.

A. Person Responsible to Submit the Certificate of Installation

The Certificate of Installation is required to be submitted by a person eligible under Division 3 of the Business and Professions Code to accept responsibility for construction for all residential lighting projects (Title 24 California Code of Regulations, Part 1, §10-103(a)3.) In this Certificate of Installation, the person accepting responsibility for the project declares that the installed residential lighting complied with all of the applicable lighting requirements.

B. Number of Certificates of Installation Required

A residential lighting project may require one, or more than one, Certificate of Installation to be submitted. For example, if one qualified person accepts responsibility for the lighting installation of an entire lighting project, only one Certificate of Installation will need to be submitted. However, if one qualified person accepts responsibility for the installation of the lighting controls, and another qualified person accepts responsibility for the installation of the luminaires, then each qualified person will need to submit a separate Certificate of Installation.

A Certificate of Installation must be submitted to the responsible code enforcement agency for any residential lighting project that is regulated by Part 6, whether that lighting project is for only one luminaire, or for the lighting of an entire building.

The Certificate of Installation for residential lighting is completed and signed by the contractor responsible for installing hard-wired lighting systems. The installer verifies compliance with the mandatory requirements for lighting, and whether high efficacy lighting and the required controls (i.e., vacancy sensors, dimmer switches) were installed.

C. Registration

New requirements for a documentation procedure called “registration” were introduced with the 2008 Energy Standards. Registration is now required for all low-rise residential buildings for which compliance requires Home Energy Rating System (HERS) field verification (see Title 20 California Code of Regulations §1670 et seq.). When registration is required, the Certificates of Installation must be submitted electronically to an approved HERS provider data registry for registration and retention.

Registration requirements are detailed in Chapter 1 of the 2016 Residential Compliance Manual.

The builder or installing contractor responsible for the installation must provide a copy of the completed, signed, and registered Certificate(s) of Installation to the HERS rater; post a copy at the building site for review by the enforcement agency in conjunction with requests for final inspection; and provide copies of the registered Certificate(s) of Installation to the home owner.

D. Certificate of Installation Requirements in the Standards

The following is the Energy Standards' language that requires the Certificate of Installation to be submitted when a lighting control system is installed to comply with any of the residential lighting control requirements.

- §150(k)2F – Lighting controls shall comply with the applicable requirements of §110.9.
- §110.9(a)4 – Lighting Control Systems, as defined in §100.1, shall be a fully functional lighting control system complying with the applicable requirements in §110.9, and shall meet the Lighting Control Installation requirements in §130.4.
- §130.4(b) – Lighting Control Installation Certificate Requirements
To be recognized for compliance with Part 6, an Installation Certificate shall be submitted in accordance with §10-103(a) for any lighting control system, Energy Management Control System (EMCS), track lighting integral current limiter, track lighting supplementary over current protection panel, interlocked lighting system, lighting Power Adjustment Factor, or additional wattage available for a videoconference studio, in accordance with the following requirements, as applicable:
 - Certification that when a lighting control system is installed to comply with the lighting control requirements in Part 6, it complies with the applicable requirements of §110.9 and complies with Reference Nonresidential Appendix NA7.7.
 - Certification that when an EMCS is installed to function as a lighting control required by Part 6 it functionally meets all applicable requirements for each application for which it is installed, in accordance with §110.9, §130.0 through §130.5, §140.6, §140.7, and §150.0(k); and complies with Reference Nonresidential Appendix NA7.7.2.
- §150(k)2G – An EMCS may be used to comply with dimmer requirements in §150.0(k) if, at a minimum, it provides the functionality of a dimmer in accordance with §110.9, meets the installation certificate requirements in §130.4, the EMCS requirements in §130.0(e), and complies with all other applicable requirements in §150.0(k)2.
- §150(k)2H – An EMCS may be used to comply with vacancy sensor requirements in §150.0(k) if at a minimum it provides the functionality of a vacancy sensor in accordance with §110.9, meets the installation certificate requirements in §130.4, the EMCS requirements in §130.0(e), and complies with all other applicable requirements in §150.0(k)2.
- §150(k)2I – A multi-scene programmable controller may be used to comply with dimmer requirements in §150.0(k) if at a minimum it provides the functionality of a dimmer in accordance with §110.9, and complies with all other applicable requirements in §150.0(k)2.

6.8.2 Lighting Schedule Submitted to Homeowner

New to the 2016 Energy Standards, a schedule of all interior luminaires and lamps installed must be delivered to the homeowner after final inspection (Title 24 California Code of Regulations, Part 1, §10-103(b)3). In addition to a complete list of installed lighting systems, the lighting schedule should include all necessary system information for regular operations and maintenance, and references to support future upgrades to the lighting system.

6.9 For Building Officials

This section provides guidance for enforcement agency personnel, outlining what to look for on the plans, what compliance documents to expect, and high priority issues to look for on inspections.

6.9.1 Plans

A. Confirm All Specified Luminaires Are High Efficacy

All permanently installed luminaires shown on the plans and/or specifications must be high efficacy (§150.0(k)1A). Luminaires may qualify as high efficacy in one of three ways:

1. Use one of the following lighting technologies:
 - Pin-based linear fluorescent with electronic ballast.
 - Pin-based compact fluorescent with electronic ballast.
 - Pulse-start metal halide.
 - High pressure sodium.
 - GU-24 other than LEDs.
 - Induction lamp.
 - Inseparable SSL luminaires installed outdoors.
 - Inseparable SSL luminaires with colored light sources for decorative lighting.
2. Luminaires EXCEPT recessed downlights, must comply with either:
 - JA8-certified luminaires with integral light sources.
 - Luminaires installed with JA8-certified lamps at inspection.
3. Recessed downlight luminaires must comply with BOTH:
 - JA8-certified integral source or a JA8-certified lamp.
 - Must NOT contain a screw base socket.

Plans, lighting specifications, and/or notes should clearly specify how luminaires will comply.

B. Confirm All Required Controls Are Specified

Plans and specifications should clearly indicate the controls required for compliance.

Vacancy controls should be shown on plans, or described in notes or specifications, to control at least one luminaire in each of the following spaces:

- Bathrooms
- Utility Rooms
- Laundry Rooms
- Garages

Dimmers or vacancy controls should be shown on plans, or described in notes or specifications, to control all luminaires using JA8-certified changeable lamps.

Plans, lighting specifications, and/or notes should clearly identify how luminaires will comply with the controls requirements. Notes and/or control equipment specifications should include any applicable requirements for control device operation.

C. Confirm Any Applicable Outdoor and Nonresidential Lighting Standards

Where applicable, outdoor lighting shall be shown on plans or described in specifications and/or notes to be high efficacy, and to meet the control requirements of §150.0(k)3.

Plans, specifications, and notes should also describe any applicable nonresidential common area or outdoor lighting requirements that apply.

6.9.2 Compliance Documentation

Confirm that all required compliance documentation is included with the plans.

A. Certificate of Installation

The certificate of installation (CF2R-LTG) is the primary compliance documentation for residential lighting. There will be one or more CF2R-LTG forms submitted for each project. Confirm that all lighting systems and lighting controls in the project are covered by a CF2R-LTG. Confirm that all CF2R-LTG forms are registered, if required.

B. Lighting Schedule

Builders are required to submit a lighting schedule to homeowners or occupants at the time of occupancy. This lighting schedule should describe all interior luminaires and lamps installed in the home. A draft lighting schedule should be included with the plans at plan check.

C. Documentation for Control Systems

Some lighting control systems for residential lighting will also require specific compliance documentation.

6.9.3 Inspections

A. Confirm All Luminaires Are High Efficacy

Inspectors should verify that all installed luminaires are high efficacy. Luminaires are classified as high efficacy in one of three ways:

1. Use one of the following lighting technologies:
 - Pin-based linear fluorescent with electronic ballast.
 - Pin-based compact fluorescent with electronic ballast.
 - Pulse-start metal halide.
 - High pressure sodium.

- GU-24 other than LEDs.
 - Induction lamp.
 - Inseparable SSL luminaires installed outdoors.
 - Inseparable SSL luminaires with colored light sources for decorative lighting.
2. Luminaires EXCEPT recessed downlights, must comply with either:
 - JA8-certified luminaires with integral light sources.
 - Luminaires installed with JA8-certified lamps.
 3. Recessed downlight luminaires must comply with BOTH:
 - JA8-certified integral source or a JA8-certified lamp.
 - Must NOT contain a screw base socket.

Inspectors should be able to confirm that luminaires are high efficacy by a visual inspection. High efficacy luminaire types are typically recognizable and distinct from non-high efficacy luminaire types. JA8-certified luminaires and removable JA8-certified lamps must be marked with a label reading "JA8-2016" or "JA8-2016-E." The "JA8-2016-E" marking indicates those products which meet the JA8 elevated temperature requirement and are suitable for elevated temperature applications such as in enclosed fixtures or recessed downlights.

B. Confirm All Required Controls Are Installed and Functioning

Inspectors should verify that all controls are installed and functioning.

At least one luminaire in each of the following spaces must be controlled with a vacancy controls:

- Bathrooms
- Utility Rooms
- Laundry Rooms
- Garages

Dimmers or vacancy controls must control all luminaires using JA8-certified light sources.

C. Confirm Any Applicable Outdoor and Nonresidential Lighting Standards

Inspectors should verify that all outdoor lighting attached to the residence or to other buildings on the same lot are high efficacy, and are controlled by a manual ON and OFF switch and by photocell and motion sensor and one of the following automatic control types:

1. Photocontrol AND automatic time switch control.
2. Astronomical time clock controls that automatically turns the outdoor lighting off during daylight hours.
3. Energy management control system (EMCS) that functions as an astronomical time clock, does not have an override or bypass switch that allows the luminaire to be always ON, and is programmed to automatically turn the outdoor lighting off during daylight hours.

Manual ON and OFF switches must not override the automatic control functions listed above, and any control that overrides the automatic controls to ON must automatically reactivate those controls within six hours.

Lighting that is not permanently attached to a building on a single-family site, such as decorative landscape lighting, is not regulated by the residential lighting requirements.

Inspectors should also verify compliance with any applicable nonresidential common area or outdoor lighting requirements. More information on nonresidential lighting requirements can be found in the Nonresidential Compliance Manual Chapter 5 and 6.

D. Inspections for Ceiling Recessed Downlight Luminaires

Recessed downlight luminaires must be IC rated and have a gasket or caulking between the housing and ceiling to prevent the flow of heated or cooled air between conditioned and unconditioned spaces.

Luminaire must include a label certifying airtight or similar designation to show air leakage less than 2.0 CFM at 75 Pascals when tested in accordance with ASTM E283. The label must be clearly visible for the building inspector. The building inspector may verify the IC and ASTM E283 labels during rough inspection. If verified at final inspection, the building inspector may have to remove the trim kit to see the labels.

The ASTM E283 certification is a laboratory procedure intended to measure only leakage of the luminaire housing or, if applicable, of an airtight trim kit, and not the installation. Luminaire housings labeled as airtight, airtight ready, or other airtight designation do not establish that a luminaire has been installed airtight. The luminaire manufacturer shall provide instructions that explain the entire assembly required to achieve an airtight installation.

There are different methods used by manufacturers to meet the airtight standards. These methods include the use of caulk, or use of gaskets to reduce air leakage at the luminaire housing. The residential lighting requirements do not favor one airtight method over another.

Because luminaire housing is not always installed perfectly parallel to the ceiling surface, both methods have their benefits as follows:

1. Caulk will generally fill in and seal wide and uneven gaps. However, after the caulk dries, it may permanently attach the luminaire housing or trim to the ceiling surface. Therefore, the caulk may need to be cut away from the ceiling surface in the event that a luminaire housing or trim needs to be moved away from the ceiling.
2. Many gaskets allow the luminaire housing or trim to be readily moved away from the ceiling surface after it has been installed. However, if the gasket is too thin, or not made out of an air stopping type of material, it may not sufficiently reduce the air flow between the conditioned and unconditioned spaces. Although the Standards do not specify the type of material needed for a gasket, it is likely that an open cell type of foam, particularly if the gasket is relatively thin, will not create an airtight barrier.

The primary intent is to install a certified airtight luminaire so that it is sufficiently airtight to prevent the flow of heated or cooled air between conditioned and unconditioned spaces. All air leak paths through the luminaire assembly or through the ceiling opening must be sealed. Leak paths in the installation assembly that are not part of the ASTM E283 testing must be sealed with either a gasket or caulk.

The process for verifying an airtight installation:

1. Manufacturer specifications (a "cut sheet") of the certified airtight luminaire housing(s) and installation instructions are made available with the plans to show all components of the assembly that will be necessary to ensure there is an airtight installation consistent with §150.0(k)1C. This allows the building inspector to know what method the luminaire manufacturer specifies to achieve airtight installation, and to determine what phase of construction the building inspector should inspect the luminaire for airtight compliance.
2. One of the following primary methods is specified by the luminaire manufacturer to ensure an airtight seal of the certified airtight housing to the ceiling:
 - a. A gasket is attached to the bottom of the certified airtight housing prior to the installation of the ceiling (i.e., drywall or other ceiling materials) to create an airtight seal. The gasket may be preinstalled at the factory, or may need to be field installed. For field installed gaskets, instructions on how the gasket is to be attached shall be provided by the manufacturer. The luminaire shall be installed so that the gasket will be sufficiently compressed by the ceiling when the ceiling is installed. A gasket that is too thin will not provide an airtight seal.
 - b. A gasket is applied between the certified airtight housing and the ceiling opening after the ceiling has been installed. The gasket creates the airtight seal. The cut sheet and installation instructions for achieving the airtight conditions shall indicate how the gasket is to be attached.
 - c. Caulk is applied between the certified airtight housing and the ceiling after the ceiling has been installed. The caulk creates the airtight seal. The cut sheet or installation instructions for achieving the airtight conditions shall specify the type of caulk that must be used and how the caulk shall be applied.
 - d. A certified airtight trim kit is attached to the housing after the ceiling has been installed. The certified airtight trim kit in combination with the luminaire housing makes the manufactured luminaire airtight. Note that a decorative luminaire trim that is not ASTM E283 certified does not make the manufactured luminaire airtight. Most decorative luminaire trims are not designed to make a luminaire airtight. Rather, these trims are used to provide a finished look between the ceiling and luminaire housing, and may include a reflector, baffle, and/or lens. However, some trim kits are specifically designed to be a critical component used to make a luminaire installation airtight. These trim kits shall be certified airtight in accordance with ASTM E283. Certified airtight trim kits typically consist of a one-piece lamp-holder, reflector cone, and baffle. The cut sheet and installation instructions for achieving the airtight conditions shall show which certified airtight trim kits are designed to be installed with the luminaire housing, and how the certified airtight trim kits shall be attached. A gasket shall be installed between the certified airtight trim kit and the ceiling.
3. The following methods for ensuring an airtight seal between the certified airtight housing or certified airtight trim and the ceiling shall be field verified at different phases during construction:
 - a. A gasket attached to the bottom of the certified airtight housing shall be inspected prior to the installation of the ceiling when the rough-in electrical work is visible. The inspector shall review the cut sheet or installation instructions to make sure the housing and gasket have been installed correctly. All gaskets shall be permanently in place at the time of inspection. It is important that once the ceiling

material is installed, the gasket will be in continuous, compressed contact with the backside of the ceiling and that the housing is attached securely to avoid vertical movement. The housing shall be installed on a plane that is parallel to the ceiling plane to assure continuous compression of the gasket.

- b. A gasket applied between the certified airtight housing and the ceiling after the ceiling has been installed shall be inspected after the installation of the ceiling. The inspector shall review the cut sheet or installation instructions to make sure the housing and gasket have been installed correctly. The gasket shall be permanently in place at the time of inspection. It is important that the gasket is in continuous, compressed contact with the ceiling, and that the housing is attached securely to avoid vertical movement.
- c. Caulk applied between the certified airtight housing and the ceiling after the ceiling has been installed shall be inspected after the installation of the ceiling. The inspector shall review the cut sheet or installation instructions to make sure the housing has been installed correctly and the caulk has been applied correctly. It is important that the housing is attached securely to avoid vertical movement.
- d. A certified airtight trim kit shall be inspected after the installation of the ceiling and the installation of the trim. The inspector shall review the cut sheet or installation instructions to make sure the luminaire housing and the certified airtight trim kit have been installed correctly. It is important that the housing and the certified airtight trim kit are attached securely to avoid vertical movement. The ASTM E283 certification is a laboratory procedure where the trim kit is tested on a smooth mounting surface. However, it is common for certified airtight trim kits to be installed against a textured ceiling or other irregular ceiling surface. It is important that the gasket is in continuous, compressed contact with the ceiling and the certified airtight trim kit. Therefore, it is important to visually inspect the certified airtight trim kit and gasket next to the ceiling to assure that a continuous seal has been produced. Certified airtight trim kits may be installed on luminaire housings that may or may not be certified airtight. If the trim kit is certified airtight, it shall also have a sealed gasket between the trim kit and ceiling.

6.10 For Manufacturers – Certification to the Energy Commission

For devices to be certified to the Energy Commission (as defined in §100.1), the manufacturer must comply with the requirements of certification. Certification includes a declaration of compliance, executed under penalty of perjury of the laws of California, that the regulated device meets the requirements.

For compliance with the Appliance Efficiency Regulations (Title 20 California Code of Regulations, §1606) and the Energy Standards, the Energy Commission maintains a database of appliances, controls, and other devices that have been certified to the Energy Commission.

For compliance with the residential lighting requirements, this database includes lighting controls, and lamps and luminaires that comply with the requirements in Reference Joint Appendix JA8 in order to be classified as “high efficacy.”

Building departments, builders, contractors, and lighting designers should check the Energy Commission database to verify that a regulated device has been certified to the Energy Commission by the manufacturer of that device.

The database can be found here: <http://energy.ca.gov/appliances/>

6.10.1 Luminaires and Lamps Complying with JA8 and JA10

The 2016 Energy Standards require all residential lighting installed to be high efficacy, and for some applications, to be JA8 compliant light sources.

Joint Appendix JA8 “Qualification Requirements for High Efficacy Light Sources,” is prepared as a technical specification with requirements for high efficacy light sources which can be luminaires and lamps. The table below provides highlights of JA8 requirements. Those who are interested in the technical aspects of high efficacy light sources should refer to Reference Joint Appendix JA8 for details.

Table 6-6: JA8 High Efficacy Light Source Requirements Highlights

METRIC	JA8 REQUIREMENTS
Light Source Type	LED, OLED Fluorescent, HID, Incandescent, Other
Product type	Omnidirectional lamp, Directional lamp, Decorative lamp, LED light engine, inseparable SSL luminaire, other
Lab accredited by NVLAP or accreditation body operating in accordance with ISO/IEC 17011?	Yes
Initial Efficacy	≥ 45 lumens/Watt
Power Factor at Full Rated Power	≥ 0.90
Start time	≤ 0.5 sec
Correlated Color Temperature (CCT)	For inseparable SSL luminaires, LED light engines and GU24 LED lamps: ≤4000 Kelvin For all other sources: ≤ 3000 Kelvin
Duv	≥-0.0033 and ≤ +0.0033
Color Rendering Index (CRI)	≥ 90
Color Rendering R9 (red)	≥ 50
Ambient or elevated temperature test for rated life, lumen maintenance, and survival rate	“Ambient” allowed only for omnidirectional lamps <10W, and decorative lamps, or labeled “not for use in enclosed fixtures,” lamps and light engines that are labeled “not for use in recessed fixtures” and “inseparable SSL luminaires.” All others must report “Elevated.”
6,000 hour lumen maintenance	≥ 86.7% or NA for integral luminaires providing TM-21 L70 projections based on light source LM80 data
LM-80 and TM-21 Projected Time to L70	≥ 25,000 hours, or N/A for light sources providing 6,000 hour lumen maintenance testing
Rated life	≥ 15,000 hours
6,000 hour survival rate	≥ 90% or NA for integral luminaires whose lumen maintenance/rated life is evaluated using light source LM-80 data.
Minimum dimming level	≤ 10%
Dimming control compatibility	At least one type must be listed
NEMA SSL 7A compatible?	If compatible with forward phase cut dimmer control, “Yes.” If not, “No.”
FLICKER: See JA10 Table 10-1 for flicker data requirements and permissible answers	<30% for frequencies of 200 Hz or below, at 100% and 20% light output
AUDIBLE NOISE: 100% light output: Audible Noise	≤ 24 dBA
20% light output: Audible Noise	≤ 24 dBA
MARKING: Marked in accordance with JA8.5	Yes. “No” allowed only for lamps and LED light engines with diameter less than 1.0” and decorative lamps with a diameter less than 2.0” ¹
¹ As stated, marking is not required for lamps and LED light engines with diameter less than 1 inch and decorative lamps with diameter less than 2 inch. However, the manufacturer of such products may opt to put a JA8 marking on these lamps and light engine products to show JA8 compliance.	

Joint Appendix JA10 “Test Method for Measuring Flicker of Lighting Systems and Reporting Requirements,” is prepared as a supplement for the reduced flicker operation requirement of JA8. JA10 is also technical in nature and describes the test method to measure the fluctuation of light from the lighting system and process this signal to quantify flicker as a percent amplitude modulation below a given cut-off frequency. Signal processing is used to

remove high frequency components. Refer to Reference Joint Appendix JA10 for details of the test method.

6.10.2 Self-Contained Lighting Controls

Self-contained lighting controls are required to be certified to the Energy Commission by the manufacturer. A self-contained lighting control is defined in §100.1 as a unitary lighting control module that requires no additional components to be a fully functional lighting control.

Self-contained lighting control devices cannot be sold or offered for sale in California unless they have been certified to the Energy Commission according to the Title 20 Appliance Efficiency Regulations.

Figure 6-1: Self-Contained Lighting Controls



6.10.3 Lighting Control Systems

A lighting control system is defined by §100.1 as two or more lighting control components installed to provide all of the functionality of a compliant self-contained lighting control.

Lighting control systems are not required to be Certified to the Energy Commission, but are instead required to comply with the minimum performance requirements in §110.9, and a Certificate of Installation must be submitted in accordance with the requirements in §130.4:

1. The minimum performance requirements in §110.9 require that a lighting control system functionally meet all of the requirements that a self-contained lighting control is required to meet. For example, a vacancy sensor system must functionally meet all of the requirements in the Title 20 Appliance Efficiency Regulations for a self-contained vacancy sensor.
2. A single lighting control system that is installed to provide the functionality of more than one lighting control device is required to provide all of the functionality of each respective lighting control for which it is installed.
3. Whenever a lighting control system is installed to comply with lighting control requirements in the Energy Standards, a licensee of record must submit a Certificate of Installation in accordance with the requirements in §130.4.

Specific types of lighting control systems must also meet the following requirements:

1. An Energy Management Control System (EMCS) may be used to comply with dimmer requirements if at a minimum it provides the functionality of a dimmer.
2. An EMCS may be used to comply with vacancy sensor requirements if at a minimum it provides the functionality of a vacancy sensor.

3. A multi-scene programmable controller may be used to comply with dimmer requirements if at a minimum it provides the functionality of a dimmer.
4. Lighting controls and equipment are required to be installed in accordance with the manufacturer's instructions.

6.10.4 Ballasts for Compact Fluorescent Luminaires

When used in residential recessed luminaires, all ballasts for compact fluorescent luminaires must be certified by the manufacturer to the Energy Commission according to §110.9(f), as meeting the following conditions:

1. Have a minimum rated life of 30,000 hours when operated at or below a specified maximum case temperature. This maximum ballast case temperature specified by the ballast manufacturer shall not be exceeded when tested in accordance to UL 1598 test procedure 19.15; and
2. Have a ballast factor of not less than 0.90 for non-dimming ballasts and a ballast factor of not less than 0.85 for dimming ballasts.

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7. Solar Ready

§110.10

This chapter of the residential compliance manual addresses residential solar-ready buildings requirements. The intent of the solar-ready requirements is to provide a penetration-free and shade-free portion of the roof, called the *solar zone*. This solar zone helps ensure that future installation of a solar energy system is not precluded by the original design and layout of the building and associated equipment. There are no infrastructure related requirements, such as installation of conduit or piping, inclusion of collateral structural loads, or preinstalled mounting hardware.

The requirements for solar-ready buildings are mandatory measures for newly constructed single-family and low-rise multifamily residential buildings and do not apply to either additions or alterations.

7.1 Overview

All solar ready provisions are mandatory; there are no prescriptive and performance compliance paths. Since the provisions are mandatory, there are no tradeoffs allowed, and applicants must demonstrate compliance with each measure. There are, however, exceptions. Exceptions to mandatory requirements are described in the corresponding sections.

7.2 Covered Occupancies

§110.10(a)

The residential solar-ready requirements apply to single-family residences and low-rise multifamily residential buildings.

A. Single-Family Residential Buildings

The solar-ready requirements are applicable to newly constructed single-family residential buildings located in subdivisions with 10 or more residences...

B. Low-Rise Multifamily Buildings

The solar-ready requirements are applicable to newly constructed low-rise multifamily buildings. By the definition of the Energy Standards, low-rise multifamily buildings have three habitable stories or fewer.

7.3 Solar Zone

§110.10(b)

The solar zone is an allocated space that is unshaded, unpenetrated, and free of obstructions. It serves as a suitable place that solar panels can be installed at a future date.

For single-family residential building the solar zone shall be located on the roof or overhang of the building.

For low-rise multifamily buildings the solar zone can be located at any of the following locations:

1. Roof of building
2. Overhang of the building
3. Roof and overhang of another structure located within 250 feet of the primary building
4. Covered parking installed with the building project
5. Other structures include, but are not limited to, trellises, arbors, patio covers, carports, gazebos, and similar accessory structures.

The solar zone design must comply with the access, pathway, smoke ventilation, and spacing requirements as specified in Title 24, Part 9 or in any requirements adopted by a local jurisdiction. These additional requirements are located in other Parts of Title 24, including Parts 2, 2.5, and 9 that are adopted by the California Building Standards Commission as part of the California Building Standards Code.

7.3.1 Minimum Area

§110.10(b)1

The total area of the solar zone may be composed of multiple subareas. No dimension of a subarea can be less than five feet. If the total roof area is equal to or less than 10,000 square feet, each subarea must be at least 80 square feet. If the total roof area is greater than 10,000 square feet, each subarea must be at least 160 square feet.

7.3.1.1 Single-Family Residential Buildings

The solar zone shall be located on the roof or overhang of the building. The solar zone shall have a total area that is no less than 250 square feet. There are multiple exceptions, as described below, to the required total solar zone area. For Exceptions A, B, and G below, although the language in the Energy Standards implies that these three exceptions apply only to the solar zone requirements, the intent of the Standards is for the exceptions to apply to the solar zone requirement, as well as the interconnection pathway requirements described in §110.10(c), the documentation requirements described in §110.10(d), and the electric service panel requirements described in §110.10(e).

Exceptions:

- A. Single-family residential buildings are exempt from the solar zone, interconnection pathway, and documentation requirements if a solar PV system with a nameplate direct current (DC) power rating of 1000 watts or greater is permanently installed at the time of construction. The nameplate rating must be measured under standard test conditions. The permanently installed solar electric system is not required to be on the roof of the building. To verify compliance with this exception, form *CF2R-SPV-01-E Certificate of Installation: Photovoltaic Systems* must be submitted.
- B. Single-family residential buildings are exempt from the solar zone, interconnection pathway, and documentation requirements if a domestic solar water-heating system is permanently installed at the time of construction. The SWH system must comply with the installation criteria in the Reference Residential Appendix RA4.4.21 and have a minimum solar savings fraction of 0.50 (the fraction of domestic hot water demand provided by a solar water heating systems) permanently installed at the time of construction. This is the equivalent of the prescriptive solar water-heating system requirements when installing an electric-resistance storage or instantaneous water

heater serving a dwelling unit. The permanently installed domestic solar water-heating collectors are not required to be located on the roof of the building. To verify compliance with this exception, form *CF2R-STH-01-E Certificate of Installation: Solar Water Heating System* must be submitted.

- C. The solar zone may be reduced to no less than 150 square feet for single-family residential buildings with three stories or more and with a total floor area equal to 2,000 square feet or less.
- D. The solar zone may be reduced to no less than 150 square feet for single-family residential buildings with a whole-house fan and where the building is located in Climate Zones 8 through 14 and where the residence is located in the Wildland-Urban Interface Fire Area (as defined in Title 24, Part 2). This exception is to accommodate attic- and roof-venting requirements in these fire areas.
- E. The solar zone may be reduced to 50 percent of the potential solar zone area. For the Energy Standards, the potential solar zone area is the total area of the roof where annual solar access is 70 percent or greater. This exception reduces the required solar zone area when the roof is shaded by objects that are not located on the roof or any other part of the building. If the potential solar zone is smaller than the minimum solar zone area specified in §110.10(b)1A of 250 square feet, then the solar zone can be reduced to half the area of the potential solar zone. If the roof is shaded such that there is no potential solar zone area, then no solar zone is required.

For the solar ready requirements, solar access is the ratio of solar insolation including shading to the solar insolation without shading.

$$\text{Solar Access} = \frac{\text{Solar Insolation Including Shading}}{\text{Solar Insolation Without Shading}}$$

Objects that are excluded from the building project are objects that will not be moved or modified as part of the building project and include existing buildings, telephone poles, communication towers, trees, or other objects. Objects that are included in the building project are objects that will be constructed as part of the building project and include the building itself, HVAC equipment on the building, parking lot lights, and other similar objects. As mentioned, solar access does not take into account shading from objects that are included in the building project as the designer has control of the location of these potential obstructions.

Annual solar access is most easily determined using an instrument equipped with a camera with a fisheye lens and specialized imagery processing software. The instrument can calculate the annual solar access of any point on a proposed site based on the location of the building and information that is captured in the digital photograph. Since this type of instrument relies on photographs, the most appropriate use is to determine solar access on existing buildings. The instruments are not as useful in the design phase for newly constructed buildings, when capturing a digital photograph from the proposed solar zone location is not feasible.

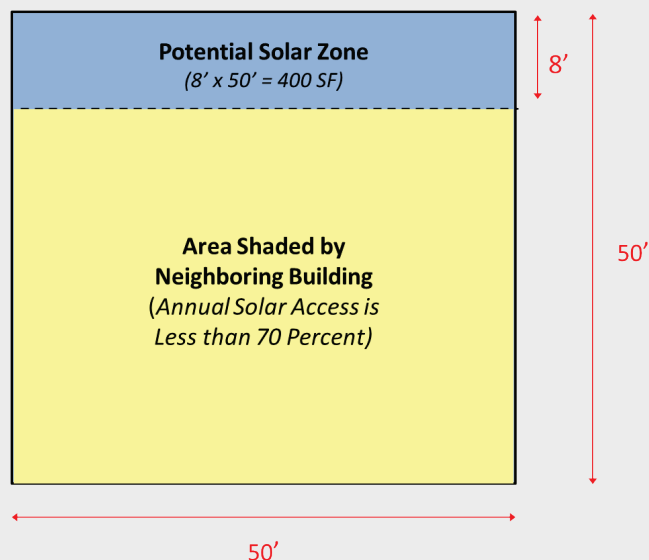
To determine the annual solar access during the design phase, designers will first evaluate whether there are any objects outside the building project that will shade the rooftop (or other prospective solar zone areas such as overhangs or parking shade structures). If an existing object is located north 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 7-2.)

If objects external to the building project could shade the solar zone, annual solar access can be quantitatively determined using several computer-aided design (CAD) software packages that can import a CAD file of the building and perform a shading analysis or several online solar quoting tools can be used that make use of both overhead and orthogonal aerial imagery. Annual solar access can be qualitatively determined using several three-dimensional modeling programs. The method/tools used to quantify that the solar access is less than 70 percent (and reduce the potential solar area) shall be documented in compliance form CF1R-SRA-02-E.

Example 7-1

Question

A house has a total roof area of 2,500 SF. The neighbor's house and trees shade the roof, so 2,100 SF of the roof has less than 70 percent annual solar access. How big does the solar zone have to be?



Answer

If the entire roof were to have an annual solar access of 70 percent or greater, the minimum solar zone would have been 250 SF. Since the potential solar zone is only $2,500 - 2,100 = 400$ SF, however, the minimum solar zone can be reduced to 50 percent of the potential solar zone, or 200 SF.

- F. The solar zone may be reduced to no less than 150 square feet if all thermostats in the residential building are occupant-controlled smart thermostats (OCST) with communications capabilities enabled to receive and respond to demand response signals. An OCST is a setback thermostat with communication capabilities that enable the occupant to receive demand response-related messages and respond to those signals by automatic adjustment of the thermostat setpoint as described in Joint Appendix JA5 (subject to occupant participation). Enabling communications capabilities requires that the OCST has one of the following:
1. onboard communications capabilities,
 2. an installed communications module for OCSTs with removable communications module(s), or

3. an installed communications gateway for an OCST where an external gateway is required for communications.
- G. Single-family residential buildings are exempt from the solar zone, interconnection pathway and documentation requirements if all of the following conditions are met:
1. All thermostats in the buildings are OCST with communications capabilities enabled to receive and respond to demand response signals (subject to occupant participation). Enabling communications capabilities requires that the OCST has one of the following: onboard communications capabilities, an installed communications module for OCSTs with removable communications module(s), or an installed communications gateway for an OCST where an external gateway is required for communications.
 2. One of the following measures shall be met:
 - a. Install a dishwasher that meets or exceeds the ENERGY STAR® program requirements and install either a refrigerator that meets or exceeds the ENERGY STAR program requirements or a whole-house fan driven by an electronically commutated motor; or
 - b. Install a home automation system capable of, at a minimum, controlling the appliances and lighting of the dwelling and responding to demand response signals; or
 - c. Install alternative plumbing piping to permit the discharge from the clothes washer and all showers and bathtubs to be used for an irrigation system in compliance with the California Plumbing Code; or
 - d. Install a rainwater catchment system designed to comply with the California Plumbing Code and use rainwater flowing from at least 65 percent of the available roof area.

7.3.1.2 Low-Rise Multifamily Residential Buildings

The solar zone shall be located on the roof or overhang of the building or on the roof or overhang of another structure located within 250 feet of the building or on covered parking installed with the building project. Other structures include, but are not limited to, trellises, arbors, patio covers, carports, gazebos, and similar accessory structures. The solar zone shall have a total area that is no less than 15 percent of the total roof area of the building after subtracting any skylight area from the roof area. There are multiple exceptions, as described below, to the required total area. For Exceptions A, B, D, and E below, although the language in the Energy Standards implies that these four exceptions only apply to the solar zone requirements, the intent of the Energy Standards is for the exceptions to apply to the solar zone requirement, as well as the interconnection pathway requirements described in §110.10(c), and the documentation requirements described in §110.10(d).

Exceptions

- A. Buildings are exempt from solar zone, interconnection pathway, and documentation requirements if a solar electric system with a nameplate DC power rating of no less than 1 watt per square foot of roof area is permanently installed at the time of construction. The nameplate rating must be measured under standard test conditions. The permanently installed solar electric system is not required to be located on the roof or overhang of the building or on the roof or overhang of another structure. To verify compliance with this exception, form *CF2R-SPV-01-E Certificate of Installation: Photovoltaic Systems* must be submitted.

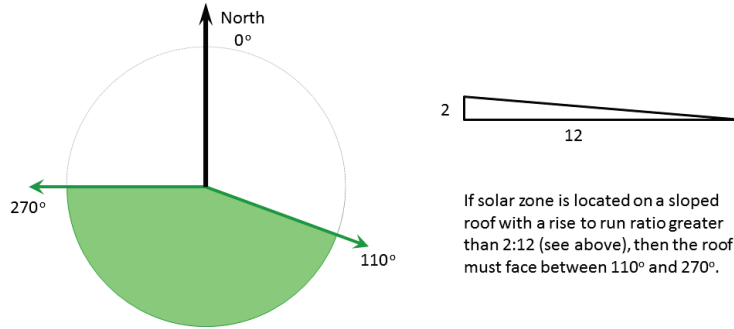
- B. Buildings are exempt from solar zone, interconnection pathway, and documentation requirements if a domestic solar water-heating system complying with §150.1(c)8Biii is permanently installed at the time of construction. This is the equivalent of the prescriptive solar water-heating system requirements when installing a water-heating system serving multiple dwelling units. The permanently installed domestic solar water-heating collectors are not required to be located on the roof or overhang of the building or on the roof or overhang of another structure. To verify compliance with this exception, form *CF2R-STH-01-E Certificate of Installation: Solar Water Heating System* must be submitted.
- C. The solar zone may be reduced to 50 percent of the potential solar zone area. The potential solar zone area is the total area of the roof where annual solar access is 70 percent or greater. This exception reduces the required solar zone area when the roof is shaded by objects that are not on the roof or any other part of the building. If the roof is shaded such that there is no potential solar zone area, then no solar zone is required.
- D. Low-rise multifamily buildings that comply with items 1 and 2 below are exempt from solar zone, interconnection pathway, and documentation requirements.
1. All thermostats in each dwelling unit are occupant controlled smart thermostats (OCST) with communications capabilities enabled to receive and respond to demand response signals. An OCST is a setback thermostat with communication capabilities that enable the occupant to receive Demand Response related messages and respond to those signals by automatic adjustment of the thermostat setpoint as described in Joint Appendix JA5 (subject to occupant participation). Enabling communications capabilities requires that the OCST has one of the following: onboard communications capabilities, an installed communications module for OCSTs with removable communications module(s), or an installed communications gateway for an OCST where an external gateway is required for communications. OCST must be certified by the Energy Commission to meet the requirements described in the Joint Appendix JA5.
 2. For each dwelling unit, one of the following measures shall be met:
 - a. Install a dishwasher that meets or exceeds the ENERGY STAR program requirements and install either a refrigerator that meets or exceeds the ENERGY STAR program requirements or a whole-house fan driven by an electronically commutated motor; or
 - b. Install a home automation system capable of, at a minimum, controlling the appliances and lighting of the dwelling and responding to demand response signals; or
 - c. Install alternative plumbing piping to permit the discharge from the clothes washer and all showers and bathtubs to be used for an irrigation system in compliance with the California Plumbing Code; or
 - d. Install a rainwater catchment system designed to comply with the California Plumbing Code and use rainwater flowing from at least 65 percent of the available roof area.
- E. Buildings are exempt from solar zone interconnection pathway and documentation requirements if the roof is designed for vehicle traffic (parking lot) or if the roof is designed as a helicopter landing zone.

7.3.2 Orientation

§110.10(b)2

For both single-family residential and low-rise multifamily buildings, all sections of the solar zone on steep-sloped roofs (ratio of rise to run of greater than 2:12) shall be oriented between 110 degrees and 270 degrees of true north. The orientation is important because it ensures a reasonable solar exposure if a solar energy system is installed in the future.

Figure 7-1: Orientation of roof if solar zone is located on steep-sloped roof



If a solar zone is located on a low-sloped roof (ratio of rise to run of 2:12 or less), the orientation requirement does not apply.

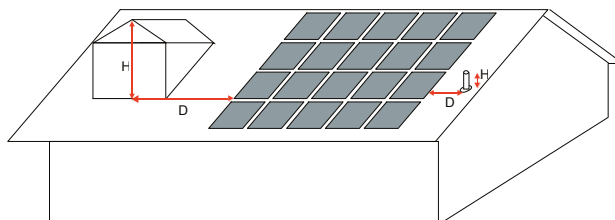
7.3.3 Shading

§110.10(b)3

For both single-family residential and low-rise multifamily buildings, the solar zone shall be free from roof penetrations and shall not have any obstructions such as vents, chimneys, architectural features, or roof-mounted equipment located in the solar zone. This requirement ensures that the solar zone remains clear and open for the future installation of a solar energy system.

For both single-family residential and low-rise multifamily buildings, any obstruction located on the roof or any other part of the building that projects above the solar zone shall be located at a sufficient horizontal distance away from the solar zone in order to reduce the resulting shading of the solar zone. For each obstruction, the horizontal distance (“D”) from the obstruction to the solar zone shall 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 (see following equation).

$$\text{Equation 7.1 } D \geq 2 \times H$$

Figure 7-2: Schematic of Allowable Setback From Rooftop Obstructions

Source: California Energy Commission

Any obstruction oriented north of all points of the solar zone is not subject to these requirements. Any obstruction that is not located on the roof or another part of the building, such as landscaping or a neighboring building, is not subject to these requirements.

7.4 Construction Documents

Construction documents must include information about the as-designed structural loads and plans for interconnecting a photovoltaic (PV) and SWH system to the electrical or plumbing system of the building.

These requirements apply to both single-family residential and low-rise multifamily buildings.

7.4.1 Structural Design Loads

§110.10(b)4

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. There are no requirements for the inclusion of any collateral loads for future solar energy systems.

7.4.2 Interconnection Pathways

§110.10(c)

All buildings that comply with the solar-ready requirements with a solar zone must also include a plan for connecting a PV and SWH system to the electrical or plumbing system of a building. The construction documents shall indicate:

1. A location for inverters and metering equipment for future solar electric systems.
2. A pathway for routing conduit from the solar zone to the point of interconnection with the electrical service. There is no requirement to install any conduit.
3. A pathway for routing of plumbing from the solar zone to the water-heating system. There is no requirement to install any piping.

7.4.3 Documentation

§110.10(d)

A copy of the construction documents or a document containing the required solar-ready information shall be provided to the occupant. The building occupant must also receive a copy of compliance forms number CF1R-SRA-01-E and CF1R-SRA-02-E. Providing this information to the building occupant is required so that the solar-ready information is available if a solar energy system is installed in the future.

7.5 Main Electrical Service Panel

§110.10(e)

This requirement applies only to single-family residential buildings. The main electrical service panel shall have a minimum busbar rating of 200 amps and shall have a reserved space to allow for the installation of a double-pole circuit breaker. The reserved circuit breaker space shall be on the opposite (load) end from the input feeder or main circuit location. The reserved circuit breaker space shall be permanently marked as “For Future Solar Electric”. These items are required to simplify the possible future installation of a solar electric system.

7.6 California Fire Code Solar Access Requirements

Under 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 the installation of rooftop solar photovoltaic systems. These regulations cover the marking, 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 brief summary of the fire code requirements for residential buildings.

PV arrays shall not have dimensions in either axis greater than 150 feet. Residential buildings with hip, ridge/valley roof features shall provide a 3-foot access pathway away from applicable eave to hip/ridge/valley features. To provide adequate smoke ventilation, PV arrays shall not be located higher than 3 feet below the ridge. Builders shall refer directly to the relevant sections of Title 24 (most currently 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 a *Solar Photovoltaic Installation Guideline* to increase public safety for all structures equipped with solar photovoltaic systems. The intent of this guideline is to provide 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 now set forth in the California Fire Code.

The entire Solar Photovoltaic Installation Guideline can be accessed at <http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf>

The following illustrations from this guideline demonstrate some acceptable solar access techniques.

Figure 7-3: Cross Gable Roof

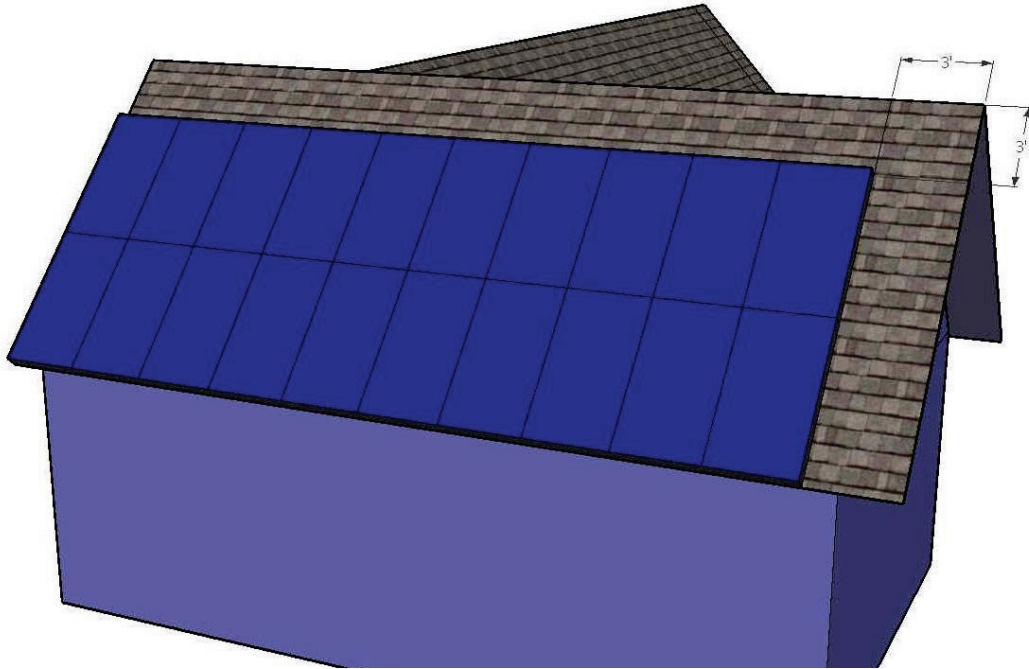


Figure 7-4: Cross Gable with Valley

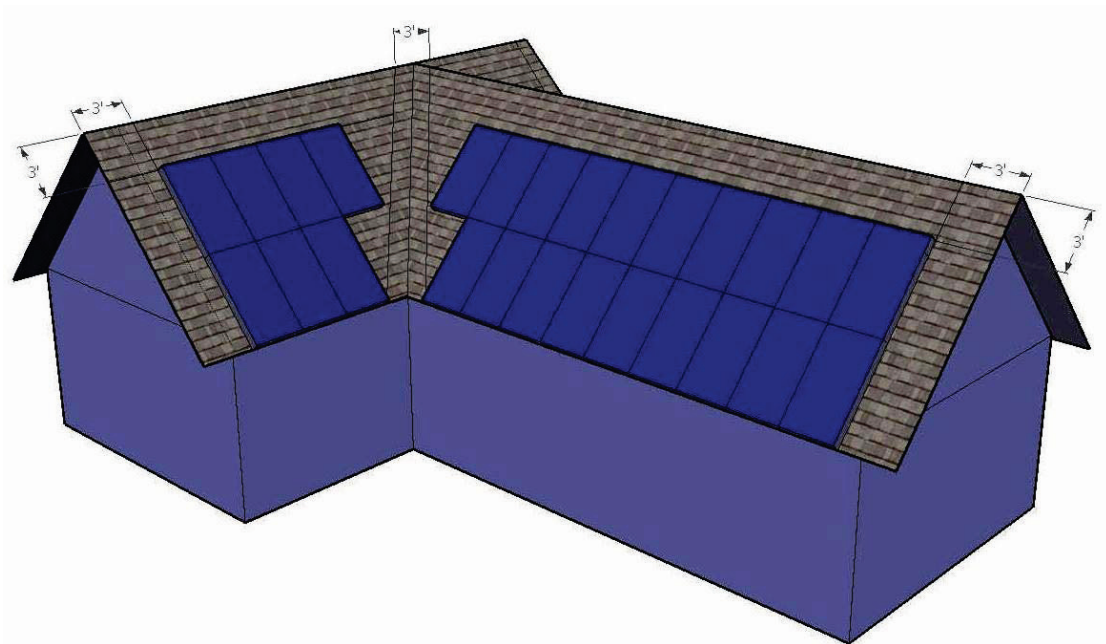


Figure 7-5: Full Gable

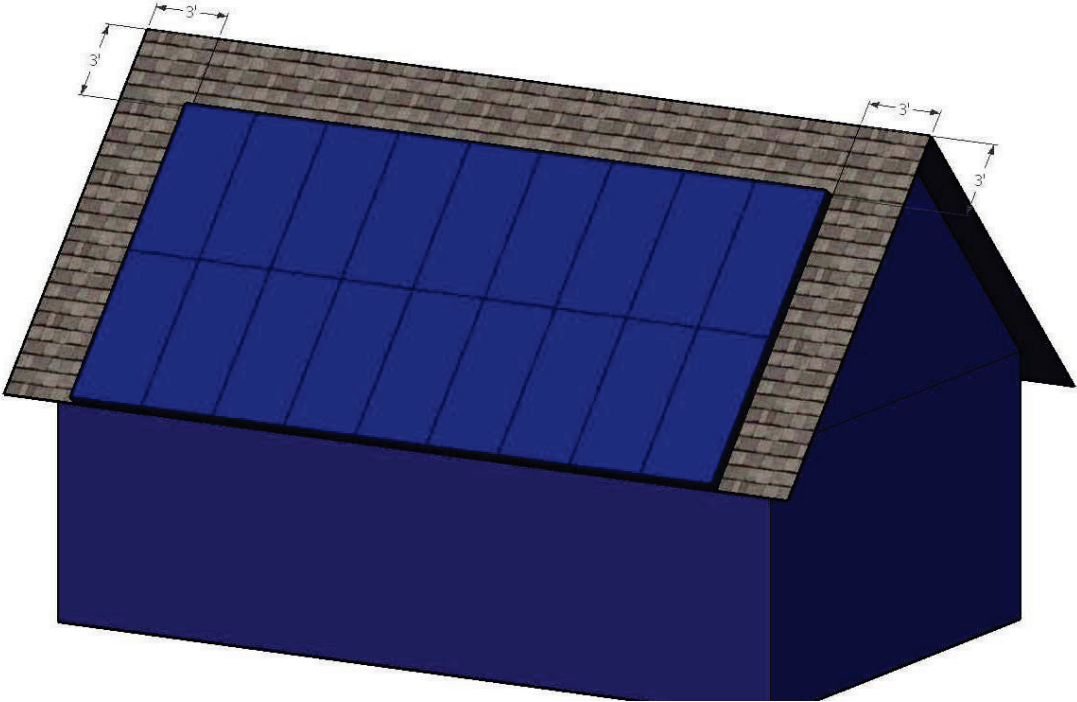
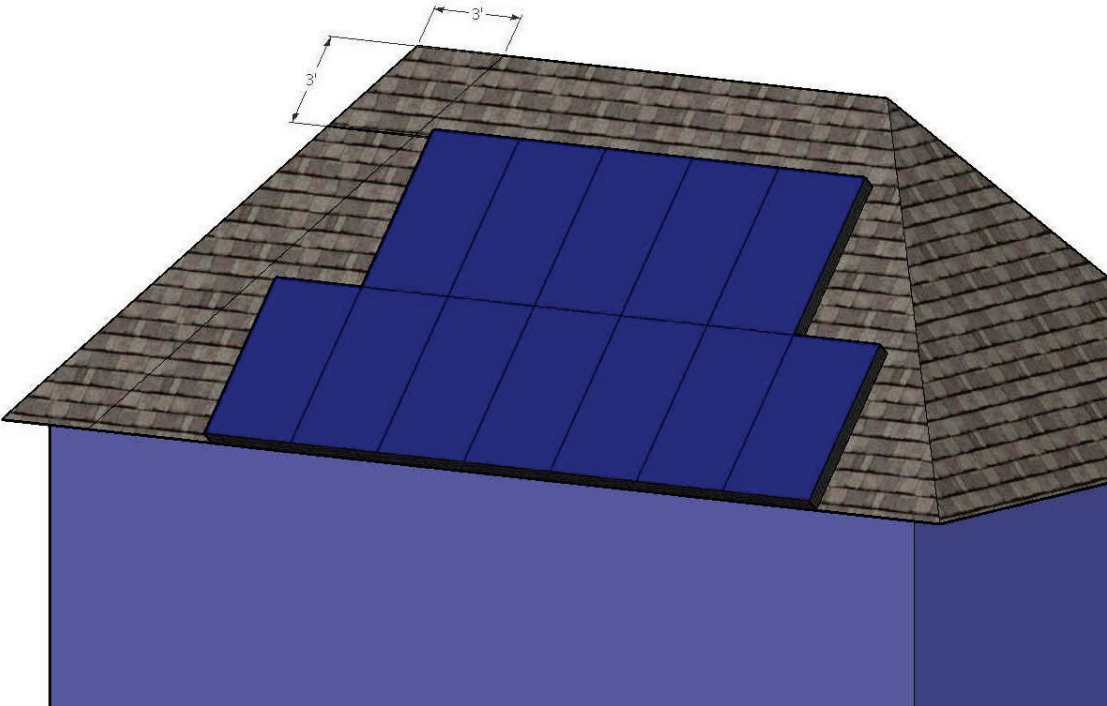


Figure 7-6: Full Hip Roof



7.7 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 forms and procedures for documenting compliance with the solar ready requirements of the Energy Standards. The following discussion is addressed to the designer preparing construction and compliance documents, and to the enforcement agency plan checkers who are examining those documents for compliance with the Standards.

There are four forms associated with the nonresidential solar-ready requirements. Each form is briefly described below.

1. CF1R-SRA-01-E: Certificate of Compliance: Residential Solar Ready Areas

This form is required for every project where the solar-ready requirements apply: newly constructed single-family residential and low-rise multifamily buildings.

2. CF1R-SRA-02-E: Certificate of Compliance: Minimum Solar Zone Area Worksheet

This form is required when buildings comply with the solar-ready requirement by including a solar zone. That is, an appropriately sized solar PV system is not installed, an appropriately sized solar water heating system is not installed, the building does not comply with all the OCST and high-efficacy lighting requirements or the roof is not designed for vehicle traffic or a heliport.

3. CF2R-SPV-01-E: Certificate of Installation – Solar Photovoltaic System

This form is required when the building is exempt from the solar zone requirements because an appropriately sized solar PV system has been installed.

4. CF2R-STH-01-E: Certificate of Installation – Solar Water Heating System

This form is required when the building is exempt from the solar zone requirements because an appropriately sized solar water heating system has been installed.

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8. Performance Method

8.1 Overview

This chapter explains the performance method of complying with the *2016 Building Energy Efficiency Standards* (Energy Standards). The method works by calculating the time-dependent valuation (TDV) energy use of the proposed design and comparing it to the TDV energy use of the standard design (the budget). The standard design is a building with the same surface areas as the proposed design but incorporates all the features of Prescriptive Package A. The energy budget includes water heating, space heating, space cooling, and indoor air quality (IAQ) fan energy. Lighting energy is not included in the performance calculations because all residential lighting measures are mandatory and therefore not eligible to be traded-off using the performance method. If the proposed design uses equal or less TDV energy than the standard design, then the building complies.

Computer programs used for compliance are approved by the Energy Commission as being capable of calculating space-conditioning and water-heating energy use in accordance with a detailed set of rules. The computer programs model the thermal behavior of buildings by calculating heat flows into and out of the various thermal zones of the building. The computer programs approved by the Energy Commission must demonstrate accuracy in analyzing annual space-conditioning and water-heating energy use of different building conservation features, levels and techniques. This method provides maximum flexibility because the building designer may trade-off the energy performance of different building components and design features to achieve compliance. Making a building more efficient will result in lower utility bills and improved comfort. The performance approach provides the ability to test different options and choose the best strategy to reduce the overall energy budget. With today's wide choice of high-efficiency materials, equipment, and controls, there are many opportunities to make a building more energy-efficient. Improving the building envelope provides several opportunities for improving efficiency, in particular with measures related to window placement, location, and efficiency. In space conditioning, there is not only equipment with very high efficiency for space heating and cooling, but many innovative system types that eliminate the need for ducts, combine space and water heating together, or use advanced designs that can dramatically improve the overall performance of the building. Improved water heating system efficiency includes a wide range of equipment that can significantly increase efficiency along with improvements to the distribution system design, which can drastically reduce energy losses.

The performance method is the most popular compliance method under the Energy Standards, with more than 95 percent of building permit applications for newly constructed buildings being submitted in this manner. The method is especially popular with production homebuilders because they can optimize performance and achieve compliance at a lower cost. This chapter provides a general overview of the performance method. Each computer program that is approved by the Energy Commission is required to have a compliance supplement that provides more detailed information regarding the use of the software for compliance purposes. The requirements for the compliance supplement along with other requirements for approved computer programs are documented in the *2016 Residential ACM Approval Manual*.

For a detailed discussion of the performance method with additions and alterations, see Sections 9.5, 9.6, and 9.7.

8.2 Compliance Basics

8.2.1 Compliance Process

Any approved computer program may be used to comply with the Energy Standards using the performance method. The following steps are a general outline of the typical computer program procedure:

1. Collect all necessary data on each component.
 - a. For the building envelope, the area of each fenestration, wall, door, roof, ceiling and floor is needed. For each component, the applicable energy characteristics needs to be defined including U-factor, solar heat gain coefficients (SHGC), solar reflectance, and thermal mass values.
 - b. For HVAC systems, the type and efficiency of space conditioning equipment are required. For hydronic space heating, the specific water heater type and efficiency are required. For fan-forced conditioning systems, the location and amount of insulation of the duct system are needed.
 - c. For domestic hot water systems, the water heater type, quantity, efficiency, and area served will be required, along with the water heating distribution system. Additional information will be required for "built-up" systems.

Other efficiency measures and options can be used to improve building efficiency.

2. Start by entering the building envelope basic data such as square footage, number of stories, occupancy type, and climate zone. Define each opaque surface with the related orientation, area, and thermal performance properties. Add the fenestration that is associated with each opaque surface, including any fixed shading such as overhangs and side-fins. Enter the data of the equipment and distribution systems for the space conditioning and water heating systems. The input values and assumptions must correctly correspond to the information on the final approved plan set and inputs must be equal to or more energy-efficient than required mandatory measures.
3. Launch a computer simulation to calculate automatically the TDV energy of the standard design and the proposed design.

For existing buildings where the values of installed features are unknown, default values may be used based on the year of the construction. Refer to the Default Assumption for Year Built, Table 8-1 at the end of this chapter.

The building energy efficiency complies if all the mandatory measures are met and the total TDV energy use of the proposed design is the same as or less than the standard design TDV energy budget.

When creating a 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 orientations and/or buildings being analyzed. Title names and explanatory comments should assist individuals involved in both the compliance and enforcement processes.

8.2.2 Defining the Standard Design

Each approved compliance software program must automatically calculate the TDV energy use of the standard design. The standard design is created based upon data entered for the proposed design using all the correctly fixed and restricted inputs.

The computer program defines the standard design by modifying the geometry of the proposed design and inserting the building features of Table 150.1-A of the Energy Standards. This process is built into each approved computer program, and the user cannot access it. Key details on how the standard design is created and calculated by the computer programs, including the listing of fixed and restricted input assumptions, are documented in the *2016 Residential ACM Reference Manual*.

The standard design assumes the same total conditioned floor area and volume as the proposed design and the same gross exterior wall area as the proposed design except that the wall area in each of the four cardinal orientations is divided equally. The standard design uses the same roof/ceiling area, raised floor area, slab-on-grade area, and perimeter as the proposed design but uses the standard insulation R-values required in Table 150.1-A of the Energy Standards.

Total fenestration area in the standard design is equal to the proposed design if the fenestration area in the proposed design is less than or equal to 20 percent of the floor area; otherwise, the fenestration area of the standard design is equal to 20 percent of the floor area. Fenestration area in the standard design is evenly distributed among the four cardinal orientations. SHGC and U-factors are the same as those listed in Package A, and no fixed shading devices such as overhangs are assumed for the standard design.

The standard design includes minimum efficiency heating and cooling equipment, as well as the minimum duct R-value and the location of the ducts, depending on whether Option A, B, or C is used from Table 150.1-A of the Energy Standards. Ducts are assumed to be sealed as required by §150.0(m). The standard design also assumes correct refrigerant charge as required by §150.1(c)7A.

For water-heating systems that serve dwelling units, the standard design is a 50 gallon gas storage water heater with an energy factor equal to the federal minimum standard. The standard design has a trunk-and-branch distribution system that includes the assumption that all mandatory measures are met (that is, the first 5 feet of hot and cold water piping from heating source) and that all piping $\frac{3}{4}$ - inch or larger is insulated and the entire length of piping to kitchen fixtures are insulated as specified in §150.0(j)2A or §150.0(j)2B.

For multiple dwelling-unit buildings, either a central distribution system may be used or a water heater may be installed in each unit. The standard design system type is based on what the proposed design uses. However, the standard design does include a pumped recirculation system that is controlled by hot water demand and hot water return temperature.

8.2.2.1 Standard Reports

For consistency and ease of enforcement, the manner in which building features are reported by compliance software programs is standardized. Energy Commission-approved compliance software programs must automatically produce compliance reports in this standard format. The principal report is the certificate of compliance (CF1R-PRF-01-E).

The CF1R-PRF-01-E has two highly visible sections, one for special features and modeling assumptions, and a second for features requiring field verification and/or diagnostic testing by approved HERS Raters. These two sections serve as a punch list for special consideration during compliance verification by the local enforcement agency and the HERS Rater. Items listed in the Special Features and Modeling Assumptions section indicate that unusual features or assumptions are used for compliance, and they call for special care by the local enforcement agency. Items listed in the HERS Required Verification section are for features that rely on diagnostic testing and independent verification by approved HERS

Providers/Raters to ensure proper field installation. Diagnostic testing and verification by HERS Providers/Raters is in addition to local enforcement agency inspections.

8.2.3 Professional Judgment

Some modeling techniques and compliance assumptions applied to the proposed design are fixed or restricted. There is little or no flexibility to choose input values for energy compliance modeling. However, other aspects of energy modeling remain for which some professional judgment may be acceptable or necessary. In those instances, the compliance software user must exercise proper judgment in evaluating whether a given input is appropriate.

Enforcement agencies have discretion to reject a particular input if the permit applicant cannot substantiate the value with supporting documentation or cannot demonstrate that appropriate professional judgment has been applied.

Two questions may be asked to resolve whether professional 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, 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 manager 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 should conform to standard engineering practice.

For assistance in evaluating the appropriateness of particular input assumptions, call the Energy Hotline or call the vendor of the compliance software program.

Example 8-1

Question

Three different-sized windows in the same wall of a new home are designed without exterior shading, and they have the same National Fenestration Rating Council (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 results whether 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.

8.3 Mixed Occupancy Buildings

§100.0(f)

Some residential buildings have areas of other occupancies, such as retail or office, in the same building. An example of this might be a three-story building with two floors of apartments above ground-floor shops and offices. The first thing to consider when analyzing the energy compliance of a mixed occupancy building is the type and area of each occupancy type.

Depending on the area of the different occupancies, you may be able to demonstrate energy compliance as if the whole building is residential for the space-conditioning and water-heating requirements. This is allowed if the residential occupancy accounts for at least 80 percent of the conditioned floor area of the building (or permitted space). Lighting compliance must be based on the requirements for each actual occupancy type.

Note: Mandatory measures apply separately to each occupancy type regardless of the compliance approach used. The residential envelope is subject to §150.0(a), (b), (c) and (d), while nonresidential envelope is subject to §120.7(a), (b) and (c).

For example, if complying under the mixed-occupancy exception, both residential and nonresidential documentation for mandatory measures must be submitted with other compliance documentation.

If the building design does not fit the criteria described above for a dominant occupancy, then the low-rise residential occupancy type must be shown to comply by itself. The remaining occupancy types must be shown to comply separately either by independent compliance for each occupancy or (for the nonresidential performance approach) by combining nonresidential occupancies in accordance with the rules of the *Nonresidential ACM Reference Manual*. This may be done by using any of the approved prescriptive or performance methods available for each occupancy type. As a result, documentation for each occupancy type must also be considered separately, and a certificate of compliance must be submitted for each occupancy type. Mixed high-rise and low-rise residential occupancies will not occur in the same building because the designation applies to the building.

8.4 Multifamily Buildings

§100.1(b)

Envelope, HVAC equipment, and outdoor lighting requirements for high-rise multifamily buildings (four or more habitable stories) are covered by the *Nonresidential Energy Standards*. These requirements are explained in the *Nonresidential Compliance Manual*. Indoor lighting in dwelling units and water-heating requirements for high-rise multifamily buildings are covered under the *Residential Energy Standards* and this compliance manual.

Low-rise multifamily buildings that are one to three habitable stories are covered by the *Residential Energy Standards*, which are covered in this manual. Compliance for a low-rise multifamily building may be demonstrated either for the building as a whole or on a unit-by-unit basis. Rental apartment buildings are usually modeled as a whole building. For multifamily buildings designed for dwelling units to be owner-occupied, the project developer may favor providing a separate, unique Title 24 compliance report for each dwelling unit. Floors and walls between dwelling units are considered to have no heat transfer and may be ignored in performance calculations.

8.4.1 Whole-Building Compliance Approach

The simplest approach to compliance for a multifamily building is to treat the building as a whole, using any of the compliance paths described in earlier chapters. In practice, this process is similar to analyzing a single-family residential building, except for some differences in water-heating budgets and internal gains, as described in the *2016 Residential ACM Reference Manual*.

Multifamily buildings that use efficiency measures that require HERS field verification must submit separate compliance documentation for each dwelling unit in the building as specified by Reference Residential Appendix Section RA2.3. This requirement does not prevent use of the whole-building compliance approach for submittal of the certificate of compliance to the enforcement agency; however, when the whole-building compliance approach has used a measure that requires HERS field verification, a separate copy of the whole-building certificate of compliance must be submitted to the HERS Provider for every dwelling unit to satisfy the requirements of the HERS Provider data registry documentation procedures. In practice, the certificate of compliance information may not need to be submitted to the HERS Provider more than once, but a relationship must be established in the HERS Provider data registry between the whole-building certificate of compliance and the corresponding dwelling-specific certificates of installation, and the dwelling-specific certificates of verification. Thus, for the whole-building compliance approach in a multifamily building that has used a compliance option that requires HERS verification, the required energy compliance documentation for each dwelling unit should consist of a whole-building certificate of compliance (CF1R-PRF-01-E), a dwelling-specific certificate of installation (CF2R), and a dwelling-specific certificate of verification (CF3R).

When the whole-building compliance approach is used for a multifamily building, some of the energy efficiency measures that require HERS field verification cannot be used for compliance credit in the performance calculations. These HERS measures are excluded from the whole-building compliance approach because they would require dwelling-specific data input into the compliance software.

The measures that cannot be used for the multifamily whole-building compliance approach, but can be used for credit when dwelling units are individually modeled, include:

1. Buried Ducts credit.
2. Deeply Buried Ducts credit.
3. Reduced Supply Duct Surface Area credit.
4. Maximum Rated Total Cooling Capacity credit.
5. Building Envelope Sealing credit (blower door test).

When the Energy Standards require registration of the compliance documents, the information for the certificate of compliance (CF1R), certificate of installation (CF2R), and certificate of verification (CF3R) must be submitted electronically to the HERS Provider data registry. Refer to Reference Residential Appendix RA2.3 for additional information on these document registration procedures.

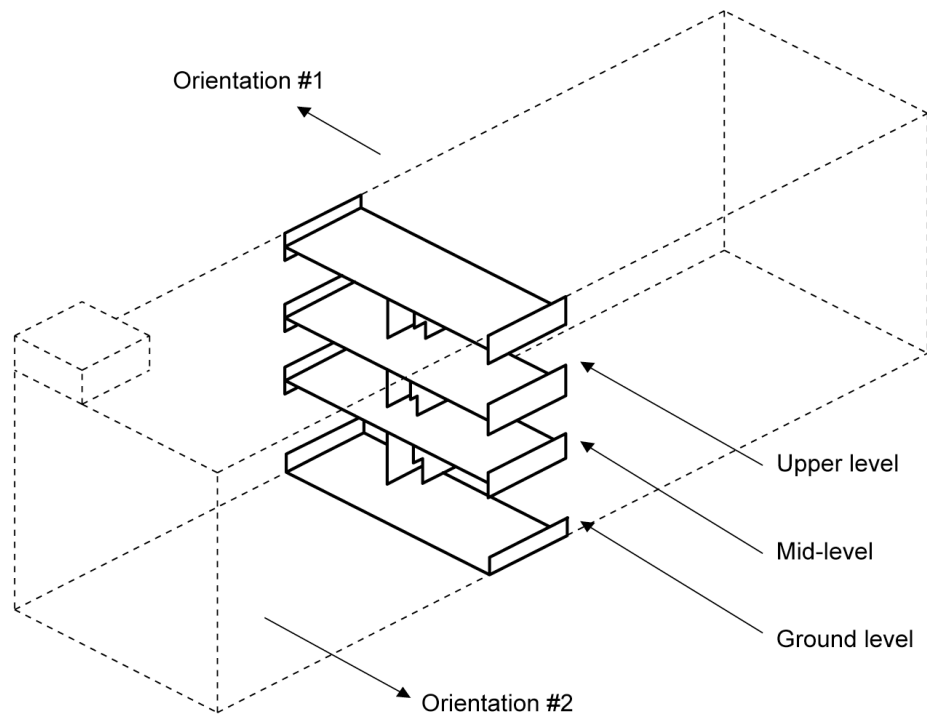
8.4.2 Unit-by-Unit Compliance Approach – Fixed Orientation Alternative

The unit-by-unit compliance approach for multifamily buildings requires that each dwelling unit must demonstrate compliance separately. The fixed orientation alternative requires that each unique dwelling unit in the building, as determined by orientation and floor level, must be separately modeled using an approved computer program. In this approach, surfaces that provide separation between dwelling units may be ignored since they are assumed to

have no heat loss or heat gain associated with them. Surfaces that provide separation between dwelling units and central/interior corridor areas must be modeled for heat transfer if the corridor area is not directly conditioned or indirectly conditioned space. (See Reference Joint Appendix JA1 for definition.) If the corridor area is conditioned, the corridor area may be modeled separately.

Different orientations and locations of each unit type within the building must be considered separately. That is, a one-bedroom apartment on the ground floor of a three-story building is different from the same plan on a middle floor or the top floor, even if all apartments have the same orientation and are otherwise identical. Likewise, end units must be modeled separately from the middle units, and opposite end units must also be modeled separately. With this approach, every unit of the building must comply with the Energy Standards, so this unit-by-unit approach is more stringent than modeling the building as a whole (See Figure 8-1).

Figure 8-1: Multifamily Building Compliance Option



Demonstrate Compliance for Each Generic Unit Type in Each of its Characteristic Locations

Example 8-2

Question

When preparing compliance calculations for a three-story apartment complex, I have the option of showing compliance for each dwelling unit or for the entire building. If I use the individual dwelling unit approach, do I need to provide calculations for every dwelling unit?

Answer

Each dwelling unit must comply with the Energy Standards when using this approach. When dwelling units have identical conditions, the calculations can be combined. This means you will show separate compliance for all unique conditions, such as:

- Front-facing north
- Front-facing west
- Front/side walls facing east and north
- Front/side walls facing east and south
- Middle units and both end units
- Exterior roof, no exterior floor
- Exterior floor, no exterior roof

Surfaces separating two conditioned spaces (such as common walls) have little heat transfer and can be disregarded in the compliance calculations.

Note: For multiple dwelling units that are identical in every way except orientation, a single multiple orientation report can be used to demonstrate compliance for those units. (See Section 8.4.3 below.)

8.4.3 Unit-By-Unit Compliance Approach – Multiple Orientation Alternative

Another option for showing unit-by-unit compliance for a multifamily building is the multiple orientation alternative. This method is similar to the method that may be used for single-family master plans in subdivisions (described in Section 8.5).

The performance method may be used to demonstrate that a dwelling unit plan in a multifamily building complies regardless of how it is oriented. To assure compliance in any orientation, the annual energy consumption must be calculated in each of the four cardinal orientations: true north, true east, true south, and true west. With this option, a dwelling unit plan must be modeled using the identical combination of energy features and levels in each orientation and must comply with the energy budget in each case. If a multifamily dwelling floor plan is used as both reversed and original/standard floor plan types, either the reversed plan or the original/standard plan may be used to demonstrate compliance, but compliance must be shown in all four cardinal orientations using only one of the plan types.

Each unique dwelling unit plan must be modeled using the worst-case condition for the energy features that the plan may contain within the multifamily building (for example, highest glazing percentage, least overhangs, largest wall surface area, and with exterior walls instead of party walls, if applicable). See Reference Residential Appendix RA 2.6.2 for information that describes how to determine when a dwelling is considered to be a unique model. Each unique dwelling plan must also be modeled separately for each unique floor level.

8.5 Subdivisions and Master Plans

Subdivisions often require a special approach to energy compliance, since they generally include one or a few basic building or unit plans repeated in a variety of orientations. The basic floor plans, as drawn, may also be used in a mirror image or reversed configuration.

The two compliance options for subdivisions are:

1. Model each individual building, or building condition, separately according to the actual orientation.
2. Model all four cardinal orientations for each building or plan type with identical conservation features for no orientation restrictions.

8.5.1 Individual Building Approach

The most straightforward compliance option for subdivisions is to analyze each building in the project separately using any compliance method. This may be practical for subdivisions with only custom buildings, or with only one or two specific orientations for each building plan. This approach requires that each unit comply separately, with separate documentation submitted for each unit plan in the orientation in which it will be constructed.

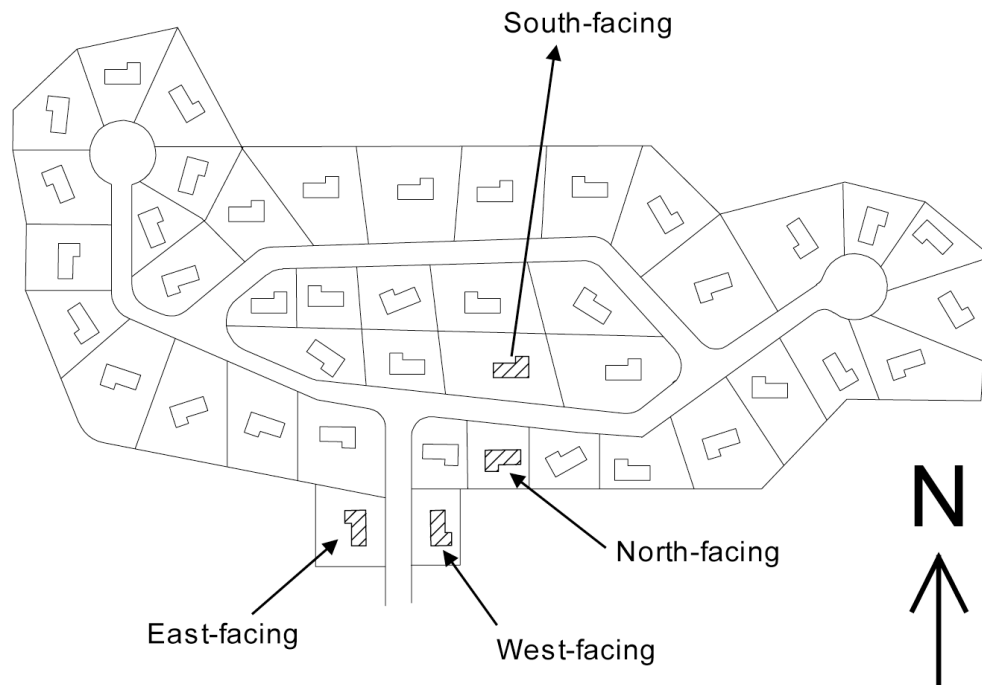
8.5.2 Multiple Orientation Alternative: No Orientation Restrictions

§150.1(b)

The performance method may be used to demonstrate that a single-family dwelling plan complies regardless of how it is oriented within the same climate zone. To assure compliance in any orientation, the annual energy consumption must be calculated in each of the four cardinal orientations: true north, true east, true south, and true west. With this option, the buildings must have the identical combination of conservation measures and levels in each orientation and comply with the energy budget in each case.

If a building floor plan is reversed, either the original plans or the reversed plans may be shown to comply in all four cardinal orientations.

Figure 8-2: Subdivisions and Master Plans Compliance Option



Demonstrate Compliance for Each Cardinal Orientation for Each Basic Model Type

For compliance, submit certificate of compliance documentation of the energy budgets for each of the four orientations to the enforcement agency. Only one CF1R form that documents compliance for all four orientations is required to be submitted to the enforcement agency for each unique plan.

Master plans that use the multiple orientation alternative and use a compliance approach that requires HERS field verification must submit a separate copy of the multiple orientation

master plan certificate of compliance to the HERS Provider for every dwelling unit in the subdivision to satisfy the requirements of the HERS Provider data registry documentation procedures. In practice, the certificate of compliance information for each multiple orientation master plan may not need to be submitted to the HERS provider data registry more than once. However, a relationship must be established in the HERS Provider data registry among the applicable multiple orientation master plan certificate of compliance and the corresponding dwelling-specific installation certificates (CF2R), and the dwelling-specific certificates of field verification and diagnostic testing (CF3R). Thus, for the multiple orientation compliance approach in a master plan subdivision that has used a compliance option that requires HERS verification, the required energy compliance documentation for each dwelling unit should consist of a multiple orientation master plan certificate of compliance (CF1R), a dwelling-specific installation certificate (CF2R), and a dwelling-specific certificate of verification (CF3R).

8.6 HVAC Issues

8.6.1 No Cooling Installed

When a building does not have a proposed cooling system, there is no compliance credit. The air-conditioning system is modeled to be equivalent to Package A. A hypothetical cooling duct system is modeled as equivalent to Package A (for example, Attic, R-6) or as matching the heating system ducts. Modeling no ducts is not an appropriate assumption.

8.6.2 Equipment Without SEER or HSPF

For equipment without a tested seasonal energy efficiency ratio (SEER), the energy efficiency ratio (EER) is used in place of the SEER. Another option is to use the EER of the equipment and use it for both the SEER and EER entry. If this approach is used, the EER must be verified by a HERS Rater.

Equipment without an heating seasonal performance factor (HSPF) rating is assumed to have 3.41 HSPF (electric resistance), 3.55 (electric radiant), or an HSPF calculated from a COP as $HSPF = (3.2 \times COP) - 2.4$.

8.6.3 Multiple HVAC Systems

Buildings with multiple HVAC systems can be treated several ways as follows:

1. For buildings that have more than one system type, equipment type, or fuel type, where the types do not serve the same floor area, model either the building zone or enter the floor area served by each zone type.
2. When multiple system types serve different thermal zones in one building, model each system and the associated thermal zone separately from other systems and zones.
Note: If both zones are associated with attic space, then a portion of the attic must be modeled with each zone.
3. Floor areas that are served by more than one heating or cooling system, equipment type, or fuel type must be modeled for compliance using the system with the most TDV energy consumption. For any areas served with electric resistance heat and another heating system (except for wood heating), the electric resistance shall be deemed to be the most TDV energy consuming system. The only exceptions to this are supplemental heating units may be installed in a space served directly or indirectly by a more efficient primary heating system. This is allowed if the thermal capacity of the supplement unit

does not exceed 2 kilowatts (kW), or 7,000 British thermal units per hour (Btu/h), and if the supplemental unit is controlled by a time-limiting device not exceeding 30 minutes. See §150.1(c)8C.

When there is more than one system meeting the heating or cooling load for the same space, all systems must still meet all the mandatory requirements of the Energy Standards.

For example, in a building with an appliance rated gas fireplace in combination with a central gas furnace, the central furnace would be used as the primary system and the fireplace would be treated as the supplemental system. The controls for the fireplace would not need to meet the setback thermostat requirements of §110.2(c) due to the exception.

For rooms such as the bedroom or bathroom, spot heating with a supplemental system may be desirable. Exception to §150.1(c)6 is provided for installing either a 2 kW electric resistance or 7,000 Btu/h gas heaters, with a 30-minute timer control for such instances. Therefore, this type of supplemental space heating need not meet the setback thermostat requirement.

8.6.4 Existing + Addition + Alteration Approach

The performance approach may be used to show compliance for alterations in existing buildings, new additions, and Existing + Addition + Alteration discussed in Section 9.7 of this manual. The following table can be used to model existing conditions based on the year of the building construction.

Table 8-1: Default Assumptions for Year Built (Vintage)

Conservation Measure	Before 1978	1978 to 1983	1984 to 1991	1992 to 1998	1999 to 2000	2001 to 2003	2004 to 2005	2006 to 2013	2014 to 2016
INSULATION U-FACTOR									
Cool Roof	0.10	0.10	0.10	0.10	0.10	0.10	0.10	Pkg. A	Pkg. A
Radiant Barrier	None	None	None	None	None	None	Pkg. A	Pkg. A	Pkg. A
Roof/Ceiling	0.079	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.031
Wall	0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102	0.102
Raised Floor –Crawl Space	0.099	0.099	0.099	0.049	0.049	0.049	0.049	0.049	0.037
Raised Floor-No Crawl Space	0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064	0.049
Slab Edge F-factor	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ducts	R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	Pkg. A	Pkg. A
LEAKAGE									
Building (ACH50)	7.7	7.7	7.7	7.7	7.7	7.7	7.7	6.8	5.0
Duct Leakage (%)	15%	15%	15%	15%	15%	15%	15%	15%	6%
FENESTRATION									
U-factor	Use Energy Standards Table 110.6-A , §110.6 for all Vintages								
SHGC	Use Energy Standards Table 110.6-B , §110.6 for all Vintages								
Shading Devices	Interior: Assumed to have draperies (not user editable). Exterior: Assumed to have 50% bugscreens, model actual overhangs.								
SPACE HEATING EFFICIENCY									
Gas Furnace (Central) AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Gas Heater (Room) AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Hydronic/Comb Hydronic	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Heat Pump HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4	7.7
Electric Resistance HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413
Electric Resistance Radiant HSPF	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.413
SPACE COOLING EFFICIENCY									
All Types, SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	13.0	13.0
WATER HEATING									
Energy Factor	0.525	0.525	0.525	0.525	0.575	0.575	0.575	0.575	0.575

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9. Additions, Alterations, and Repairs

9.1 Introduction

This chapter covers key aspects of how the Energy Standards apply to construction of residential additions, alterations to an existing residential building, or both. As explained further below, the 2016 Building Energy Efficiency Standards (Energy Standards) do not apply to repairs.

The chapter is organized as follows:

1. **Section 9.1 - Introduction.** Highlights the applicable standards definitions for additions, alterations, and repairs and provides several examples of each.
2. **Section 9.2 - What's New in the 2016 Energy Standards.** Highlights of the requirements and compliance options that have changed or are entirely new in the *2016 Energy Standards* as compared with the *2013 Energy Standards*.
3. **Section 9.3 - Compliance Approaches.** An overview of all prescriptive and performance compliance options available to meet the standards for additions only, for alterations only, and for projects that include both additions and alterations.
4. **Section 9.4 - Mandatory Requirements.** Mandatory requirements for additions and alterations as they apply to the envelope, fenestration, mechanical system, water heating system, indoor lighting, and outdoor lighting.
5. **Section 9.5 - Additions.** Detailed information on prescriptive and performance compliance methods and related information for additions, with or without alterations.
6. **Section 9.6 - Alterations.** Detailed information on prescriptive and performance compliance methods and related information for alterations, with or without an addition.
7. **Section 9.7 - Performance Method.** An explanation of the Existing + Addition + Alteration Approach with examples.

Whenever additions and alterations trigger mandatory measures – whether envelope, mechanical, water heating, indoor lighting or outdoor lighting – the certificate of compliance must be submitted with the permit documentation and included in the building plans.

When additions and alterations include changes to the envelope, mechanical systems, and/or water heating systems, a certificate of compliance must be completed prescriptively or generated by compliance software with the performance approach. The prescriptive certificate of compliance that should be used for additions and alterations in all climate zones is the CF1R-ADD or CF1R-ALT form. For HVAC-only change-outs and other mechanical system alterations, a climate zone specific CF1R-ALT-HVAC form for prescriptive compliance may be used. In addition, note that most additions and alterations that include changes in HVAC systems will include one or more measures that require HERS diagnostic testing and field verification. When a HERS measure is specified, the certificate of compliance must be registered online with an approved HERS Provider web site. Refer to Chapter 2 and to Residential Appendix RA2 for more information about document registration.

For copies of the appropriate compliance forms, refer to Appendix A of this manual.

9.1.1 Additions

An *addition* is any change to an existing building that increases conditioned floor area and conditioned volume. See §100.1.

Examples of projects considered as additions include:

1. Adding a conditioned sunroom or other rooms to an existing house.
2. Converting a garage or other existing unheated space into conditioned living space.;
3. Enclosing and conditioning an existing patio area.
4. Obtaining a permit to legalize an existing, habitable, and conditioned space that was added to a residential dwelling without a permit.
5. Adding a bay window that extends to the floor increasing both floor area and volume.

9.1.2 Alterations

An *alteration* is any change to a water-heating system, space-conditioning system, lighting system, or envelope of a building that is not an addition. See § 100.1.

Examples of projects considered alterations include:

1. Adding insulation to any existing exterior roof or ceiling, exterior wall, or raised floor over a crawl space, garage, or unheated basement.
2. Replacing or installing a new top surface to an existing roofing assembly (reroofing) and replacing portions of or the entire roof assembly.
3. Replacing existing fenestration or adding fenestration area (for example, windows, bay windows, greenhouse/garden windows, dynamic glazing, clerestories, or glass glazed doors) to existing walls.
4. Replacing an existing skylight or increasing the area of skylight to an existing roof.
5. Constructing an entirely new roof over an existing conditioned space.
6. Adding a loft within the existing conditioned volume of a home.
7. Replacing an existing heating system or adding a heating system (for example, a furnace, wall heater, heat pump or radiant floor).
8. Replacing an existing cooling system or adding a cooling system (for example, an air conditioner or heat pump).
9. Extending or replacing an existing duct system or adding an entirely new duct system.
10. Replacing the existing water heater or adding water heaters and/or hot water piping.
11. Replacing existing lighting or adding new hardwired lighting fixtures.
12. Adding window film, when complying under the performance approach only.

9.1.3 Repairs

A *repair* is “the reconstruction or renewal for the purpose of maintenance of any component, system, or equipment of an existing building. Repairs shall not increase the pre-existing energy consumption of the repaired component, system, or equipment. Replacement of any component, system, or equipment for which there are requirements in the Energy Standards is considered an alteration and not a repair.” (See §100.1).

Note: Repairs to residential buildings are not within the scope of the Energy Standards.

For example, when a component, system, or equipment of an existing building breaks or is malfunctioning and maintenance fixes are needed for it to work properly again, it is considered a repair and not subject to the standards. However, if instead of fixing the break or malfunction, it is decided to replace the component, system, or equipment with a new or different one, the scope of work is considered an alteration and not a repair and requirements of the Energy Standards pertaining the that measure must be met.

Examples of work considered repairs include:

1. Replacing a broken pane of glass but not the entire window.
2. Removing fenestration and other envelope components for maintenance or repair and then reinstalling the same fenestration or other envelope components in the same location;
3. Replacing a failed fan motor or gas valve in a furnace but not replacing the entire furnace;
4. Replacing a heating element in a water heater but not replacing the entire water heater.

Note: When any existing envelope component is moved to a new location, even when that location partially overlaps the previous location of the item, the work is considered an alteration.

Note 2: Replacement of some HVAC components for repair are defined by the Energy Standards as alterations, therefore triggering requirements that must be met. §150.2(b)1E of the Energy Standards defines the following HVAC component replacements as an alteration that triggers the requirement for duct sealing: *“replacement of the air handler, outdoor condensing unit of a split system air conditioner or heat pump, or cooling or heating coil.”* Similarly, if more than 40 linear feet of new or replacement space conditioning ducts are installed, then the entire duct system must be insulated, sealed, tested and verified for low duct leakage. (See §150.2 (b)1D)

Example 9-1

Question:

A sunspace addition is designed with no mechanical heating or cooling and a glass sliding door separating it from all existing conditioned space. This design is approved by the enforcement agency as nonhabitable or unimproved space. Under what conditions will the Energy Standards apply to this addition?



Unconditioned Sunspace

Answer:

The mechanical and envelope requirements of the Energy Standards do not apply if the space is not considered habitable or improved and, therefore, can be unconditioned as defined in §100.1; however, per §100.0(c)2, the sunspace must still comply with the applicable lighting requirements of §150.0(k). The sunspace is unconditioned if:

- The new space is not provided with heating or cooling (or supply ducts).
- All openings between the new space and the existing house can be closed off with weatherstripped doors and windows.
- The addition is not indirectly conditioned space (defined in §100.1 under CONDITIONED SPACE, INDIRECTLY).

A building official may require a sunspace to be conditioned if it appears to be habitable space, in which case the Energy Standards apply.

Example 9-2

Question:

An existing duplex is remodeled, which includes only the installation of new faucets and bathroom lighting. Do the Energy Standards apply?

Answer:

Yes, this remodel is considered an alteration. However, due to the limited scope of work and since no new conditioned space is being created, the remodel must comply only with the applicable mandatory measures described in §110.1 for appliances and §150.0(k) for residential lighting.

Example 9-3

Question:

An existing house is remodeled by adding additional floor area but not increasing the volume of the house. This was accomplished by adding a loft through an area in the house with a vaulted ceiling. As part of this remodel, new windows are replacing existing ones, and two new windows are being added. Several exterior walls are being opened up to install new wiring. What requirements will apply?

Answer:

Since floor area is being added but not conditioned volume, this is an alteration and not an addition. It will need to comply with the Energy Standards using either the prescriptive or performance method, as well as meet all the applicable mandatory measures. To comply prescriptively, the new and replacement windows must meet the maximum U-factor and SHGC requirements of §150.2(b)1. This may be done by area-weighted averaging. Newly installed and replacement windows must also comply with the mandatory measures for caulking/sealing around windows per §110.7. In alterations, it is recommended to install insulation in the exposed walls if no insulation was found when the walls were opened; for 2x4 wood framing install the mandatory minimum R-13 and for 2x6 wood framing install R-19.

Alternatively, the performance approach may be used to demonstrate compliance for the entire house, even if individual windows fail to meet the prescriptive requirements, as long as the building meets all applicable mandatory requirements. At this time, since the exterior walls are exposed or open, this allows the opportunity to insulate the walls and contribute the ability to meet energy compliance; otherwise it would be difficult to comply with overall building compliance.

9.2 What’s New in the 2016 Energy Standards

The 2016 Energy Standards include new mandatory measures and different compliance requirements for additions and alterations. This section highlights the key changes from the 2013 Energy Standards.

9.2.1 Mandatory Measures in Additions and Alterations

9.2.1.1 Envelope

- A. Ceiling and Rafter Roof: For additions of 700 ft² or less, insulation shall be installed between wood-framing members with insulation R-value of R-22 or a weighted average U-factor not exceeding U-0.043. Altered roofs limited by space may have only R-19 or 0.054 weighted average U-factor. Depending on the attic ventilation, insulation shall be installed either:
1. At the ceiling level for a ventilated attic, or
 2. At the ceiling or roof level for an unvented attic.
- B. The roofs and ceilings of additions that are 700 ft² or less shall meet the mandatory insulation requirement of §150.0(a). Additions that are greater than 700 ft² must comply with prescriptive ceiling and roof insulation (§150.1(c)1).

9.2.1.2 HVAC and Water Heating

Liquid line filter dryers are required for new HVAC systems or replaced condensers when provided by the manufacturer of the system.

9.2.1.3 Ducts and Air Distribution Systems

Installation of all new (or full replacement) duct systems:

1. Higher duct insulation levels for ducts located in unconditioned space resulting in either R-6 or R-8 dependent on climate zone §150.2(b)1D.
2. New target leakage level of 5 percent for entirely new or complete replacement duct systems §150.2(b)1D.

9.2.1.4 Lighting

The 2016 Energy Standards have simplified the residential lighting requirements with the following important changes:

1. All installed luminaires must be high-efficacy light sources as specified in Table 150.0-A of the Energy Standards. This change eliminates the previously required kitchen wattage calculation.
2. The definition of *high-efficacy lighting* has been expanded to include luminaires (including screw-based luminaires) that are installed with light sources or lamps that meet the requirements of JA8. This allows for installation of efficient lamps to be used for compliance with §150.0(k).
3. The only place screw-based luminaires **cannot** be used is for recessed downlights in ceilings. Recessed downlights are required to contain JA8-compliant light sources that also meet elevated temperature requirements.

More details of the 2016 Energy Standards residential lighting requirements can be found in Chapter 6.

9.2.2 Prescriptive Additions

1. All new size (conditioned floor area) categories and new special requirements for prescriptive additions as outlined in this section and Tables 9-3A through 9-3E.
2. Extensions of existing wood-framed walls may retain the dimensions of the wall being extended. For example, continuous insulation would not be required for an extension if the existing wall did not already have continuous insulation. Wall extensions shall be insulated with cavity insulation of R-15 in 2x4 framing and R-19 in 2x6 framing.

9.2.3 Prescriptive Alterations

New requirements for duct insulation apply when the new ducts are located in unconditioned spaces.

See Table 9-4 in this chapter for a summary of how the compliance software sets the standard design (energy budget) for alterations.

9.3 Compliance Approaches

Apart from meeting all applicable mandatory requirements as outlined in Section 9.4, an addition or alteration must also demonstrate energy compliance using a prescriptive or performance method.

There are several compliance alternatives or compliance paths to demonstrate that an addition or alteration meets the Energy Standards. Compliance alternatives depend on whether the scope of permitted work is:

1. **Addition only**, where no changes are being made to the existing building except removal of roofs, exterior walls, and floors required as a result of the addition; and removal of any fenestration in those same removed roofs and exterior walls to make way for the addition.
2. **Alterations only**, where there is no addition (that is, no increase in conditioned floor area and volume).
3. **Addition and alterations**, where there are both additions and alterations to the existing building.

For each of these permit scenarios, Table 9-1 summarizes the available compliance approaches for low-rise residential additions and alterations.

Table 9-1: Compliance Alternatives for Residential Additions and Alterations

Project Scope	Prescriptive Approach	Performance Approach ^{1, 2}
1. Addition Only:	Additions ≤ 400 ft ² ; or	Addition Alone
	Additions > 400 ft ² and ≤ 700 ft ²	
	Additions > 700 ft ² ; or	
2. Alteration Only:	Meet All Applicable Requirements for Prescriptive Alterations	Existing + Alterations Without Third Party Verification of Existing Conditions; or
		Existing + Alterations With Third Party Verification of Existing Conditions; or
		Existing + Alterations as All New Construction

3. Addition and Alteration Combined:	Meet All Applicable Requirements for Prescriptive Alterations and a Prescriptive Addition Approach (see Additions Only above)	Existing + Addition + Alterations Without Third Party Verification of Existing Conditions; or
		Existing + Addition + Alterations With Third Party Verification of Existing Conditions; or
		Existing + Addition + Alterations as All New Construction
<p>1) In the performance method, the building must be modeled with Energy Commission-approved compliance software as explained in Chapter 8 of this manual.</p> <p>2) The Existing + Alterations performance approach with or without third party verification may be used only if there are at least two types of altered components in the existing building. This requirement does not apply to the Existing + Addition + Alterations compliance method.</p>		

9.3.1 Additions Only

9.3.1.1 Prescriptive

The prescriptive requirements for new addition construction are listed in §150.2(a)1. Unless otherwise noted, the prescriptive requirements contained in §150.1(c) also apply.

- A. **Additions of ≤ 300 ft²:** Does not require a cool roof to be installed;
- B. **Additions ≤ 400 ft²:**
 - 1. Total glazing area up to 75 ft² or 30 percent of the conditioned floor area, whichever is greater.
 - 2. Total glazing area maximum for west facing glazing is 60 ft² or 5 percent in Climate Zones 2, 4, and 6-16.
 - 3. Mandatory ceiling insulation of R-22.
 - 4. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-frame walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-frame walls, insulation shall be R-19.
- C. **Additions > 400 ft² and ≤ 700 ft²:**
 - 1. Total glazing area up to 120 ft² or 25 percent of the conditioned floor area.
 - 2. Total glazing area maximum for west-facing glazing is 60 ft² or 5 percent in Climate zones 2, 4, and 6-16.
 - 3. Mandatory ceiling insulation of R-22.
 - 4. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-frame walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-frame walls, insulation shall be R-19.
- D. **Additions > 700 ft²:**
 - 1. Total glazing area up to 175 ft² or 20 percent of the conditioned floor area, whichever is greater.

2. Total glazing area maximum for west-facing glazing is 70 ft² or 5 percent in Climate zones 2, 4, and 6-16.
3. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-frame walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-frame walls, insulation shall be R-19.

Note: Except as noted, all applicable prescriptive requirements for additions must be met when using the prescriptive approach. Otherwise, the building must comply using the performance approach.

For prescriptive additions, a certificate of compliance (CF1R-ADD) form must be completed and submitted for permit. If any mandatory or prescriptive measures require HERS verification and/or testing, the certificate of compliance for the project must be registered online with a HERS Provider before submittal to the enforcement agency. Refer to Section 2.2.2 and Section 2.5.

9.3.1.2 Performance

Additions may comply using the performance approach by meeting the requirements in §150.2(a)2 and explained further in Section 9.7. The performance options are:

A. Addition Alone

In this compliance scenario, the addition alone is modeled using the compliance software, and the existing building is not modeled at all. This approach may work well when the existing building is not undergoing alterations, and the permitted work scope covers only the addition.

1. **Advantages:** Data for the existing building are not needed except for the total existing conditioned floor area that is used to calculate the fractional “number of dwelling units” for the addition. The existing building is not modeled and not analyzed for altered components or systems. This typically saves a large amount of time performing the analysis.
2. **Disadvantages:** The prescriptive allowances for additions do not apply to the addition alone performance approach. If the addition includes a large area of glazing or is otherwise deficient in comparison with the prescriptive requirements, it may be difficult to demonstrate compliance under this approach. Alterations to the existing conditions that improve the energy performance of the existing building cannot be used in this approach as “trade-offs” with the addition.

B. Existing + Addition + Alteration

In this compliance scenario, the entire building is included in the analysis. This approach does not require unaltered existing components to be brought in to compliance.

1. **Advantages:** This approach offers the most flexibility by modeling improvements to the existing building. The energy budgets include the more generous glazing allowances given to prescriptive compliance.
2. **Disadvantages:** Plans and data for the existing building are needed, increasing the time and complexity of the calculations.

C. Existing + Addition as New Construction

Demonstrating compliance as a whole new building, which entails combining existing plus the addition as all new construction, is another approach. This approach is used when the addition alone does not comply or changes are extensive. Compliance can be hard to achieve because all existing features must be brought up to the current code.

9.3.2 Alterations Only

9.3.2.1 Prescriptive

Alterations may comply prescriptively by meeting all applicable requirements in §150.2(b), which are explained further in Section 9.6 and summarized in Tables 9-5 and 9-9. Several prescriptive alteration requirements are specific to the building site climate zone. There are also several exceptions to the prescriptive requirements based on either climate zone or other conditions listed in the Energy Standards.

Note: Every applicable prescriptive alteration requirement must be met to use the prescriptive approach; otherwise, the building must comply using a performance approach.

Under the prescriptive alteration approach, the appropriate certificate of compliance (for example, CF1R-ALT or CF1R-ALT-HVAC) form must be completed and submitted for a permit. If any mandatory or prescriptive measures require HERS verification or testing (see Section 2.5, HERS Field Verification and Diagnostic Testing of this manual), the certificate of compliance for the project must be registered online with a HERS Provider (see Section 2.3 of this manual) before submittal to the enforcement agency.

9.3.2.2 Performance

Alterations may comply using the performance approach by meeting the requirements in §150.2(b)2. This is explained in Section 9.7 and summarized in Table 9-1. The main options are:

1. **Existing + Alterations:** When two or more types of components or systems are being altered in the existing building, then the existing + alterations performance approach may be used.
2. **Compliance Without Third-Party Verification** allows for compliance of the alterations without the need for third-party inspection to verify existing conditions being altered.
3. **Compliance With Third-Party Verification** allows for compliance of the alterations only with third-party inspection to verify existing conditions being altered.
4. **Existing + Alterations** as new construction: Demonstrating alterations compliance as a whole new building is usually difficult to achieve but still an option. Typically this approach is used when prescriptive alterations cannot meet the prescriptive requirements in Table 150.1-A in the Energy Standards.

Note: Every applicable prescriptive alteration requirement must be met to use the prescriptive approach; otherwise, the building must comply using a performance approach.

9.3.3 Additions and Alterations Combined

9.3.3.1 Prescriptive

When a low-rise residential project includes both an addition and any alterations, the prescriptive requirements for each condition must be met. The addition may comply with any of the prescriptive addition options explained above and documented with the appropriate

compliance forms (for example, CF1R-ADD). The alterations must also meet all prescriptive requirements and be documented with the specific compliance forms for alterations (for example, CF1R-ALT, CF1R-ALT-HVAC).

9.3.3.2 Performance

The performance path that includes both additions and alterations is the “**Existing + Addition + Alterations**” approach. (See Section 9.7.) There are two ways to analyze the building using this method: compliance with third-party verification of all existing conditions altered or compliance without third-party verification.

9.4 Mandatory Requirements

The mandatory measures apply to all newly added or altered envelope components regardless of whether the prescriptive or performance compliance method is used. This section describes the mandatory requirements for low-rise residential buildings as they apply to additions and alterations. More information on the mandatory measures can be found in Chapters 3, 4, 5, and 6.

9.4.1 Envelope Measures

Envelope mandatory measures are listed below, including the relevant reference in the Energy Standards and the section number in this manual. The following measures include fenestration products, exterior doors, insulation, roofing products, and radiant barriers. See Sections 3.2 – 3.8 and the Energy Standards for more information.

- A. Manufactured fenestration products and exterior doors air leakage infiltration rates, see §110.6(a)1, Section 3.5.3.1
- B. Fenestration U-factor, SHGC, VT ratings, see §10-111, §110.6(a)2, 3 & 4, Section 3.5.3.2
- C. Fenestration temporary and permanent labels, see §110.6(a)5, Section 3.5.3.3
- D. Fenestration maximum weighted average U-factor = 0.58, see §150.0(q), Section 3.5.3.4
- E. Installation of field-fabricated fenestration and exterior doors, see §110.6(b), Section 3.5.3
- F. Sealing joints and other openings, see §110.7, Section 3.6.1.1
- G. Certification of insulating materials, see §110.8(a), Section 3.6.1.2
- H. Restrictions on use of urea formaldehyde foam insulation, see §110.8(b), Section 3.6.1.3
- I. Flame spread insulation ratings, see §110.8(c), Section 3.6.1.4
- J. Insulation placement on roof/ceilings, see §150.0(a), Section 3.6.1.9;
- K. Minimum roof/ceiling insulation, see §150.0(a), Section 3.6.1.9
- L. Minimum roof/ceiling insulation in an existing attic, see §110.8(d)1 and §150.0(a), Section 3.6.1.9
- M. Roofing products (cool roofs) solar reflectance and thermal emittance rating and labeling, see §10-113 and §110.8(i), Section 3.6.1.7
- N. Radiant barrier, see §110.8(j), Section 3.6.1.8

- O. Loose-fill insulation, see §150.0(b), see Section 3.6.1.10
- P. Minimum wall insulation, see §150.0(c), see Section 3.6.1.11
- Q. Minimum floor insulation, see §150.0(d), see Section 3.6.1.12
- R. Slab edge insulation moisture resistance and physical protection, see §150.0(f), Section 3.6.2.3
- S. Insulation requirement for heated slab floors, see §110.8(g), Section 3.6.1.14
- T. Vapor retarder §150.0(g), see Section 3.6.1.15.

9.4.1.1 Ceiling/Roof and Wall Insulation

When insulation is installed in the attics of existing buildings, at least R-22 shall be installed in all climate zones. When ceilings without attics are altered, at least R-19 shall be installed between wood-framing members, or enough insulation shall be installed to achieve the equivalent of R-19 insulation between wood-framing members. When the space between framing members becomes accessible as a part of a ceiling/roof modification, the ceiling/roof is considered altered, and the insulation measure applies. However, if the roofing surface material is replaced but the roof sheathing is not being removed, there is no insulation requirement.


Existing buildings that already have R-11 insulation installed in framed walls are exempt from the mandatory minimum R-13 or R-19 wall insulation required by §150.0(c) if the building can demonstrate performance method compliance with the walls modeled as R-11.

9.4.1.2 Roofing Products: Cool Roof

Roofing products installed to meet prescriptive requirements or to take performance compliance credit for reflectance and emittance are referred to as “cool roofs” Cool roofs are specially designed to reflect much of the sun’s radiant energy back into space instead of transferring it as heat into the building below. The two basic characteristics that determine the performance of a cool roof are solar reflectance and thermal emittance. These roofing products must be certified by the Cool Roof Rating Council (www.coolroofs.org) per §10-113 and §110.8(i).

To be considered a cool roof, the roofing products manufacturer must have its roofing product tested for solar reflectance and thermal emittance, and be listed in the Cool Roof Rating Councils (CRRC) Rated Product Directory. Figure 9-1 provides an example of an approved CRRC product label.

Figure 9-1: CRRC Product Label and Information

	<u>Initial</u>	<u>Weathered</u>	
	Solar Reflectance	0.00	Pending
	Thermal Emittance	0.00	Pending
	Rated Product ID Number	-----	
Licensed Seller ID Number	-----		
Classification	Production Line		
<small>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.</small>			
<small>Manufacturer of product stipulates that these ratings were determined in accordance with the applicable Cool Roof Rating Council procedures.</small>			

If the aged value for the reflectance is not available in the CRRC's Rated Product Directory, then the equation below can be used until the aged rated value for the reflectance is posted in the directory.

Equation 9-1: Aged Reflectance

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

Where:

ρ_{initial} = Initial Reflectance listed in the CRRC Rated Product Directory

β = soiling resistance value listed in Table 9-2

Table 9-2: Soiling Resistance Value β , by Product Type

PRODUCT TYPE	β
Field-applied coating	0.65
Other	0.70

9.4.1.3 Fenestration

New or replacement (altered) glazing, including skylights, must meet the maximum U-factor requirement in one of three ways:

1. All fenestration products (glazed opening) must meet the mandatory maximum U-factor of 0.58; or
2. All new or replacement fenestration combined must meet the mandatory maximum of 0.58 U-factor using an area weighted average calculation; or
3. The area of new and replacement fenestration up to 10 ft² or 0.5 percent of the conditioned floor area (CFA), whichever is greater, is exempt from the maximum U-factor requirement per Exception to §150.0(q).

Example: An existing 2,500 ft² house undergoes an alteration with all the existing windows being replaced. The owner may install up to 12.5 ft² of new glazing (that is, up to 0.5 percent of 2,500 ft²) without meeting the maximum U-factor of 0.58, if the overall alterations meet the Energy Standards with the prescriptive or performance approach.

Consistent with Exception 1 to §150.1(c)3A: For each dwelling unit, up to 3 ft² of new glazing area installed in doors and up to 3 ft² of new tubular skylight area with dual-pane diffusers shall not be required to meet or be included in the area-weighted average fenestration calculation to meet the mandatory requirement of §150.0(q).

9.4.1.4 Greenhouse Windows

Greenhouse or garden windows are special windows that project from the façade of the building. They are typically five-sided structures. NFRC-rated U-factors for greenhouse windows are comparatively high and may not meet the mandatory maximum U-factor of 0.58.

For new buildings and additions, §150.0(q) includes an exception from the U-factor requirement for dual-glazed greenhouse or garden windows that total up to 30 ft² of fenestration area. However, the exempted area shall be included in the area-weighted average calculation.

For additions with more than 30ft² of greenhouse and garden windows, the area-weighted average for all new and replacement fenestration must be used to show that the combined average U-factor complies with the U-factor requirement.

For alterations, dual-glazed greenhouse or garden windows are deemed to comply with U-factor requirements.

9.4.2 Mechanical (HVAC) and Water-Heating Measures

Mechanical (HVAC) system and water-heating mandatory measures are listed below for additions and alterations. They include measures applicable to space-conditioning equipment, controls, and systems; water heaters, controls, and systems, pool and spa equipment, controls, and systems; outdoor air ventilation; pipe insulation; air ducts and plenums; and fireplaces. See Energy Standards and manual section references below:

1. Appliance efficiencies and verification, see §110.1, Section 4.1.4
2. Space conditioning equipment efficiencies, see §110.2(a), Sections 4.2.1 & 4.3.1
3. Heat pump controls, see §110.2(b), Sections 4.2.1.2
4. Setback thermostats (in most cases), see §110.2(c), Section 4.5.1
5. No continuously burning gas pilot lights, see §110.5, Sections 4.2.1.5
6. Heating and cooling load calculations, see §150.0(h), Sections 4.2.1.3 & 4.3.1.4
7. Pipe insulation and refrigerant line insulation, see §150.0(j), Section 5.3.5.1 & 4.3.1.2
8. Duct insulation and protection of insulation, see §150.0(m), Section 4.4.1
9. Dampers to prevent air leakage, see §150.0(m), Section 4.4.1.8
10. Flexible duct labeling, see §150.0(m), Section 4.4.1.7
11. Duct connections and closures, see §150.0(m), Section 4.4.1.2
12. Duct system sealing and leakage testing, see §150.0(m)11, Section 4.4.1.12
13. Zonally controlled central forced-air systems, see §150.0(m)13, Section 4.4.1.17
14. Mechanical ventilation for indoor air quality, see §150.0(o), Section 4.6
15. Fireplaces, decorative gas appliances, and gas logs, see §150.0(e), Section 3.6.1.13
16. Water-heating systems, see §150.0(n), Chapter 5
17. Solar water heating, see §150.0(n)3, Section 5.5
18. Pool systems and equipment installation, see §150.0(p), Section 5.6.

9.4.3 Mechanical Ventilation

The whole-building ventilation airflow requirement in ASHRAE 62.2 is required only in new buildings and buildings with additions greater than 1,000 ft². However, all other mechanical ventilation requirements in §150(o), including local exhaust, must be met, as applicable, in all additions and alterations.

When whole-building ventilation airflow is required for compliance, field verification and diagnostic testing of airflow performance are required in accordance with the procedures in Residential Appendix RA3.7. In that case, a Certificate of Compliance CF1R form must be registered online with a HERS Provider. (See Section 2.5 and Appendix A.)

9.4.4 Lighting Measures

Highlights of the residential lighting measures are listed below. All residential indoor and outdoor lighting measures are mandatory. Details of the *2016 Energy Standards* residential lighting requirements can be found in Chapter 6.

1. Luminaire (light fixture) requirements, see §150.0(k)1, Section 6.2
2. Indoor lighting controls, see §150.0(k)2, Section 6.3
3. Lighting in bathrooms, garages, laundry rooms, and utility rooms, see §150.0(k)2J, Section 6.3.3
4. Recessed downlight fixtures, see §150.0(k)1C, Section 6.2.3
5. Outdoor lighting, see §150.0(k)3, Section 6.5
6. Internally illuminated address signs, see §150.0(k)4, Section 6.5.4
7. Residential garages for eight (8) or more vehicles, see §150.0(k)5, Section 6.6
8. Interior common areas of low-rise multifamily buildings, see §150.0(k)6, Section 6.4

Altered lighting and any newly installed lighting equipment are required to comply with the residential lighting standards, which apply to permanently installed lighting and associated lighting controls.

Only the lighting equipment that is altered needs to comply with the Energy Standards. Existing lighting equipment is not required to be replaced to comply with the Energy Standards.

Example 9-4

Question:

I am doing minor renovations to my kitchen that has six recessed incandescent cans and I am adding a new luminaire over the sink. Does this luminaire have to be a high-efficacy luminaire?

Answer:

Yes, in kitchens all new luminaires must be high efficacy.

Example 9-5

Question:

In the kitchen above, I am replacing one of the recessed downlight luminaires. Must the new downlight luminaire be high-efficacy?

Answer:

Yes, newly installed luminaires must be high-efficacy and meet the requirements in §150.0(k). Note that Screw-based sockets are not permitted for newly installed recessed downlight luminaires in ceilings.

Example 9-6

Question:

I am completely remodeling my kitchen and putting in an entirely new lighting system. How do the Energy Standards apply to this case?

Answer:

When an entirely new lighting system is installed, it is treated like new construction. The new lighting system must comply with all of the mandatory lighting requirements in §150.0(k)1 and (k)2.

See Section 6.2 and 6.3 of this manual for additional information.

Example 9-7

Question:

I am replacing my incandescent bath bar in the bathroom. Must the new luminaire meet the Energy Standards requirements?

Answer:

The new luminaire is the altered component and must meet requirements in §150.0(k), including the high-efficacy luminaire and lighting control requirements. The *2016 Energy Standards* now allow the installation of Joint Appendix JA8-compliant lamps in screw-based fixtures as a way to comply with the high-efficacy lighting requirements as long as the luminaire is not a recessed downlight in ceiling. See Sections 6.2 and 6.3 of this manual for details.

9.5 Additions

For a definition of an addition in the Energy Standards and several useful examples of additions, see Section 9.1 of this chapter.

For a summary of compliance alternatives for additions, see Section 9.3.1 of this chapter.

This section provides more specific information, descriptions, and guidelines on how to meet the Energy Standards using each of the available compliance paths. Copies of compliance forms referenced here are included in the Compliance Forms Summary, Appendix A of this manual.

9.5.1 Prescriptive Requirements

In general, the prescriptive requirements apply to additions in the same way they apply to entirely new buildings and must be documented on the CF1R-ADD Form. However, there are a few exceptions as noted below and summarized in Table 9-3A.

There are three prescriptive paths available for additions based on the total conditioned floor area (CFA) of the addition. The total CFA of the addition may include floor areas representing several physically separate additions to the building under the same permit.

Table 9-3A summarizes the key features of the prescriptive envelope requirements for the three prescriptive addition options in §150.2(a)1. Envelope requirements unique to that type of prescriptive addition are shown in bold face on white background. Table 9-3E shows that all prescriptive additions have the same mechanical system and water heating system requirements as the Package A prescriptive measures for new construction listed in §150.1(c) and explained in Chapters 4 and 5. For more details on the residential envelope requirements and compliance options, refer to Chapter 3.

A. Additions ≤ 400 ft²

All prescriptive Package A requirements must be met **except**:

1. Total glazing area may be up to 75 ft² or 30 percent of conditioned floor area, whichever is greater.
2. West-facing glazing area may be up to 60 ft².

3. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-framed walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-framed walls, insulation shall be R-19.
4. No requirement for a whole-house fan (WHF) to provide ventilation cooling.
5. Mandatory roof and ceiling insulation requirements (§150.0a).
6. For additions $\leq 300 \text{ ft}^2$, cool roof compliance is not required.

B. Additions > 400 ft² and \leq 700 ft² :

All prescriptive Package A requirements must be met **except**:

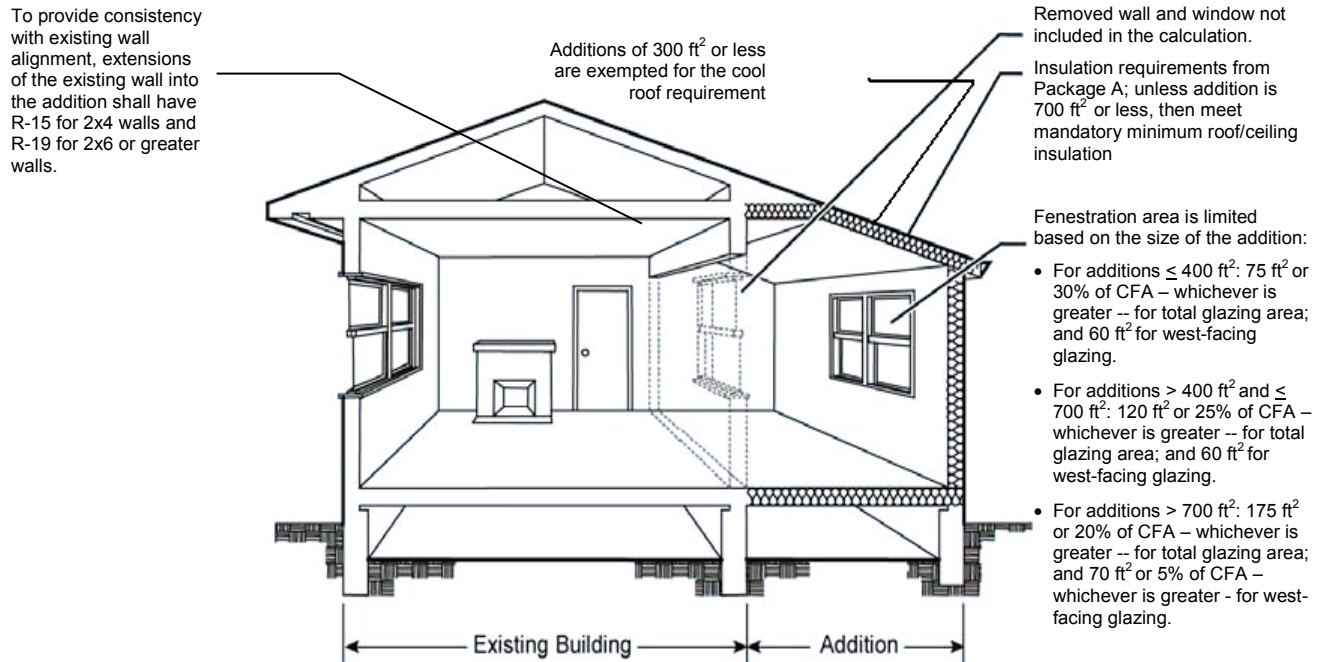
1. Total glazing area may be up to 120 ft^2 or 25 percent of conditioned floor area, whichever is greater.
2. West-facing glazing area may be up to 60 ft^2 .
3. Extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-framed walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-framed walls, insulation shall be R-19.
4. No requirement for a whole-house fan (WHF) to provide ventilation cooling.
5. Mandatory roof and ceiling insulation requirements (§150.0(a)).

C. Additions > 700 ft²

All prescriptive Package A requirements must be met **except**:

1. Total glazing area may be up to 175 ft^2 or 20 percent of conditioned floor area, whichever is greater.
2. West-facing glazing area may be up to 70 ft^2 or 5 percent of conditioned floor area, whichever is greater.
3. If the total proposed fenestration area exceeds the standard maximum glazing area of 20 percent, then the performance compliance approach must be used. Likewise, if the proposed west-facing fenestration area in Climate Zones 2, 4, and 6-16 exceeds 5 percent of the conditioned floor area, then the performance compliance approach must be used.
4. To provide consistency with existing wall alignment, extensions of existing wood-framed walls may retain the dimensions of the existing walls and require the following cavity insulation:
 - a. In 2x4 wood-framed walls, insulation shall be R-15.
 - b. In 2x6 or greater wood-framed walls, insulation shall be R-19.
5. Whole-house fan (WHF) requirement:
 - a. If the addition is $1,000 \text{ ft}^2$ or less, there is no requirement for WHF to provide ventilation cooling.
 - b. Additions greater than $1,000 \text{ ft}^2$ must include provide ventilation cooling with a WHF, as indicated in §150.1(c)12 in climate zones 8-14.

Figure 9-2: Prescriptive Addition Envelope Requirements



9.5.2 Compliance Forms for Prescriptive Additions

The permit applicant must submit a completed version of the Certificate of Compliance, CF1R-ADD form for prescriptive additions when less than 1000 ft².

All projects that require third-party diagnostic testing and/or field verification by a HERS Rater *must also have the CF1R-ADD form uploaded and registered online with a HERS Provider.* (See Chapter 2.)

Use the CF1R-ADD form to document fenestration by orientation. The total percentage of fenestration should be no greater than the amount summarized above and in Table 9-3A. West-facing area includes skylights tilted to the west or tilted in any direction when the pitch is less than 1:12 (9.5 degrees from the horizontal) and must not exceed 5 percent of the conditioned floor area (CFA) in Climate Zones 2, 4, and 6-16.

Plan checkers will verify on the CF1R-ADD form that the total proposed glazing area is less than or equal to the standard maximum glazing area, and that the proposed west-facing glazing area is less than or equal to the standard west-facing glazing area.

9.5.3 Fenestration Exceptions

New fenestration in prescriptive additions must meet the area-weighted average U-factor and SHGC requirements in §150.1(c)3A, with the following exceptions particularly relevant to additions:

1. **EXCEPTION 1:** For each dwelling unit, up to 3 ft² of new glazing in doors and up to 3 ft² of tubular skylights with dual-pane diffusers are exempt.

2. **EXCEPTION 2:** For each dwelling unit, up to 16 ft² of skylights with a maximum U-factor of 0.55 and a maximum SHGC of 0.30 is exempt.

See Section 3.5 for further information on fenestration that meets or is exempt from §150.1(c)3A in new construction.

Other Prescriptive Addition Envelope Measures

For further information on prescriptive envelope measures which are not specific to additions and not mentioned above, see Chapter 3.

Prescriptive Mechanical Measures

For a summary and discussion of prescriptive mechanical requirements when installing new or replacement space-conditioning equipment and/or ducts, see Section 9.6.2.

Example 9-8

Question:

When using the performance approach for the addition alone, do the refrigerant charge requirements in §150.1(c)7A and fan airflow and watt draw measurements in §150.0(m)13 need to be met for existing central split-system air conditioners serving an addition?

Answer:

If existing equipment is used to serve the addition, the refrigerant charge, airflow, and watt draw requirements do not need to be met as specified by Exception 5 to §150.2(a). However, if added ducts to serve the addition are more than 40 linear feet and they are in unconditioned space, then the ducts must be tested and verified by a HERS Rater as described in §150.2(b)1D. All installed ducts regardless of length and location shall be sealed and meet insulation levels as described in §150.0(m) Items 1 through 6.

If a new central split system is installed to serve the addition, it must meet all of the requirements for air conditioners in a new residence.

Table 9-3A: Envelope Roof/Ceiling Requirements for Prescriptive Additions

Component	Requirements of Additions ≤ 400 ft ²	Requirements of Additions > 400 ft ² and ≤ 700 ft ²	Requirements of Additions > 700 ft ²
Roof/Ceiling Insulation:	Mandatory requirements	Mandatory requirements	Option A, B, or C (see Table 9-3B below).
Roof Products (Cool Roof):	<u>Package A:</u> <u>Steep-Sloped (> 2:12):</u> CZ10-15: Reflect.=0.20 and Emittance=0.75; or SRI=16	<u>Package A:</u> <u>Steep-Sloped (> 2:12):</u> CZ10-15: Reflect.=0.20 and Emittance=0.75; or SRI=16	<u>Package A:</u> <u>Steep-Sloped (> 2:12):</u> CZ10-15: Reflect.=0.20 and Emittance=0.75; or SRI=16
	<u>Package A:</u> <u>Low-Sloped (< 2:12):</u> CZ13 & 15: Reflect.=0.63 and Emittance=0.75; or SRI=75	<u>Package A:</u> <u>Low-Sloped (< 2:12):</u> CZ13 & 15: Reflect.=0.63 and Emittance=0.75; or SRI=75	<u>Package A:</u> <u>Low-Sloped (< 2:12):</u> CZ13 & 15: Reflect.=0.63 and Emittance=0.75; or SRI=75
	<u>Exception:</u> Additions ≤ 300ft ² exempt from all cool roof requirements.		
Radiant Barrier Above Attic:	<u>Package A:</u> CZ2-15: Radiant Barrier above Attic Spaces	<u>Package A:</u> CZ2-15: Radiant Barrier above Attic Spaces	<u>Package A:</u> CZ2-15: Radiant Barrier above Attic Spaces, except when complying with Option B from §150.1(c)

Figure 9-3: Ventilated Attic Prescriptive Compliance Choices for Additions >700ft²

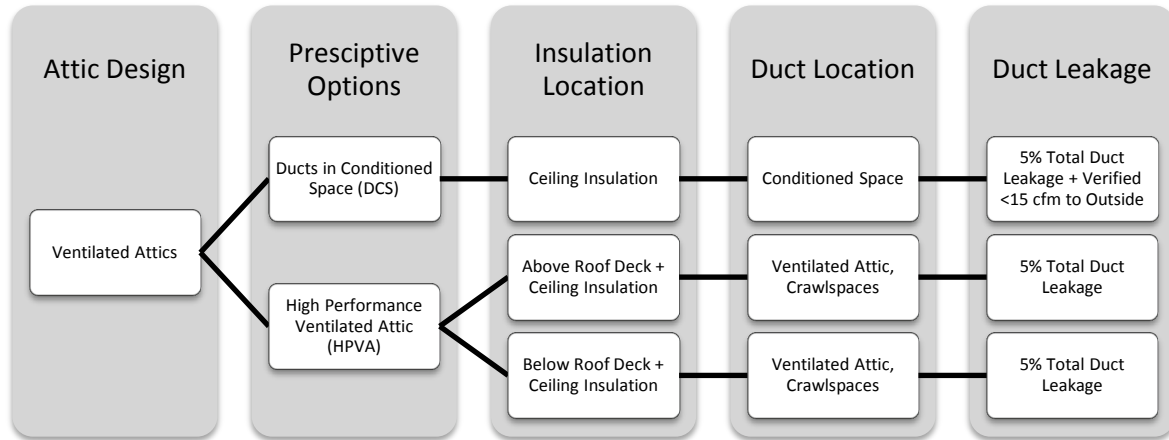


Table 9-3B: Roof and Ceiling Requirements for Prescriptive Additions

	Option A (CZ 4, 8-16)	Option B (CZ 4, 8-16)	Option C (CZ 4, 8-16)
Roof Deck Insulation ^{1,2}	Above deck continuous insulation: R6 (with air space), R8 (no air space)	Below deck insulation: R13 (with air space), R18 (no air space)	None required (NOTE: This attic requires ducts in conditioned space)
Ceiling Insulation	R38	R38	CZ 4, 8-10: R30 CZ 11-16: R38
Duct Location	Attic allowed	Attic allowed	Conditioned Space

1. Roof deck insulation should be installed flush with the roof deck. Above deck insulation is applied as continuous insulation. Below deck insulation is installed in the cavities between trusses.

2. A designed air space may exist between the roof deck and the finishing roofing material, triggering lower required insulation values.

Table 9-3C: Envelope Glazing Requirements for Prescriptive Additions

Component	Requirements of Additions ≤ 400 ft ²	Requirements of Additions > 400 ft ² and ≤ 700 ft ²	Requirements of Additions > 700 ft ²
Total Glazing Area:	Up to 75 ft ² or 30% of Conditioned Floor Area, whichever is greater	Up to 120 ft ² or 25% of Conditioned Floor Area, whichever is greater	Up to 175 ft ² or 20% of Conditioned Floor Area, whichever is greater
West-Facing Glazing Area: In Climate Zone 2, 4, 6-16	Up to 60 ft ²	Up to 60 ft ²	The greater of 70 ft ² or 5% of Conditioned Floor Area in Climate Zones 2, 4, 6-16
Glazing U-Factor & SHGC ¹ :	Package A: All CZs: U = 0.32 CZ 2, 4 & 6-16: SHGC = 0.25	Package A: All CZs: U = 0.32 CZ 2, 4 & 6-16: SHGC = 0.25	Package A: All CZs: U = 0.32 CZ 2, 4 & 6-16: SHGC = 0.25

1. See §150.0(q) and §150.1(c)3 for new and replaced window and skylight exceptions.

Table 9-3D: Envelope Insulation Requirements for Prescriptive Additions

Component	Requirements of Additions $\leq 400 \text{ ft}^2$	Requirements of Additions $> 400 \text{ ft}^2$ and $\leq 700 \text{ ft}^2$	Requirements of Additions $> 700 \text{ ft}^2$
Exterior Framed Wall ¹ Insulation:	Package A: CZ 1-5, 8-16: U=0.051 CZ 6 & 7:U=0.065	Package A: CZ 1-5, 8-16: U=0.051 CZ 6 & 7:U=0.065	Package A: CZ 1-5, 8-16: U=0.051 CZ 6 & 7:U=0.065
Raised Floor ¹ Insulation:	Package A: All CZs: R-19 or U=0.037	Package A: All CZs: R-19 or U=0.037	Package A: All CZs: R-19 or U=0.037
Slab Floor ¹ Insulation:	Package A: CZ1-15: No Requirement; CZ 16: R-7.0 or U=0.58	Package A: CZ1-15: No Requirement; CZ 16: R-7.0 or U=0.58	Package A: CZ1-15: No Requirement; CZ 16: R-7.0 or U=0.58
1. R-values refer to wood framing, and U-factors refer to metal framing.			

Table 9-3E: HVAC and Water Heating Requirements for Prescriptive Additions

Component	Requirements of Additions $< 400 \text{ ft}^2$	Requirements of Additions $> 400 \text{ ft}^2$ and $< 700 \text{ ft}^2$	Requirements of Additions $> 700 \text{ ft}^2$
Ventilation Cooling ¹ (Whole House Fan)	No Requirement.	No Requirement.	Additions $< 1,000 \text{ ft}^2$: No requirement Additions $> 1,000 \text{ ft}^2$: Package A Whole House Fan, §150.1(c)12 CZ 8-14
Adding New Space Conditioning System(s)	All Package A requirements.	All Package A requirements.	All Package A requirements except requirements for Ducts in Conditioned Space ²
Replacing Existing Space Conditioning System(s)	All Package A requirements.	All Package A requirements.	All Package A requirements except requirements for Ducts in Conditioned Space ²
Adding All New Complete Duct System(s)	All Package A requirements.	All Package A requirements.	All Package A requirements except requirements for Ducts in Conditioned Space ²
Extending Existing Duct System(s) by > 40 Feet	All Package A duct insulation requirements; duct system sealing and HERS Verified	All Package A duct insulation requirements; duct system sealing and HERS Verified	All Package A duct insulation requirements; duct system sealing and HERS Verified. Except requirements for Ducts in Conditioned Space ² .
<p>1. (Note: also mandatory mechanical ventilation per ASHRAE 62.2 with HERS verification for additions $> 1,000 \text{ ft}^2$)</p> <p>2. For more information about ducts in conditioned space, see Section 3.2.6</p>			

9.5.4 Prescriptive Water Heating System

If an addition increases the number of water heaters serving a dwelling unit, the addition can comply prescriptively if any one of the following conditions contained in §150.2(a)1D.i, ii and iii are met:

1. If the additional water heater is a natural gas or propane water heater, there are two options to comply. In all cases, if recirculation distribution system is used, only demand recirculation systems with manual control pumps shall be used. The two options are described below:
 - Option 1: Install a natural gas or propane instantaneous water heater with an input rating of 200,000 BTU per hour or less.
 - Option 2: Install a natural gas or propane storage water heater with a rated storage volume greater than 55 gallons and an input rating of 105,000 BTU per hour or less. The user must also do one of the following:
 1. Use a compact hot water distribution design for the addition, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards. (See Reference Appendix RA4.4.16.)
 2. Insulate all domestic hot water pipes for the addition, which requires that a HERS Rater verify that the pipe insulation is designed and installed in accordance to the Energy Standards.
2. If the building does not have natural gas or propane connected to the building, the additional water heater is an electric storage or instantaneous water heater with an EF equal to or greater than the federal minimum standards. If recirculation distribution system is used, only demand recirculation systems with manual control pumps shall be used.
3. A water-heating system determined by the Executive Director of the Energy Commission to use no more energy than the one specified in Item 1 above or, if no natural gas is connected to the building, a water-heating system determined by the Executive Director to use no more energy than the one specified in Item 2 above.

If none of these conditions can be met when adding a water heater to an existing dwelling unit, then the prescriptive addition compliance path cannot be used. In that case, the existing + addition + alterations compliance approach must be used to demonstrate overall compliance with whatever combination of existing and new water heaters serves the dwelling unit. This is summarized in §150.2(a)1Div and discussed as part of the overall performance method in Section 9.7.

For other alterations to the water heating system that occur as part of an addition, see Section 9.6.

Example 9-9

Question:

A small addition of 75 ft² is being planned for a house in Climate Zone 7. An existing porch off the master bedroom is being enclosed by using 2x4 wood-framed walls. The existing heating and air-conditioning system will serve the new conditioned space, including an extension of less than 40 linear feet of new ducts. The contractor wants to follow the prescriptive requirements. What requirements apply?

Answer:

Since the addition is smaller than 400 ft², the total fenestration area is limited to a maximum of 75 ft², and west-facing fenestration area is limited to 60 ft². The fenestration must meet the U-factor and SHGC requirements of Package A. For Climate Zone 7, these fenestration requirements are a maximum U-factor of 0.32 and a maximum SHGC of 0.25. For an addition of this size, insulation must meet only the mandatory requirements of R-22 ceiling insulation and R-19 floor insulation. The new 2x4 walls are extensions of existing walls, so they need only R-15 cavity insulation. Since the addition is also less than 300 ft², there is no cool roof requirement.

Since the existing heating and cooling equipment is being used for the addition, that equipment does not have to meet the mandatory equipment efficiency requirements. Mandatory duct insulation requirements of §150.0(m) apply, including R-6.0 minimum in unconditioned space. All other mandatory requirements in §150.0 must be met.

Example 9-10

Question:

If I remove a window from the existing house and reuse this window in an addition to that house, does the relocated window have to meet the prescriptive requirements of Package A?

Answer:

Yes, if using prescriptive compliance, in which case the relocated window must be treated as a new window and must meet the U-factor and SHGC requirements of Package A, §150.1(c)3. If you use this existing window in the addition, you must use the actual or default U-factor and SHGC of the window in showing compliance. Therefore, meeting the prescriptive requirements may not be possible, and performance compliance may be the only option. Window certification and labeling requirements of §110.6(a) do not apply to existing used windows.

Relocated windows must also meet the maximum area-weighted average U-factor in §150.0(q) with the EXCEPTION of up to 10 ft² or 0.5 percent of conditioned floor area, whichever is greater.

Example 9-11

Question:

I am doing an alteration in Climate Zone 12 in which I am moving an existing 25 ft² window to another location within the same existing wall and am not increasing total glazing area. Does the relocated window need to meet any prescriptive requirements?

Answer:

Removing an area of glazing in an existing wall and reinserting up to the same area of glazing in a different opening is considered replacement fenestration as defined in §150.2(b)1B. Exception 1 to §150.2(b)1B states that up to 75 ft² of vertical replacement fenestration in Climate Zone 12 must meet a prescriptive U-factor = 0.40 and an SHGC = 0.35.

Example 9-12

Question:

For additions and alterations that include a greenhouse window (also known as garden window), what are the U-factor and SHGC requirements? What is the area used for calculations for greenhouse windows?

Answer:

Not many greenhouse windows meet the mandatory maximum fenestration U-factor of 0.58 or the prescriptive addition or alteration U-factors or SHGCs on their own. The default U-factor for a dual-pane, metal-framed greenhouse window from Table 110.6-A is 1.40, while the default SHGC from Table 110.6-B assumes fixed clear, glass is 0.73. By comparison, fenestration in prescriptive additions has to meet the Package A U-factor of 0.32 for all climate zones and an SHGC of 0.25 in all climate zones except 1, 3 and 5, which have no SHGC requirement. However, there are several options and exceptions available in the Energy Standards.

For alterations, Exception 1 to §150.2(b) allows any dual-pane greenhouse windows to meet the prescriptive U-factor and SHGC requirements of Package A. This makes it possible for greenhouse windows to comply with the Energy Standards as part of a prescriptive alteration, as long as the U-factor and SHGC meet the requirements either by themselves or when area-weighted with all of the new and replacement fenestration in the project. The existing plus alteration performance method may also be considered if at least one other component of the building that will be upgraded in addition to the fenestration.

For new construction and additions, Exception 2 to §150.0(q) exempts up to 30 ft² of dual-pane greenhouse windows from the mandatory maximum U-factor of 0.58. This allows additions with up to 30 ft² of dual-pane greenhouse windows to comply using the performance approach, even if the actual NRFC-rated or default U-values of the greenhouse windows are greater than 0.58. Compliance in that case would depend on higher than average energy efficiency for some other components of the project to offset the poor performance of the greenhouse windows.

Alternatively, greenhouse windows can also meet the prescriptive maximum area-weighted average U-factor and SHGC in combination with other new and replacement fenestration in the project.

Greenhouse windows may use one of three methods for determining the proposed SHGC:

- 1) NFRC rated SHGC
- 2) Default SHGC from Table 110.6-B
- 3) If site-built greenhouse windows, then $SHGC_T$ can be calculated from the manufacturer's center of glass SHGC ($SHGC_c$) and using the following equation: $SHGC_T = 0.08 + 0.86 \times SHGC_c$.

Comparable methods are available for determining U-factors.

For compliance, the area used for greenhouse windows is the rough opening in the wall.

9.5.5 Performance Method: Additions and Existing + Addition + Alterations Approach

The table below summarizes the basic rules for modeling a low-rise residential building using the existing + addition + alterations performance approach. For more detailed information, see Section 9.7 and the *Residential ACM Reference Manual*.

Table 9-4: Modeling Rules for Existing + Addition + Alterations

Type of Component or System Modeled	Standard Design <i>Without</i> Third Party Verification of Existing Conditions	Standard Design <i>With</i> Third Party Verification of Existing Conditions
"EXISTING" – Components or Systems That Remain Unchanged	Model each component or system as "Existing"	Model each component or system as "Existing"
"ALTERED" – Components or Systems Being Changed/Replaced	Model each altered component or system as "Altered" but do not model the "Praltered Existing" conditions	Model each component or system as "Altered" and also model the "Praltered Existing" conditions
"NEW" – Components or Systems Being Added	Model each component or system as "New"	Model each component or system as "New"
"REMOVED" – Components or Systems Being Removed and Not Replaced	These components and systems are omitted entirely from the model	These components and systems are omitted entirely from the model

9.6 Alterations

This section provides a road map and a few relevant summaries that identify the requirements in the Energy Standards that are unique to alterations. Envelope, mechanical, and water-heating system alterations must meet all applicable mandatory measures as discussed in Section 9.4 and must comply with the Energy Standards using the prescriptive or performance approach. If a building does not meet all applicable prescriptive measures, then the performance method using approved compliance software is the alternative. (See Section 9.7.)

Residential lighting alterations need to meet applicable mandatory measures since there are no prescriptive lighting requirements in residential buildings.

9.6.1 Prescriptive Requirements

Although alterations must meet many of the same prescriptive requirements for new construction and additions, there are several exceptions or special allowances for certain types of alterations. Table 9-5 provides a detailed outline of envelope requirements for alterations, and Table 9-10 provides a similar outline for HVAC and water-heating alterations. For each type of alteration, the tables list:

1. The highlights of the mandatory measures applicable to that kind of alteration.
2. A summary of the relevant prescriptive measures.
3. Key exceptions, exemptions, or special allowances to the prescriptive measures.
4. The list of prescriptive compliance forms that must be submitted for permit.

9.6.1.1 **Prescriptive Envelope Alterations**

Table 9-5 summarizes requirements for the following types of residential envelope alterations:

1. Adding ceiling or roof insulation to an existing roof, or constructing a new roof on an existing building.
2. Replacing the roof sheathing of an existing roof.
3. Replacing part or the entire roof surface of an existing building.
4. Replacing or adding skylights.
5. Adding exterior wall insulation, or constructing new walls in an existing building.
6. Adding raised floor insulation over unconditioned space.
7. Replacing vertical fenestration: windows, clerestories, and glazed doors.
8. Adding vertical fenestration: windows, clerestories, and glazed doors.

Table 9-5: For Residential Alterations, Summary of Mandatory and Prescriptive Measures

Type of Envelope Alteration	Highlight(s) of Applicable Mandatory Measures ¹	Summary of Relevant Prescriptive Measure(s) ²	Exception(s) to the Prescriptive Measures	Prescriptive Compliance Form(s)
Adding Ceiling or Roof Insulation to an Existing Roof; or a New Roof on an Existing Building	Ceiling w/ Attic and Roof Rafters: R-19, U=0.054 §150.0(a) Exception: Where the space in the attic or rafter area is not large enough to accommodate R-19, the entire space shall be filled with insulation provided it does not violate Section 1203.2 of Title 24, Part 2.		N/A	CF1R-ALT
Adding Exterior Framed Wall Insulation³ or a New Wall in an Existing Building	In 2x4 Framing: R-13, U=0.102 In 2x6 Framing: R-19, U=0.074 Exception: Walls already insulated to R-11 §150.1(c)	In 2x4 Framing: R-13, U=0.102 In 2x6 Framing: R-19, U=0.074 (same as Mandatory)	N/A	CF1R-ALT
Replacing Roof Sheathing	§110.8(j)	CZ 2 - 15: Radiant Barrier above Attic Spaces	(a) No requirement in CZ1 and CZ16; (b) Not required when installing below roof deck insulation	CF1R-ALT

<p>Replacing > 50% of the Existing Roof Surface</p>	<p>§110.8(i)</p>	<p><u>Steep Sloped</u> (≥ 2:12): CZ 10 - 15: Reflect.=0.20 and Emittance=0.75; or SRI=16</p>	<p>(a) Air space of 1.0" between roof deck and bottom of roofing product. (b) Profile ratio of rise to width of 1:5 for >50% width of roofing product. (c) Existing ducts in attic insulated and sealed per §150.1(c)9. (d) Roof has ≥ R-38 ceiling insulation. (e) Roof has a radiant barrier per §150.1(c)2. (f) There are no ducts in the attic. (g) In CZ10-15, ≥R-4.0 insulation above the roof deck.</p>	<p>CF1R-ALT</p>
		<p><u>Low Sloped</u>< 2:12: CZ13 & 15: Reflect.=0.63 and Emittance=0.75; or SRI=75</p>	<p>(a) There are no ducts in the attic. (b) Reflectance and Roof Deck Insulation R-value in Table 150.2-A are met.</p>	<p>CF1R-ALT</p>
<p>Replacing Entire Roof, including sheathing</p>	<p>§150.0(a) Ceilings and rafter roofs achieve R19 or weighted U=0.054</p>	<p>CZ 4, 8-16: Roof deck, ceiling insulation, and radiant barrier according to §150.1(c)1A using Option A or B.</p>	<p>N/A</p>	<p>CF1R-ALT</p>
<p>Adding or Replacing Skylight³</p>	<p>Weighted average U-factor = or < 0.58 <u>Exemption:</u> Up to 10 ft² or 0.5% of Conditioned Floor Area, whichever is greater, is exempt from the U-factor requirement §150.1(q)</p>	<p>Must not exceed the 20% Total or 5% West Fenestration Area with a U-factor = 0.32 (all CZs); in CZ2, 4 & 6-16: SHGC = 0.25 §150.2(b)1.A.</p>	<p>Added fenestration up to 75 ft² need not meet Total or West-facing fenestration area per §150.2(b)1A Exception 1. Replacement skylights up to 16 ft² with a U=0.55 and SHGC=0.30 and not meet the total fenestration and West-facing area requirements per §150.2(b)1 A Exception 2.</p>	<p>CF1R-ALT</p>
<p>Adding Raised Floor Insulation</p>	<p>R-19 or equivalent U-factor Exception: Floors over controlled ventilation or unvented crawlspaces per §150.1(d)</p>	<p>R-19 or equivalent U-factor (same as Mandatory)</p>	<p>N/A</p>	<p>CF1R-ALT</p>

<p>Replacing Vertical Fenestration⁴ (Altered Glazing)</p>	<p>Weighted average U-factor = or < 0.58 <u>Exemption:</u> Up to 10 ft² or 0.5% of Conditioned Floor Area, whichever is greater, is exempt from the U-factor requirement §150.0(q)</p>	<p>All CZs: U-factor = 0.32 CZ 2, 4 & 6-16: SHGC = 0.25 §150.2(b)1.B.</p>	<p>Replacement of vertical fenestration up to 75 ft²: U=0.40 (in all CZs) and SHGC=0.35 in CZs 2, 4 & 6-16 as per §150.2(b)1B Exception 1 .</p>	<p>CF1R-ALT</p>
<p>Adding Vertical Fenestration⁴ (New Glazing) and Greenhouse</p>	<p>Weighted average U-factor = or < 0.58 <u>Exemption:</u> Up to 10 ft² or 0.5% of Conditioned Floor Area, whichever is greater, is exempt from the U-factor requirement §150.0(q)</p>	<p>Must not exceed the 20% Total or 5% West Fenestration Area U-factor = 0.32 (in all CZs); In CZ2, 4 & 6-16: SHGC = 0.25 §150.2(b)1.A.</p>	<p>Added fenestration up to 75 ft² need not meet total or west-facing fenestration area requirements as per §150.2(b)1A Exception 1. Added Greenhouse must either meet the maximum U-factor of 0.58 or weighted average U-factor of 0.58 or up to 10ft² or 0.5% of CFA whichever is greater as per §150.0(q)1.</p>	<p>CF1R-AL</p>
<p>1: Alterations must comply with all applicable mandatory measures in §110.0 and §150.0 of the Energy Standards as explained in Chapters 3, 4, 5 and 6 of this Manual, except as noted in §150.2(b).</p>				
<p>2: Several prescriptive measures are Climate Zone (CZ) specific.</p>				
<p>3: There are no mandatory measures or prescriptive requirements when altering below-grade or exterior mass walls.</p>				
<p>4: Replacement fenestration is new fenestration that is located in the same existing wall or roof in which the same or larger area of existing fenestration is being removed. It labeled as "altered." Any new fenestration area that increases the total net area of fenestration in any existing wall or roof is labeled as "new."</p>				

9.6.1.2 Greenhouse Windows

Greenhouse or garden windows are special windows that project from the façade of the building and are typically five sided structures. An NFRC-rated U-factor for greenhouse windows is typically high and may not meet the mandatory requirements for the fenestration U-factor of 0.58.

To meet this mandatory measure, greenhouse windows:

1. Must have a maximum U-factor of 0.58 or better; or
2. Must use the area-weighted average for all new and replacement fenestration with a combined mandatory maximum of 0.58 U-factor as per §150.0(q)2; or
3. Must meet the Exception to §150.0(q)1 for up to 10 ft² or 0.5 percent of CFA, whichever is greater; or
4. When using the performance approach Exception 1 as per §150.2(b) - Any dual-glazed greenhouse or garden window installed as part of an alteration complies automatically with the U-factor and meets the requirements as per §150.1(c)3.

9.6.1.3 Adding Insulation to Existing Roof/Ceilings, Walls and Raised Floors

The prescriptive requirement for alterations is to add the equivalent of the specified level of insulation that fits within the cavity of wood framed assemblies:

1. R-19 or greater in between wood-framing members or a weighted average U-factor equal to or less than 0.054 for insulation installed at ceilings and rafter roofs; and

2. R-13 in 2x4 exterior walls, and R-19 in 2x6 or greater exterior walls, with no exterior rigid insulation required; or
3. R-19 in raised floors over crawl spaces, over open outdoor areas, unheated basements, and garages.

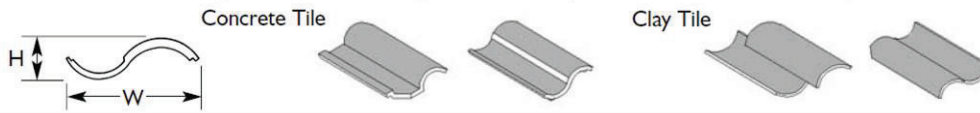
9.6.1.4 Replacing the Roof Surface or Roof Sheathing (partial or entire replacement)

A. Steep-Sloped Roofs ($\geq 2:12$)

In Climate Zones 10 through 15, if 50 percent or more of the existing building's roof surface is being replaced, the minimum cool roof requirement for the replaced steep-sloped roofing area shall have an aged solar reflectance of 0.20, thermal emittance equal to 0.75, or a minimum SRI of 16. The requirements above apply unless one of the following is present (considered equivalent to the cool roof requirements in §150.2(b)1Hi):

1. Air space of 1.0" (25mm) between the roof deck and the bottom of the roofing product.
2. Roofing product profile ratio of rise to width is at least 1:5 for >50 percent width of roofing product.

High Profile Tile – Tiles having a rise to width ratio greater than 1:5 (measured in installed condition)



3. Existing ducts in attic are insulated and sealed according to §150.1(c)9.
4. Building has at least R-38 roof/ceiling insulation.
5. Roof of attic spaces has a radiant barrier according to §150.1(c)2.
6. There are no ducts in the attic space.
7. In Climate Zones 10 through 15, greater than R-2.0 insulation above the roof deck.

B. Low-Sloped Roofs ($< 2:12$)

In Climate Zones 13 and 15, if 50 percent or more of the existing building's roof surface is being replaced, the minimum cool roof requirements for low-sloped roofs shall have an aged solar reflectance of 0.63, thermal emittance of 0.75, or a minimum SRI of 75 per §150.2(b)1Hii. These apply unless one of the following is present which are considered equivalent to the cool roof requirements in §150.2(b)1Hii:

1. There are no ducts in any attic space.
2. The aged solar reflectance can be traded off with additional insulation added at the roof deck as specified in Table 150.2-A of the Energy Standards.

Table 9-6: Aged Solar Reflectance Insulation Trade Off

Aged Solar Reflectance	Roof Deck Insulation R-value	Aged Solar Reflectance	Roof Deck Insulation R-value
0.62 – 0.60	2	0.44 – 0.40	12
0.59 -0.55	4	0.39 – 0.35	16
0.54 - 0.50	6	0.34 – 0.30	20
0.49 – 0.45	8	0.29 – 0.25	24

C. Roof Sheathing

In Climate Zones 2 through 15, if roof sheathing over an attic space with a continuous radiant barrier is being replaced, a continuous radiant barrier must be re-installed.

In Climate Zones 4, and 8 through 16, if the entire roof sheathing over a ventilated attic space is being replaced, roof and ceiling insulation must be installed to meet the following prescriptive requirements (as specified in §150.1(c)1A):

1. Option A: R-8 or R-6 above roof deck insulation (see explanation on required R-value in Chapter 3) **and** R-38 ceiling insulation.
2. Option B: R-18 or R-13 below roof deck insulation (see explanation on required R-value in Chapter 3) **and** R-38 ceiling insulation.
3. Option C: Verified ducts in conditioned space **and** R-30 or R-38 ceiling insulation.

Example 9-13

Question

There is a Victorian building that has been converted to an office building and needs to have a shake roof replacement. This building has a vented unconditioned attic with the insulation on the ceiling. Would I need to meet §150.2(b)Hi?

Answer

No, this section does not apply. The occupancy type has been changed to nonresidential. Since the Victorian building has a shake roof and is considered a steep sloped roof, §141.0(b)2Bib for nonresidential buildings would apply.

Example 9-14

Question

On an existing building, 50 ft² of 85 ft² of vertical glazing is being removed from an existing south facing wall and new glazing will be replaced as part of the alteration in the same opening. What requirements apply?

Answer

Since 50 ft² is treated as “replacement” fenestration and 35 ft² is considered existing, the replaced fenestration must comply with the requirements in §150.2(b)1B; or for this example Exception 1 to §150.2(b)1B can be used. Vertical fenestration no greater than 75 ft² can meet the requirements by installing fenestration no greater than a U-factor of 0.40 in Climate Zones 1-16 and SHGC of 0.35 in Climate Zones 2, 4, and 6 through 16.

9.6.1.5 Replacement Fenestration

Any fenestration (i.e., windows, skylights, clerestories, and glazed doors) that is being removed and replaced in an exterior wall or roof is considered “replacement fenestration.”

Replacement fenestration is an area of new fenestration that replaces an equal or greater area of glazing removed in the same existing wall or roof area. It is labeled as “altered” fenestration, and it need not occur in the same exact openings as the glazing being removed as long as it is being installed in the same existing wall or roof surface which remains a part of the existing building. Any added fenestration area that is larger than the total altered glazing area) is labeled as “new.”

9.6.1.6 New Fenestration in Alterations

The Energy Standards have relaxed some of the prescriptive restrictions on new vertical fenestration for alterations in existing dwellings. When new vertical fenestration is added in existing dwellings, up to 75 ft² are not required to meet the overall total fenestrations limit (20 percent of the CFA) and the west facing area limit (5 percent of the CFA). This provides for additional flexibility to meet the Energy Standards requirements using the prescriptive approach, without having to resort to the performance approach. However, this additional fenestration must meet the prescriptive U-factor and SHGC requirements of Package A or meet the U-factor and SHGC requirements of Exceptions 1 and 2 to §150.2(b)1B.

Example 9-15

Question

An existing house in Climate Zone 12 has all single-pane windows. All of the windows (300 ft² total) will be replaced within existing openings, except a pair of 40 ft² French doors, which will replace an existing 30 ft² window. What requirements apply?

Answer

For prescriptive compliance, replacement fenestration (equal to or less than the area of existing windows in each wall being altered) and new additional fenestration area must both meet the U-factor (0.32) and SHGC (0.25) in Package A. There are only 10 ft² of added fenestration, so the project meets Exception 1 to 150.2(b)1A and is not required to meet the Package A total glazing area requirement. All installed fenestration also must meet applicable mandatory measures.

To use the performance approach, two or more energy measures must be used as a trade-off within the house per §150.2(b)2. The two altered components may be the same type, such as trade-off between two or more windows, or different types such as replacing one window and a water heater. Once the project has at least two altered components, then the Existing + Alterations calculation is available as a compliance alternative. In that case:

- (a) In the Existing + Alterations approach *without* third party verification, replacement fenestration that achieves the fenestration values in Table 150.2-B of the Energy Standards is compared to those same values in the Standard Design. Replacement fenestration that does not reach these values is penalized.
- (b) In the Existing + Alterations approach *with* third party verification, replacement fenestration that achieves the fenestration values in Table 150.2-B of the Energy Standards is compared to §Tables 110.6-A and 110.6-B default values for the existing fenestration condition. Replacement fenestration that does not reach these values is penalized.
- (c) The use of window films in lieu of fenestration replacement are considered as an alteration option to existing fenestration for energy compliance. Similar to fenestration replacement, the window film must also meet the Standard Design for an altered component *with* or *without* third party verification as indicated in Table 150.2-B of the Energy Standards. Also, see window film installation protocols in RA4.2.3.

Example 9-16

Question

An existing building has all single-pane, metal-frame windows. A proposed remodel will replace all the windows; no other work is being done as part of the remodel. What applies?

Answer

Since only the windows are being replaced, all replacement windows must meet the prescriptive requirements of Package A, and new fenestration must also meet applicable mandatory measures of §110.6, §110.7 and §150.0.

If the prescriptive requirements of Package A cannot be met, the Existing + Alteration performance method can be used because more than two windows are being replaced.

Example 9-17

Question

An existing building has all single-pane, wood-frame windows. Two double-pane, metal-frame greenhouse windows will be added as part of a remodel. How should the greenhouse windows be treated?

Answer

Since greenhouse windows add conditioned volume, but do not add conditioned floor area, this remodel is considered an alteration rather than an addition. For the purposes of alterations, any dual-glazed greenhouse windows installed as part of an alteration may use §150.0(q) to meet the U-factor and Package A to meet SHGC requirement.

If two or more types of altered energy measures are in the existing building, the Existing + Alterations performance method may be used. All applicable mandatory measures must be met.

Note: Any dual glazed greenhouse or garden window installed as an alteration shall comply with the U-factor requirements in §150.1(c)3.

Example 9-18

Question

Why are low-sloped roofing products requirement only listed for Climate Zones 13 and 15?

Answer

These two climate zones are the only climate zones which show energy cost-effectiveness for having a low-slope roofing product (cool roof) requirement.

Example 9-19

Question

Why are there so many exceptions to the addition and alterations section that can be considered equivalents to roofing products?

Answer

There are several energy features that are equivalent or having greater impact on energy savings than the roofing products. For example, older homes often have ducts under the house, and newer homes may have materials slightly below current requirements or equal to one of the items considered to be equivalent. If the ducts are insulated and air leakage controlled to meet current requirements, energy savings are expected to be at least equal the benefit of reflective roof coverings.

Example 9-20

Question

What happens if I have a low-slope roof on most of the house but steep-sloped roof on another portion? Do I have to meet two different criteria for the roofing products?

Answer

Yes. If your house is in Climate Zones 13 or 15, you will need to meet the low-slope criteria for the areas with low-slope. The areas with steep-slope roof will need to meet the other cool roof criteria.

Example 9-21

Question

I am replacing my existing wood shake roof with asphalt shingles. Would this be considered a repair?

Answer

No. A repair is defined as a reconstruction or renewal for the purpose of maintenance of any component, system or equipment of an existing building. A replacement of any component (i.e., roof top), system, or equipment for which there are requirements in the Energy Standards is considered an alteration and not a repair.

Example 9-22

Question

Where do radiant barriers need to be installed when using prescriptive Package A or meeting the performance standards where credit is taken for retrofitting a radiant barrier in the existing house?

Answer

The radiant barrier only needs to be installed on the underside of an attic roof assembly and the gable wall ends associated with an addition. The prescriptive requirement is the same for entirely new buildings.

Example 9-23

Question

I am considering reroofing my house. Under what conditions will I be required to put on a cool roof?

Answer

Cool roof requirements are triggered when 50 percent or more of the roof area is being replaced. Prescriptive requirements are waived if one of the Exceptions to §150.2(b)1H below applies:

Prescriptive Exceptions for Steep-Sloped Roofs

1. Air-Space of 1.0 inch (25 mm) is provided between the top of the roof deck and the bottom of the roofing product.
2. The installed roofing product has a profile ratio of rise to width of 1 to 5 for 50 percent or greater of the width of the roofing product.
3. If existing ducts in the attic are insulated and sealed according to §150.1(c)9.
4. Buildings with at least R-38 ceiling insulation.
5. Buildings with an attic radiant barrier meeting the requirements of §150.1(c)2.
6. Buildings with no ducts in the attic.
7. Buildings in Climate Zones 10-15, R-2 or greater insulation above the roof deck.

Prescriptive Exceptions for Low-Sloped Roofs

1. Buildings with no ducts in the attic.
2. Aged solar reflectance and roof deck insulation R-value in Table 150.2-A are met.

Alternatively, the building may show compliance using the performance approach.

Example 9-24**Question**

I am building a 450 ft² addition on my house. Do I have to meet cool roof requirements in the prescriptive package?

Answer

Yes. If using prescriptive compliance, the roof must meet the cool roof requirements of Package A for the type of roof slope and density. To avoid the cool roof requirements, you may use the performance approach and tradeoff against other energy efficiency features of the addition alone or the existing building by using the Existing + Addition + Alterations approach.

9.6.2 Prescriptive HVAC System and Water Heating Alterations

The Energy Standards apply to alterations of the heating and cooling system whether or not the alterations correspond to an addition to the building. This section describes the conditions where compliance is necessary and describes the corresponding prescriptive requirements.

If the heating and cooling system is left unchanged as part of an addition or alteration, then compliance with the requirements for altered HVAC systems is not necessary. Extension of a duct is not considered a change to the existing heating and cooling equipment. However, the new ducts must meet mandatory requirements described in Section 9.4.2; and prescriptive requirements described below.

To meet the prescriptive alteration requirement for water heating, the water heating system shall be one of the following:

1. A natural gas storage or propane, non-recirculating water heater with an EF (Energy Factor) equal to or greater than the federal minimum; or
2. If no natural gas is connected to the building, electric storage tank water heater less than 60 gallons, or electric instantaneous with an EF equal to or greater than the federal minimum standards.
3. A water-heating system determined by the Executive Director to use no more TDV energy than item 1 above, or item 2 above if no natural gas is connected to the building.

Note: The performance compliance approach can be used to demonstrate that the proposed water heating system uses no more TDV energy than the system defined in item 1 above.

If it takes an extended period of time for hot water to get to a fixture, a common and cost effective solution may be to install a demand recirculation system. These systems can reduce both wait time and water waste (see Section 5.3.2 for more information). The installation of a manually controlled demand recirculation system that meets the requirement of RA4.4.9 meets the prescriptive alteration requirement of the Standards. Any other alteration to the hot water distribution system, such as timer or temperature control

recirculation systems, must be analyzed using the performance compliance approach to show that the energy use of the building has not been increased.

To decrease the wait time, another alternative may be to install a second water heater close to the fixture. Installing an additional water heater into an existing building's water heating system must be analyzed using the performance compliance approach to show that the energy use of the building has not been increased. However, if a natural gas or propane instantaneous water heater is added, the water heating system is pre-determined to comply with the prescriptive water heating alteration requirements. If instead, an additional storage water heater were to be added, the performance compliance approach must be used, as the added storage will increase the standby losses of the water heating system and that energy increase will need to be offset with other efficiency improvements.

Example 9-25

Question

I want to install an additional water heater to a single family residence with an existing natural gas water heater. Does this comply?

Answer

When there is an increase in the number of water heaters with an existing water heating system, the system must be analyzed using the performance compliance approach to show that the energy use of the system has not been increased. However, if the additional water heater is a natural gas or propane instantaneous water heater, the system automatically complies. No water heating calculations are needed.

The following table lists replacement heat pump water heating systems by climate zones that have equal or lower TDV energy than a standard design system with natural gas, LPG, or electric fuel source. These systems have been pre-calculated to comply with the prescriptive water heating alteration requirements when serving a single dwelling unit, with or without natural gas connection. These are only a few of many possible combinations that will comply using the performance compliance approach.

Table 9-7: Pre-calculated Replacement Heat Pump Water Heating Systems for Single Dwelling Units

CZ	Energy Factor greater than or equal to
1	2.75
2	2.75
3	2.75
4	2.8
5	2.75
6	2.33
7	2.5
8	2.33
9	2.33
10	2.33
11	2.5
12	2.8
13	2.5
14	2.5
15	2.33
16	EF \geq 3, plus a solar water heating system with solar saving fraction \geq 0.4

Example 9-26

Question

An existing 1,500 ft² single family residence is getting a 500 ft² addition. A new 50 gallon gas water heater will replace the existing water heating system. How do the water heating requirements apply?

Answer

Since this is an alteration to an existing water heating system, no water heating calculations are required for compliance of the addition alone. However, applicable mandatory measures apply. For newly installed piping, all the applicable insulation requirements of §150.0(j)2 shall be met. For existing piping that are accessible, the insulation requirements §150.0(j)2i, iii, and iv shall be met, which include the first five feet of hot and cold water lines from the storage tank, piping between heating source to storage tank, and all piping associated with a recirculation system. If building energy compliance is achieved with the Existing + Addition + Alterations calculation, the EF and other energy features of the water heating system are modeled in the performance method.

Example 9-27

Question

An existing 2,000 ft² single family residence has one 50 gallon gas water heater, and a 600 ft² addition with a new instantaneous gas water heater is proposed. How does this comply?

Answer

When there is an increase in the number of water heaters with an addition, the Energy Standards allow addition alone compliance in certain circumstances. Since this is an instantaneous gas water heater, it may be installed prescriptively with no water heating calculations. The mandatory requirements still apply.

The alternative to show compliance is by using the existing-plus-addition or whole building compliance.

Example 9-28

Question

An existing single family residence with one electric water heater has a 500 ft² addition with a 30 gallon electric water heater proposed. Does this comply?

Answer

When there is an increase in the number of water heaters with an addition, the Energy Standards allow addition alone compliance in certain circumstances.

If this residence does not have natural gas connected to the building and the new water heater has an EF equal to or greater than the federal minimum standards, the system complies prescriptively. No water heating calculations are required.

If it does have natural gas connected, then the new water heater must be natural gas, or calculations are required to show the proposed water heater would use no more TDV energy than an instantaneous natural gas water heater.

9.6.2.1 HVAC "Changeouts"

The Energy Standards make a distinction between two HVAC "changeout" situations:

1. Entirely new or complete replacement space conditioning systems;
2. Altered space conditioning systems.

The differences in the requirements for these two types of HVAC changeout situations are discussed in the following sections.

A. Entirely New or Complete Replacement Space Conditioning Systems

When an *Entirely New or Complete Replacement Space Conditioning Systems* is installed, the system must meet all applicable mandatory measures, including:

§150.0(h) – Space conditioning equipment loads, design, installation, etc.

§150.0(i) – Thermostat requirements.

Note: The Mercury Thermostat Collection Act of 2008 requires manufacturers to establish a collection and recycling program for out-of-service mercury-added thermostats. For more information go to: www.dtsc.ca.gov/thermostats

§150.0(j)2 – Refrigerant line insulation thickness.

§150.0(j)3 – Refrigerant line insulation protection.

§150.0(m)1 – California Mechanical Code(CMC) compliance.

§150.0(m)2 – Factory fabricated duct system UL requirements.

§150.0(m)3 – Field fabricated duct system UL requirements.

§150.0(m)4 – Duct R-value minimum ratings.

§150.0(m)5 – Duct insulation thickness and R-value.

§150.0(m)6 – Duct labeling requirements.

§150.0(m)7 – Backdraft damper requirements on vent systems.

§150.0(m)8 – Gravity ventilation system dampers.

§150.0(m)9 – Protection of insulation.

§150.0(m)10 – Prohibition of using porous inner core.

§150.0(m)11 – Duct system sealing and leakage testing for new systems.

§150.0(m)12 – Air filtration requirements.

§150.0(m)13A – HSPP/PSPP, mandatory return duct sizing (or diagnostically tested airflow and fan efficacy).

§150.0(m)13B-C – Requirements for zonally controlled systems.

These systems must also meet the prescriptive requirements found in:

§150.1(c)6 – Allowed heating system types.

§150.1(c)7 – Space heating and cooling system minimum efficiencies and refrigerant charge verification in Climate Zones 2, 8 through 15.

§150.1(c)9 - Duct insulation requirements.

§150.1(c)10 – Central fan integrate systems added or required as part of an addition or alteration must meet the 0.58 watts per cfm requirement.

These requirements are discussed in detail in Chapter 4, HVAC Requirements.

Note: Completely New or Replacement Duct Systems in *multifamily* dwelling units shall meet the 12 percent (total leakage protocol), or 5 percent (leakage to outside protocol) criteria used for newly constructed systems (may also use the smoke test protocol if the system does not meet these criteria). Otherwise, altered duct systems in multifamily dwelling units shall meet the 15 percent (total leakage protocol), or 10 percent (leakage to outside protocol), or smoke test criteria given in §150.2(b)1Diib.

A system installed in an existing dwelling shall be considered an Entirely New or Complete Replacement Space Conditioning System when:

1. The air handler and all of the system heating/cooling equipment (e.g., outdoor condensing unit and indoor cooling or heating coil for split systems; or complete replacement of a package unit), are new, and
2. The duct system meets the definition of an *Entirely New or Complete Replacement Duct System (including systems less than 40 feet in length)*.

An altered duct system installed in an existing home shall be considered an Entirely New or Complete Replacement Duct System when:

1. At least 75 percent of the duct material is new, and
2. Any remaining components from the previous system are accessible and can be sealed.

Altered duct systems that do not meet the definition of *Entirely New or Complete Replacement Duct Systems* shall be considered an *Extension of an Existing System*.

Space conditioning systems that do not meet the definition of Entirely New or Complete Replacement Space Conditioning Systems shall be considered Altered Space Conditioning Systems.

B. Altered Duct Systems – Duct Insulation and Sealing Requirements

When more than 40 linear feet of ducts are installed in an unconditioned space, it must be insulated to an installed minimum R-value as described in Table 9-8.

Table 9-8: Duct Minimum R-Value

<i>Climate Zone</i>	1 -10, 12 & 13	11, 14 -16
<i>Duct R-value</i>	R-6	R-8

When more than 40 linear feet of ducts are installed in conditioned space, the ducts must be insulated to the minimum mandatory insulation level of R-4.2 and be verified to be in conditioned space by both visual verification and diagnostic testing in accordance to RA3.1.4.3.8.

Entirely New or Complete Replacement Duct Systems must meet the mandatory requirements of:

1. §150.0(m)12 – Air filtration requirements, and
2. §150.0(m)13 – HSPP/PSPP, mandatory return duct sizing (or diagnostically tested airflow and fan efficacy).

These requirements are discussed in detail in Chapter 4.

Entirely New or Complete Replacement Duct Systems must also be sealed to the criteria for “new duct systems” found in Table RA3.1-2, discussed below.

An Entirely New or Complete Replacement Duct Systems may also include the original air handler, which may leak substantially more than the new equipment. Therefore, an attempt should be made to seal the duct system and the air handler to meet the 5 percent (of nominal system central fan airflow) leakage rate criteria. If the 5 percent leakage rate criteria cannot be met, a smoke test should be performed to verify that the excess leakage is

non-accessible, and not from other *accessible* portions of the duct system. Note that the protocol for Smoke Test for accessible-duct sealing is given in RA3.1.4.3.7.

Note that this will satisfy the sealing requirement and does not cause the system to no longer meet the definition of an *Entirely New or Complete Replacement Duct Systems*.

Altered duct systems that do not meet the definition of *Entirely New or Complete Replacement Duct Systems* shall be considered an *Extension of an Existing System*. These duct systems are required to meet one of the leakage criteria for “altered existing systems” cases in Table RA3.1-2.

Duct sealing is a mandatory measure; therefore, alterations to an existing duct system, such as adding or replacing sections of duct, will trigger duct sealing. However, cost-effectiveness must also be taken into account. Having to seal an entire system because one foot of duct is being removed may not be cost effective. The Energy Standards set the length of 40 feet of duct that triggers this requirement.

If 40 feet of duct are being added or replaced, this work alone can trigger the requirement for duct sealing and field verification. The system would have to meet one of the leakage criteria for “altered existing systems” cases in Table RA3.1-2.

In addition to the duct sealing requirements, the added or replaced ducts must also meet the air distribution requirements of §150.0(m) and the duct insulation requirements of §150.1(c)9. The air distribution and duct insulation requirements must comply in all climate zones; however, these requirements apply to only new or replaced ducts, the existing and unaltered ducts do not need to comply with these requirements.

Installing 40 feet or less of new or replacement ducts alone will not trigger the sealing requirements described above; however, the new ducts and connections must still meet the air distribution and duct insulation requirements of §150.0(m) and §150.1(c)9.

C. Altered Space-Conditioning Systems - Duct Sealing

Existing duct systems must be sealed and verified by a HERS rater when portions of the heating and cooling system are altered. The requirement applies in all climate zones.

An air handler is installed or replaced.

Ducts must be sealed (as described below) under any of the following conditions:

1. An outdoor condensing unit of a split system air conditioner or heat pump is installed or replaced.
2. A cooling or heating coil is installed or replaced.
3. More than 40 feet of new or replacement ducts are installed.

If a residence has more than one duct system, only the ducts connected to the altered equipment need to be sealed and verified.

There are three options for showing compliance for existing duct systems listed below. The HERS Rater or installing contractor must at least attempt compliance with the first option (15 percent leakage); then any of the other options can be utilized:

1. Total leakage is less than 15 percent of nominal system fan airflow (RA3.1.4.3.1).
2. Leakage to the outside is less than 10 percent of system fan airflow (RA3.1.4.3.4).
3. If the first option (15 percent) leakage target cannot be met, then compliance can be achieved by sealing all accessible leaks verified by a HERS Rater inspection. When using this option, sampling is not allowed (RA3.1.4.3.5-7).

- a. HERS field verification is required for all options listed above. For options 1, and 2, verification can be accomplished through sampling as described in *Sampling for Additions or Alterations* below. For option 3, sampling is not allowed; a certified HERS Rater must do the visual inspection and the smoke test on every house.
- b. Since test equipment must be set up for the first three options, it may be most efficient to test and record the results for the existing system and then attempt to meet each option sequentially until compliance is achieved.
- c. There are a few cases where duct sealing and duct leakage verification are not required. These exceptions include the following:
 - Ducts that have already been sealed, tested, and certified by a HERS rater;
 - Duct systems with less than 40 feet of duct;
 - Duct systems that are insulated or sealed with asbestos.

D. Accessible Ducts

Several code sections and protocols require a smoke test to demonstrate that all accessible leaks have been sealed.

Accessible is defined in JA1 as “having access thereto, but which first may require removal or opening of access panels, doors, or similar obstructions.”

Ducts located in an attic or crawlspaces are generally considered accessible because code requires access to those spaces. Access is usually gained by opening a door, hatch, or other moveable panel. If this can be done without causing damage that would need to be repaired, this is considered accessible. It is not expected that drywall sections have to be cut or damaged to gain access.

Some judgment is required in determining if ducts are accessible. The local code enforcement agency will have the final say when it is not immediately obvious.

For example:

If a boot is buried in insulation, then the boot would be considered accessible since the insulation could be moved or the register could be taken off to gain access so that it can be sealed.

When an air handler is replaced, the removal of the air handler would give the installer access to the attached plenums and ducts. These newly accessible areas of the duct work shall be sealed since they may be source of air leakage. Special attention should be given to where wall cavities are used as plenums and ducts.

If the ducts are buried under insulation, and gaining access to the leaks in these ducts would require moving insulation, this would also be considered accessible.

If a leak in the duct system is in a space between framing members that is too small for the average person to reach the joint to seal it, this area is probably not accessible.

If ducts are suspended far above the ground and reaching them would require scaffolding or special equipment other than normal ladders, then these are probably not accessible.

If sheet metal ducts are wrapped with insulation and a smoke test indicates multiple small leaks along the lengthwise seams in the ducts in many locations, it is probably not cost effective to remove the insulation to find and seal these leaks. However, if one or more location shows a very obvious and substantial leak, it must be sealed.

All other portions of the duct system for which a smoke test identifies the presence of leakage must be sealed to comply. The exemption for inaccessible portions of the duct system is applicable only if the other criteria for duct leakage compliance cannot be met.

The installing contractor may perform a smoke test to locate and seal accessible leaks, or assess whether or not the duct leaks are accessible. However, compliance by smoke test and sealing all accessible leaks must be determined by a smoke test that has been conducted by a HERS rater.

E. Refrigerant Charge Verification

In climate zones 2, and 8 through 15, when a refrigerant containing component of an air conditioner or heat pump is replaced or installed in an existing building, §150.2(b)1F requires a system that does not have a fault indicator display (FID) installed to have refrigerant charge field verified in accordance with all applicable procedures specified in RA3.2.2, or RA1.

The Refrigerant Charge Verification (RCV) procedures in RA3.2 are not intended to replace the equipment manufacturer's charging procedures and specifications. The installer must first charge the system according to the manufacturer's instructions and specifications. It is important to know that the procedures in RA3.2 are not procedures for charging a system; rather, they are procedures for verifying proper charge. HERS raters are not allowed to adjust the refrigerant charge in systems that they are verifying. Raters are also prohibited from performing the weigh-in charge verification procedures. However, when specified by the Energy Standards, a rater may observe the installer while the installer performs the weigh-in procedure to verify compliance as specified in RA3.2.3.2 (described below).

In both cases the HERS rater must also confirm minimum system airflow.

1. **Fault indicator display.** As an alternative to RCV, the installer may install a special device called a fault indicator display (FID). When this alternative is used by the installer, a HERS rater must still field verify the installation and operation of the FID as well as confirm minimum system airflow.

This device provides real-time monitoring of the air conditioning system and will show a warning visible to the home's occupants when the system is either over or undercharged, or if the system airflow rate does not meet the minimum requirement. The display unit must be located within one foot of the thermostat.

When applicable, systems shall be equipped with an FID device that provides a clearly visible indication to the occupant when the air conditioner fails to meet the required system operating parameters specified in Section JA6 for the installed FID technology. The FID indication display shall be constantly visible and within one foot of the air conditioners thermostat. FID installations shall be confirmed by field verification and diagnostic testing utilizing the procedures specified in RA3.4.2.

2. **Minimum Airflow.** When RCV is required for compliance, the system must also comply with the minimum airflow of 300 cfm/ton according to the procedures specified in RA3.3.

Entirely New or Complete Replacement Space Conditioning Systems, as specified in §150.2(b)1C, must meet the minimum 350 cfm/ton airflow rate compliance criterion or the duct design alternative specified in §150.0(m)13.

3. **Alternative to Refrigerant Charge and Verification requiring at least 300 cfm per ton of airflow.** If the altered HVAC that requires RC&V is not able to comply with the 300 cfm per ton of airflow, the HVAC installer may choose the alternative procedure outlined in RA3.3.3.1.5, *Alternative to Compliance with Minimum System Airflow*

Requirements for Altered Systems, provided that the system thermostat is an Occupant Controlled Smart Thermostat (OCST) which conforms to the requirements of JA5.

Under RA3.3.3.1.5, the installer must take a series of remedial steps, including but not limited to cleaning filters, removing obstructions from registers and dampers, replacing crushed or blocked ducts, cleaning the evaporator coil, making sure that the air handler is set to high speed and conforms to manufacturer specifications, and enlarging/adding the return duct and the return grill. These steps must be verified by a HERS Rater.

Again, as mentioned above, when the installer chooses this option, the system thermostat must be an OCST.

4. **Applicability of the protocols.** The RCV protocols in RA3.2 and RA1 are applicable only to air-cooled air conditioners and air-source heat pumps. Equipment types such as ground source, water source, and absorption air conditioners and heat pumps cannot be verified using the protocols in RA3.2 and RA1. When a system other than an air-cooled air conditioner or air-source heat pump is installed, the requirements in §110.1 may provide further direction for compliance.

If an aspect of the RA3.2.2 or RA1 verification protocol is not applicable to the system, alternative requirements may be specified §150.2(b)1F; however, the procedures in RA3.2.2 or RA1 that are applicable to the system shall be performed.

For example, if a system does not have both a high side and low side refrigerant access port, and cannot conform to the sub-cooling or superheat RCV procedure, but is a ducted system that can conform to the airflow measurement protocol, the system must comply with the minimum airflow requirement specified in RA3.2.2.7. Similarly, if the outdoor temperature is below 55°F which precludes use of the RA3.2.2 protocol for verification of the charge, and if the RA1 protocol cannot be used, then the weigh-in charging procedure in RA3.2.3.1 shall be used, and the minimum system airflow rate shall be verified using the protocols in RA3.3.

The installer must determine which procedures are applicable to a system and verify compliance accordingly.

5. **Thermostats.** When an existing system has a refrigerant containing component added or replaced, the thermostat must be upgraded to a digital setback type that meets §110.2(c)
6. **Package Units.** Package units are typically pre-charged at the factory prior to shipment. When a new package unit is being installed or is replacing an older unit, it may not require RCV if the installer certifies that it is factory charged and the installation did not alter the system in any way that would affect the refrigerant. The installer must submit a certificate of installation documenting this and third party verification of refrigerant charge by a HERS rater is not required. This only applies to new equipment shipped from the manufacturer. Any modification to existing equipment that adds or replaces refrigerant containing components voids this exception. It is important to note that this does not relieve the contractor from the requirement to verify that the system meets the minimum 300 cfm per ton airflow rate requirement.
7. **Mini-Splits and Other System Types.** Some air-cooled air conditioning systems and air-source heat pumps cannot use the standard charge verification procedure, as specified in RA3.2.2, due to the design or construction of the system components. These include certain “mini-split” systems and variable speed condenser systems. In these cases, the installer must use the weigh-in charge procedures specified in RA3.2.3.1, and these systems must be HERS verified using the RA3.2.3.2 procedure for HERS Rater observation of the weigh-in charge procedure. These systems must also be

equipped with an Occupant Controlled Smart Thermostat (OCST) which complies with the requirements of JA5.

It is important that the installation of these types of systems be coordinated with the third party verification. When these systems are ducted, they are still subject to the minimum system airflow requirements.

1. **Winter Refrigerant Charge Verification.** Most systems will normally be verified using the RA3.2.2 standard charge verification procedure to demonstrate compliance. However, when the outdoor temperature is less than 55°F, and the standard charge verification procedure or an RA1 protocol cannot be used, the installer may elect to use the weigh-in charge method to demonstrate compliance. Compliance with HERS verification when the outdoor temperatures are less than 55°F can be demonstrated using one of the following alternatives:
 - a. The installer may use the weigh-in charging procedure, but elect to have the system verified by a HERS rater using the RA3.2.2 standard charge verification procedure at a time when the temperature is warmer. However, this option can delay the project. In this case, the installer must include the signatures of the homeowner and the HERS Rater on the CF2R - MCH25c form to notify the local enforcement agency that a correct refrigerant charge will be verified at a later time (RA 2.4.4). The installer must also provide written notice to the homeowner that the charge has not yet been verified (RA2.4.4).
 - b. EXCEPTION 1 to §150.2(b)1Fiib provides for an alternative HERS verification procedure if the weigh-in method is used. This exception allows the installer to use the HERS Rater verification procedure in RA3.2.3.2 in which the rater observes the installer while the installer performs the weigh-in charging procedure. However, when the HVAC installer elects this option, as specified in RA3.2.3.2, the system thermostat must be an OCST that conforms to the requirements of JA5.
2. **Weigh-in Procedure During Warm Weather.** The installer may use the weigh-in procedure when the outdoor temperature is at or above 55°F; in this case the rater must use the standard charge verification procedure.
3. **Weigh-in Procedure Description.** The weigh-in procedure involves charging the system by determining the appropriate weight of refrigerant based on the size of the equipment and refrigerant lines rather than by actual performance of the system. Systems using the weigh-in procedure by the installer for any reason may not be third party verified by using sample groups.

There are two variations of the weigh-in procedures. One involves the adjustment to the amount of refrigerant in a system by adding or removing a fraction of the refrigerant as specified by the manufacturer (weigh-in charge adjustment). The other involves evacuating the entire system and recharging it with the correct amount of refrigerant by weight (weigh-in total charge).

The weigh-in charge adjustment procedure may only be used when a new factory-charged condenser is being installed and the manufacturer provides adjustment specifications based on evaporator coil size and refrigerant line size and length.

The weigh-in total charge may be used for any weigh-in procedure but still requires manufacturer's adjustment specifications.
4. **Standard Charge Procedure Description.** The standard charge verification procedure also has two variations. One is for systems that have a fixed orifice and the

other is for systems that have a variable metering device such as a thermostatic expansion valve (TXV) or electronic expansion valve (EXV).

Both procedures, whether performed by the installer or the rater require that adequate airflow be confirmed prior to verifying charge. If the airflow is less than the minimum requirement of 300 cfm per ton, the system is not operating near its designed capacity or efficiency and the standard charge verification procedure is not valid.

The standard charge verification procedures involve taking refrigerant line temperatures and pressures, calculating equipment performance parameters and comparing those to targets either provided by the manufacturer or obtained from standard tables. All temperature and pressure measurements must be taken using calibrated digital meters. Analog gauges are no longer allowed for refrigerant charge verification procedures due to a lack of accuracy and precision.

In systems that have metering devices, the proper installation and performance can be verified by similar measurements and is an important part of the standard charge verification procedure for systems that have metering devices.

- 5. Verifying Minimum System Airflow.** The procedures for measuring total system airflow are found in RA3.3. They include plenum pressure matching using a fan flow meter, a flow grid, a powered flow hood, and the traditional (non-powered flow hood). The airflow verification procedures for refrigerant charge verification no longer include the temperature split method.

If a system does not meet the minimum airflow requirements, remedial steps may be required to bring the airflow up. More airflow is generally better for systems with air conditioning. Not only does this allow proper refrigerant charge to be verified, but it also improves the overall performance of the system. Minimum system airflow must always be verified regardless of the refrigerant charge verification procedure. §150.2(b)1F states that systems must be installed with “all applicable procedures,” which includes the minimum system airflow requirements.

In some cases, improving airflow may be cost prohibitive. The process for documenting this is in RA3.3.3.1.5. When this option is used, verification by sample groups is not allowed.

- 6. Temperature Measurements.** To properly perform the standard RCV procedure, a means of taking an accurate return air dry-bulb temperature must be provided by the installer. In most systems, this is accomplished by drilling a 5/16” measurement access hole in the return side of the air handler or return plenum as shown in Figure RA3.2-1. If the correct location for these holes is not accessible, an alternative location may be provided as long as an accurate return air temperature measurement of the air as it enters the return side of the equipment can be made.

In other cases, taking the return air dry-bulb temperature at the return grill may be appropriate. This is true when the return is located entirely within conditioned space and not subject to leakage or conduction that may change the temperature of the air after it passes through the return grill and before it enters the evaporator coil. This may also apply to equipment where the return grill is an integral part of the air handler, such as enclosed soffit-mounted air handlers (pancake units).

- 7. Maintaining 70°F Return Air Temperature.** During the data collection portion of the standard charge verification procedures, the return air dry bulb temperature, as measured at the measurement access hole, must remain at or above 70°F. This is to ensure proper refrigerant charge conditions, including but not limited to preventing the moisture on the coil from freezing. This requirement may be problematic during cooler

outdoor conditions (above 55°F but below 70°F). The return air temperature can be maintained above 70°F by utilizing the home's heating system or supplemental heaters. Note that the weigh-in method is always an option for the installer in these cases.

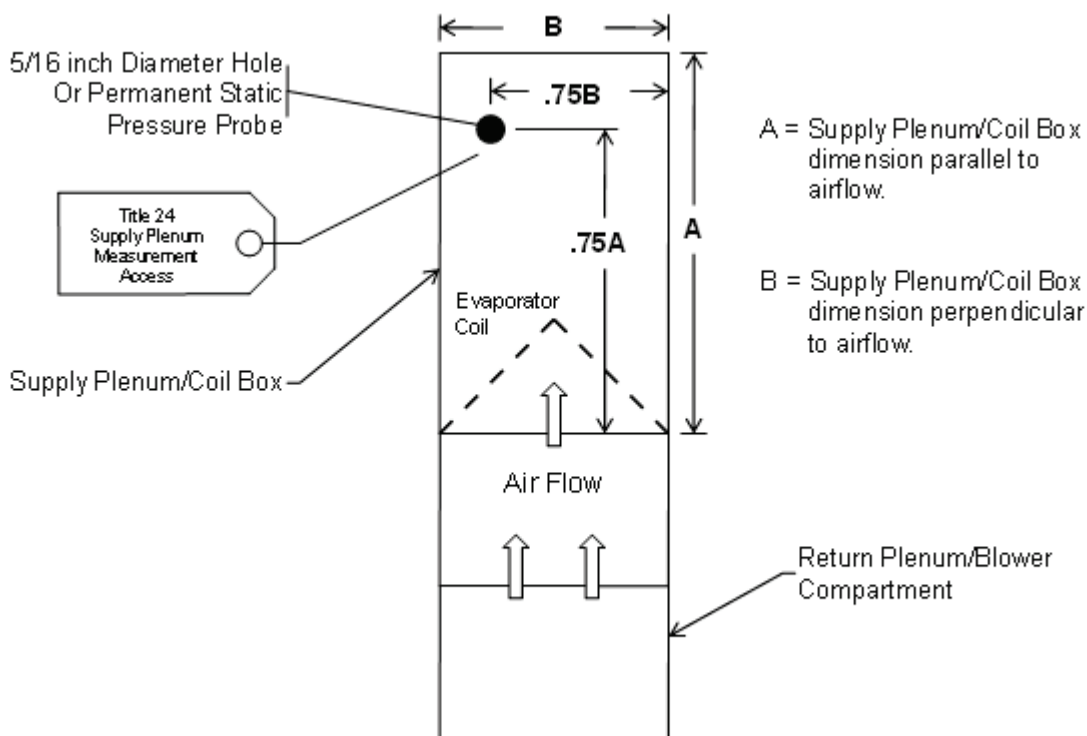
F. Airflow and Fan Efficacy

In all climate zones when an entirely new or replacement duct system is installed, the central forced air fan of all ducted air conditioners and heat pumps must simultaneously, in every zonal control mode, demonstrate airflow of greater than 350 CFM/ton of nominal cooling, and a fan watt draw of less than 0.58 W/CFM in accordance with the procedures in RA3.3.

As an alternative to the field verified air flow and fan efficacy requirements, the system's return ducts can be sized according to Tables 150.0-C or 150.0-D.

In addition to either the airflow/fan efficacy or return duct sizing alternative, the system installer must provide in the supply plenum, a hole for the placement of a static pressure probe (HSPP) or a permanently installed static pressure probe (PSPP), downstream of the evaporator coil that meets the specifications of RA3.3.1.

Figure 9-4: Hole for the Placement of a Static Pressure Probe (HSPP) or Permanently Installed Static Pressure Probe (PSPP)



These requirements are mandatory measures and cannot be traded off by using the performance approach; which is discussed in detail in Chapter 4.

Heating only space-conditioning systems are not required to meet the prescriptive cooling coil airflow and fan watt draw requirements.

G. Sampling for Alterations

When compliance for an alteration requires field verification and diagnostic testing, the building owners or their agents may choose to have testing and field verification completed for the dwelling unit alone, or as part of a closed sample group of dwelling units for which the same installing company has completed work that requires testing and field verification for compliance.

Registration of the compliance documentation is required and the procedures for this must be followed as described in Chapter 2 of this manual and in RA2.

Notes regarding sampling for alterations:

1. The sample group shall be no larger than seven.
2. The installing company may request a smaller group for sampling.
3. Homes in a sample group must all have the same set of features to be verified (duct testing, airflow/fan efficacy, refrigerant charge, etc.)
4. Homes with systems utilizing the weigh-in method for refrigerant charge verification by the installer cannot be sampled.
5. Whenever the HERS Rater for the group is changed, a new group will be established.
6. Field verification and diagnostic testing shall be completed by the HERS rater for at least one randomly selected dwelling unit in each group.
7. Re-sampling, full testing, and corrective action shall be completed if necessary, as specified in RA2.6.3.
8. The installing contractor must self-test and register certificates of installation for all features to be tested prior to the rater choosing a home for verification by sampling.
9. **Third Party Quality Control Program.** An approved Third Party Quality Control Program may serve some of the functions of HERS raters for field verification and diagnostic testing purposes but does not have authority to sign the Certificate of Verification (CF3R) as a HERS rater, as specified in RA2.7.

When a Third Party Quality Control Program is used, the HERS Rater must still submit completed, signed, registered copies of the CF3R to the enforcement agency, the installing contractor, and the builder or building owner for all dwellings that must demonstrate compliance.

1. **Setback Thermostat.** When a split system air conditioner or heat pump is altered by the installation or replacement of any refrigerant containing component and the existing thermostat is not a setback thermostat, then a new setback thermostat must be installed as described in Chapter 4 of this manual and as specified in §150.2(b)1Fi.
2. **Fuel Switching.** For prescriptive compliance, new electric resistance heating systems are prohibited in alterations unless the system being replaced is an electric resistance heating system. If the existing system is gas, propane, or LPG, then new electric resistance systems are not permitted. However, changing from a gas, propane, or LPG space heating system to an electric heat pump is allowed as long as the heat pump efficiency meets minimum efficiency standards, and the heat pump installed size is shown to result in no more TDV energy use than the standard design heat pump using the performance method as specified in §150.2(b)1C.

Table 9-9: Acceptable Replacement Heating System Fuel Source(s)

Existing Heating System Fuel Source	Acceptable Replacement Heating System Fuel Source(s)
Electric	Electric, natural gas, or equipment with efficiency equal to or better than existing system.*
Natural gas	Natural gas or equipment with efficiency equal to or better than existing system* or a heat pump with equal or lower TDV energy use than a standard design system.
LPG	Liquefied petroleum gas, natural gas, or equipment/system with efficiency equal to or better than existing system* or a heat pump with equal or lower TDV energy use than a standard design system.

* Proof that equipment has an efficiency that is equal to or better than the existing system can be demonstrated by an approved compliance program or other approved alternative calculation method to compare the TDV energy use of the existing system to the proposed system.

Table 9-10 summarizes requirements for the following types of residential mechanical and water heating system alterations:

1. New or complete replacement space conditioning system: all new equipment and all new ducts with more than 40 linear feet of duct.
2. Altered space conditioning system with forced air ducts.
3. Altered mechanical cooling system.
4. Altered duct systems: when more than 40 linear feet of new or replacement ducts.
5. Installed a zonally controlled central forced air system.
6. Replaced water heater(s) and altered hot water pipe(s).

It is important to accurately identify the type(s) of alteration within the permitted scope of work. For example, duct sealing and HERS testing is a mandatory measure when there is a new or complete replacement space conditioning system and greater than 40 linear feet of duct. However, when only new or replacement ducts are being installed, and there is no new space conditioning equipment involved, duct sealing and HERS testing is a prescriptive measure. A key to using Table 9-10 effectively is to have a good understanding of the scope of the proposed alterations.

Example 9-29

Question

Do I have to seal the ducts if I replace the outdoor units in my house without changing the indoor unit?

Answer

Yes, replacing the outdoor unit (or indoor unit) by itself will trigger the duct sealing and verification requirement (§150.2(b)1E). However, there are two exceptions that might apply:

1. If the ducts have been previously sealed and verified as sealed, the ducts do not have to be sealed again and re-verified.
2. If there is less than 40 linear feet of the duct.

Example 9-30

Question

I have an existing electric furnace and I'm adding a new bedroom. Can I extend the existing ducts to the new room and use the existing furnace?

Answer

Yes. If ducts are extended from an existing space conditioning system, §150.2(b)1D allows the existing system but requires duct sealing if more than 40 linear feet of the new duct work is installed. The existing furnace must have adequate heating capacity to meet California Building Code requirements for the additional space.

Example 9-31

Question

I am adding a bedroom to a house that has a central forced air natural gas furnace. I would like to heat the room with an electric resistance baseboard heater rather than extend the existing ductwork to reach the new space. Is this allowed?

Answer

No. If using prescriptive compliance and since the existing system is gas, the addition cannot use an electric heating system. Options for heating the space include:

1. Extending the existing natural gas furnace system as long as there is adequate capacity to meet the California Building Code requirement.
2. Heating the added bedroom with an electric resistance heater is allowed if the performance approach is taken and the relatively high TDV energy consumption of the electric resistance heater is made up by TDV energy reductions from energy efficiency measures in the addition or in an accompanying alteration.

Note: If there are more than 40 linear feet of added ducts, then the ducts must be sealed, tested and verified as sealed by a HERS rater.

Example 9-32

Question

My central gas furnace stopped working. Since it is about 30 years old, I decided to get a new more efficient unit rather than repair the existing one. What are the requirements?

Answer

Mandatory requirements apply to the components being replaced. The furnace, of course, must meet minimum efficiency requirements, but all systems sold in California should already meet the minimum efficiency requirements. If the existing thermostat is not a setback thermostat, it must be replaced with a setback thermostat, as specified in §150.2(b)1Fi that meets the requirements described earlier in this chapter.

All new ducts must meet insulation and construction requirements. All existing and new ducts must be sealed and HERS verified, as specified §150.2(b)1E.

Prescriptively, the new heating unit must be natural gas or heat pump.

The performance approach could be applied but only if the alteration includes “tradeoffs between two or more altered components that are listed in Table 150.2-B” (insulation, fenestration, space conditioning equipment, air distribution systems, water heating system, roofing, and other measures). Thus, if other alterations are also being done, one could specify other heating equipment such as a high efficiency heat pump, condensing gas furnace, or electric resistance, as long as the overall project has a lower TDV energy consumption than the “standard design.” When using the performance approach one can decide to either use the default standard design efficiencies that the alteration is compared against. Alternately one can hire a HERS rater to document the existing efficiencies and these existing efficiencies can be used in the standard design of performance calculation.

Example 9-33

Question

As part of an upgrade in an existing house, one of the ducts is being replaced because of deterioration of the insulation and jacket. What requirements apply to the replacement duct?

Answer

This is an alteration to the space conditioning system; therefore the mandatory measures for ducts apply. If more than 40 feet of the ducts are altered, then the requirements of §150.2(b)1D would trigger diagnostic testing and HERS verification of the whole duct system.

Example 9-34

Question

An upflow air-handling unit with a furnace and air conditioning coil is located on a platform in the garage of an existing house. The platform is used as a return air plenum. The air-handling unit is being replaced and the platform is being repositioned to the corner of the garage (three feet away from the current location). What requirements apply to this alteration?

Answer

The mandatory requirements apply to this alteration. In particular, §150.0(m) prohibits raised platforms or building cavities from being used to convey conditioned air (including return air and supply air). When the platform is relocated, it is being altered, and the mandatory requirement applies. Ducts made from sheet metal, duct board, or flexible ducts must be installed to carry the return air to the replaced air handler. This requirement would not apply if the platform were not being altered.

Since the air handler is being replaced the prescriptive duct sealing requirements apply per §150.2(b)1E, unless the ducts have been previously sealed and confirmed through verification or there is less than 40 linear feet of duct.

Example 9-35

Question

What is meant by the term "air handler?"

Answer

The term "air handler" is used to identify the system component that provides the central system forced air movement for the ducted heating or cooling space-conditioning system. The term "air handler" may be properly used to identify various types of central system forced air-moving components that must meet the functional requirements for different types of space-conditioning systems. For instance, a "gas furnace" air handler includes a gas combustion heat exchanger and the central system fan, but does not include a DX cooling coil; an "electric furnace" air handler has electric heating coils and the central system fan, but does not include a DX cooling coil; a "fan-coil unit" air handler for a split system heat pump has a DX cooling/heating coil and a central system fan; a "hydronic heat pump" air handler includes the air-side DX coil, compressor, water-cooled condenser, and the central system fan. There are other air handler configuration variations as well.

Example 9-36

Question

I have a residential building that was constructed in the 1920s. It has a freestanding gas furnace and I want to change it to an electric wall heater. Is this permitted?

Answer

No. §150.2(b)1Cii states that the new space-conditioning system be limited to natural gas, liquefied petroleum gas, or the existing fuel type unless it can be demonstrated that the TDV energy use of the new system is more efficient than the existing system. For your situation you would have to use gas or a heat pump for compliance.

Table 9-10: Residential Alteration, Summary of Mandatory and Prescriptive Measures

Type of Mechanical System Alteration	Highlight(s) of Applicable Mandatory Measures ¹	Summary of Relevant Prescriptive Measure(s)	Exception(s) to the Prescriptive Measures	Prescriptive Compliance Form(s)
<p>New or Complete Replacement Space Conditioning System (New Equipment and All New Ducts > 40 ft.)</p>	<p>New equipment must meet all minimum efficiency and other requirements in §150.0(h), 150.0(i), 150.0(j)2, 150.0(j)3, 150.0(m)1 thru 11: duct sealing & HERS testing with forced air duct systems</p>	<p>All requirements of §150.1(c)6,7,9 & 10, 150.2(b)1D; and heating system limited to natural gas, LPG or existing fuel type</p>	<p>Exemption from fuel type requirement if new system can be shown to use less TDV energy than the existing system.</p>	<p>CF1R-ALT or CF1R-ALT-HVAC; (CF1R must be registered w/ a HERS Provider)</p>
<p>Altered Space Conditioning System with Forced Air Ducts</p>	<p>New equipment must meet all the minimum efficiency and other requirements in §150.0(h), §150.0(i), §150.0(j)2, §150.0(j)3, §150.0(m)1 thru 11</p>	<p>Duct sealing & HERS testing per §150.2(b)1.E</p>	<p>(1) Duct systems documented as previously sealed and HERS tested; or, (2) Duct systems with < 40; or, (3) Existing duct system constructed, insulated or sealed with asbestos</p>	<p>CF1R-ALT or CF1R-ALT-HVAC; (CF1R must be registered w/ a HERS Provider)</p>
<p>Altered⁽⁵⁾ Mechanical Cooling (Refrigerant-Containing) System</p>	<p>New equipment must meet all the minimum efficiency and other requirements in §110.2(c), §150.0(h), §150.0(i), §150.0(j)2, §150.0(j)3, §150.0(m)1 thru 11</p>	<p>In CZ2, 8-15: refrigerant charge per RA3.2.2 and & HERS testing per §150.2(b)1.F.i.b. Minimum system airflow per §150.2(b)1Fia</p>	<p>(1) Packaged systems w/ correct, verified and documented refrigerant charge do not require HERS testing (2) When outdoor temperature < 55o F. and refrigerant weigh-in charging used and HERS test RA3.2.3.2 used, system thermostat must be Demand Response.</p>	<p>CF1R-ALT or CF1R-ALT-HVAC; (CF1R must be registered w/ a HERS Provider)</p>

<p>Altered Duct Systems: When > 40 ft. of New or Replacement Ducts are Installed</p>	<p>New ducts must meet applicable portions of §150.0(m)1 thru 11 including duct insulation in Table 150.1-A. Entirely new and complete replacement duct systems must meet additional requirements in §150.0(m)12 and 13.</p>	<p>New or Replacement Duct System: duct insulation per §150.2(b)1i., sealing & HERS testing per §150.2(b)1.D.ii.a. Extension of Existing Ducts By > 40 ft: HERS testing of existing duct system per §150.2(b)D.ii.b.</p>	<p>Exception to 150.2(b)D.ii.b. Duct Sealing: when existing duct system is constructed, insulated or sealed with asbestos.</p>	<p>CF1R-ALT or CF1R-ALT-HVAC; (CF1R must be registered w/ a HERS Provider)</p>
<p>Installing Zonally Controlled Central Forced Air System</p>	<p>Airflow > 350 CFM/Ton cooling Fan < 0.58 W/CFM HERS testing §150.0(m)13</p>	<p>Bypass ducts that deliver conditioned supply air directly to the return duct airflow may not be used §150.1(c)13</p>	<p>N/A</p>	<p>CF-1R-ALT or CZ-Specific CF-1R-ALT-HVAC, MF-1R (CF-1R must be registered w/a HERS Provider)</p>
<p>Replacement Water Heaters and Altered Piping</p>	<p>New equipment must meet minimum efficiency and other requirements in §110.1, 110.3 and 150.0(j)2 Exception to §150.0(j)2: Inaccessible piping requires no insulation</p>	<p>(1) A natural gas or propane water heater. With recirculation system, only Demand Recirculation with manual controls or, (2) If no natural gas is connected to the building: an electric water heater. For electric resistance storage water heaters, storage tank < or = 60 gallons. With recirculation system, only Demand Recirculation with manual controls</p>	<p>According to a calculation method approved by the CEC. Any water heating system that uses no more TDV energy than the prescriptive natural gas/propane water heater, or When no natural gas is connected to the building, any heating system that uses no more TDV energy than the prescriptive electric water heater.</p>	<p>CF-1R-ALT, or CF-1R-ALT-HVAC, MR-1R</p>
<p>Note: Alterations must comply with all applicable mandatory measures in §110.0 and §150.0 of the Energy Standards as explained in Chapters 3, 4, 5, and 6 of this manual, except as noted in §150.2(b).</p>				

9.7 Performance Method

9.7.1 Addition Alone

Additions may comply using the performance approach for an addition alone. With only two exceptions, the energy budget is the same as is required for new construction. The two exceptions are: (1) For additions that are 300 ft² or less no cool roof requirements apply, and (2) if Package A requires a whole house fan, the requirement does not apply to additions that are 1,000 ft² or less.

9.7.2 Summary of Existing + Additions + Alterations

1. Performance compliance may not be used for tradeoffs for an alteration alone unless there are at least two or more altered components listed in §150.2 and Table 150.2-C.
2. Existing roofs/ceilings removed as part of an addition or alteration--and all existing skylights being removed as part of the removed roofs/ceilings--**are excluded** (not modeled) in the Existing + Addition + Alterations (E+A+A) performance calculations.
3. Existing exterior walls removed as part of an addition or alterations--and all existing vertical fenestration (windows, clerestories, glazed doors) being removed as part of the removed walls--**are excluded** (not modeled) in the E+A+A performance calculations.
4. Only “Existing,” “Altered,” and “New” building components and/or systems are included and modeled in the E+A+A performance calculations.
5. Existing fenestration not being removed as part of an alteration can now be improved with window films and can be modeled in the E+A+A performance calculations.
6. **Without** third party verification of the building’s existing (pre-alteration) conditions, the E+A+A approach no longer provides energy credits based on altered components which upgrade (improve) the existing conditions until a fairly high threshold is met. See §150.2(b)2B and Table 150.2-C of the Energy Standards.
7. **With** third party verification of the building’s existing (i.e., pre-alteration) conditions, the E+A+A approach still provides energy credits based on altered components which upgrade (improve) the existing conditions. See §150.2(b)2B and Table 150.2-C of the Energy Standards.

9.7.3 Performance Method: Existing + Addition + Alterations Approach

Additions may comply using the performance approach with one of the following compliance paths summarized in Section 9.3, Table 9-1:

1. E + A + A Without Third Party Verification;
2. E + A + A With Third Party Verification;
3. E + A + A as New Construction.

Energy Commission-approved compliance software is used to model the building as explained in Chapter 8. Whichever compliance path is selected, the Certificate of Compliance (CF1R) generated by the software must be submitted for permit. If the CF1R includes energy measures that require HERS testing or verification, the CF1R must also be registered online with a HERS provider. See Chapter 2 of this manual.

To learn more about using the Existing + Addition + Alterations performance approach, see Table 9-4.

9.7.3.1 Existing + Addition + Alterations Without Third Party Verification

The existing building with all alterations is modeled together with the addition and **existing** conditions are not verified by a third party HERS Rater. The Standard Design that sets the energy budget for this approach is automatically based only on the type of each altered component and not on the existing conditions. Under this performance path the building is modeled as follows:

1. Addition: All new components at the addition and all new systems serving the addition are modeled including roof/ceilings, skylights, exterior walls, glazing (fenestration),

raised floors and slab floors, HVAC equipment, ducts, and water heating. All of these components are tagged within the compliance software as "New."

2. **Existing Components to Remain Unchanged:** Existing components and systems to remain as is (untouched) are modeled and tagged within the compliance software as "Existing."
3. **Existing Components to be Altered or Replaced:** Each altered component (i.e., a new component which replaces an existing component) is modeled and tagged within the performance compliance program as "Altered." For example, a new water heater that replaces an existing water heater would be labeled "altered" whereas a new water heater that is added to supplement an existing water heater would be labeled "new." Also, new mechanical equipment that does not replace existing mechanical equipment would be tagged as "new." Verification of existing conditions is not required for this compliance path; therefore, no "existing" (pre-alteration) conditions are specified.
4. **Existing to be Removed:** Existing roof/ceilings to be removed as part of the permitted work, plus any skylights within those removed roof/ceilings, are excluded from the model (i.e., they are completely omitted from the calculations); exterior walls to be removed and all fenestration areas in those walls are not modeled; raised floors and slab-on-grade floors to be removed are also omitted.

Note: Portions of new fenestration including skylights that will occur in the existing opening of fenestration to be replaced are tagged "altered." Portions of new fenestration that will occur where there is no existing fenestration opening are labeled "new."

- **Advantages:** Energy improvements to the existing building that go beyond the Standard Design levels are an energy credit that can be "traded" against features of the addition that are less energy efficient than required by the prescriptive levels that set the Standard Design for the addition alone. For example, an addition with a large glazing area may comply by replacing the existing HVAC system with high-efficiency equipment.
- **Disadvantages:** Detailed plans and other information on the existing building may be difficult to document and obtain. The E+A+A analysis may be relatively complex and time-consuming.

9.7.3.2 Existing + Addition + Alterations With Third Party Verification

The existing building with alterations is modeled together with the addition(s); and existing conditions of the components being altered must be verified by a third party HERS Rater before construction begins. The Standard Design that sets the energy budget may, depending on the energy efficiency of the altered component or system, be based on the pre-altered existing conditions. In those instances, energy credit is calculated as a function of the difference between pre-altered existing conditions and post-alteration energy measures. Under this approach the building is modeled as follows:

1. **Addition:** All new components for the addition and all new systems serving the addition are modeled including roof/ceilings and skylights, exterior walls and glazing (fenestration), raised floors and slab floors, HVAC equipment, ducts, and water heating. All these elements are tagged within the compliance software as "new."
2. **Existing Components to Remain Unchanged:** Existing components and systems to remain as is (untouched) are modeled and tagged within the compliance software as "Existing."

3. **Existing Components to be Altered or Replaced:** First, select “HERS verification of existing conditions” in the compliance software. This unlocks software inputs for both “existing” and “altered” characteristics for those particular building features. The compliance software will not give the option to enter pre-altered existing conditions, if you do not specify that the existing conditions will be HERS-verified.

Each altered component (i.e., a new component that replaces an existing component) is modeled and tagged within the performance compliance program as “Altered.” The corresponding HERS verified existing component or system to be changed is modeled and tagged within the same entry in the compliance software as “existing.” For example, if existing HERS-verified single pane metal frame window are replaced with NFRC-rated super-efficient windows, to receive the maximum energy credit one must identify the existing windows to be HERS-verified. Then, each altered window input would include both “existing” and “altered” window types.

Note: Any window area in addition to that being replaced would be labeled “new” not “altered.”

5. **Removed Surfaces:** Existing roof/ceilings to be removed as part of the permitted work, plus any skylights within those removed roof/ceilings, are excluded from the model (i.e., they are completely omitted from the calculations). Exterior walls to be removed and all fenestration areas to be removed in those walls are not modeled; raised floors and slab-on-grade floors to be removed are also omitted.
- **Advantages:** Energy improvements meeting certain threshold values are credited based on the difference between existing conditions and the altered component or system. These energy credits can be “traded” against features of the addition that are less energy efficient than required by the prescriptive levels that set the Standard Design for the addition alone. For example, an addition with a large glazing area may comply by upgrading insulation levels in the existing house.
 - **Disadvantages:** Detailed plans and other information on the existing building may be difficult to document and obtain. The E+A+A analysis may be relatively complex and time-consuming. A third party verification must be conducted of selected existing conditions to be altered prior to construction, and verification must be registered online with a HERS provider prior to permit submittal.

9.7.3.3 Existing + Addition + Alterations as New Construction

A compliance approach rarely used, but available within the Energy Standards, is to model Existing + Addition + Alterations as all “new” components and systems and the compliance software sets the energy budget as if the project were an entirely new building.

- **Advantages:** Modeling the existing building with alterations and additions as all new makes the performance analysis relatively simple and less time-consuming. This method will provide the owner and designer with energy efficiency compliance relative to requirements for new construction. Any owner who wants to bring their building up to new construction efficiency levels should have their project modeled as “new.”
- **Disadvantages:** The energy budget with this approach is very stringent. Unless a building is going through a complete retrofit of all its envelope components, as well as replacing all mechanical and water heating systems, it is unlikely that the building will meet the Energy Standards with this approach.

9.7.3.4 Summary of Modeling Rules

Table 9-4 summarizes the basic rules for compliance software users analyzing a residential addition or alteration using the Existing + Addition + Alterations approach. For further information, see the specific compliance software user's manual for details on how to input data correctly.

Example 9-37

Question

A 1,600 ft² house built in 1980 in climate zone 12 is being renovated as follows:

1. A 500 ft² room will be added, including 120 ft² of new windows.
2. A 200 ft² wall and 100 ft² of old window will be removed.
3. Attic insulation in the existing house will be upgraded to R-38.
4. The addition will be connected to the existing HVAC and duct system.

If the performance approach is used to demonstrate compliance, how does the compliance software establish the standard and proposed designs?

Answer

Table 9-4 summarizes the Modeling Rules for Existing + Addition + Alterations which must be followed to have the compliance software accurately set the standard design and model the proposed design. Under the 2016 Standards performance rules, the 200 ft² wall removed and the 100 ft² of old window within it are not included in the energy model and will have no impact on the standard design. The standard design for the addition portion is set using the prescriptive requirements of §150.1(c). If the existing duct system is extended by 40 linear feet or more, the standard design assumes the duct alterations requirements summarized in Table 9-5.

The standard design assumptions for the existing house follow the rules summarized in §150.2(b)2 and Table 150.2-B based on whether there is a third party verification of the existing conditions. Without third party verification, upgraded energy components in the existing house are modeled as fixed assumptions in the standard design that represent levels of efficiency reasonably expected for each altered component. If the energy analyst using the compliance software selects third party verification of energy components in the existing house to be upgraded, the standard design assumes the existing conditions for those components to be as part of the alterations.

If the proposed design including Existing + Addition + Alterations does not pass, other energy components of the existing building and/or the addition may have to achieve compliance. For example, the water heater or the HVAC equipment in the existing portion of the house may be upgraded to achieve additional credits towards compliance. In the addition, higher performing windows and higher levels of roof and wall insulation may also be used to achieve compliance.

Example 9-38

Question

For the 1980 house in the examples above, an operable single pane metal window is replaced with a 0.55 U-factor window. Does this alteration result in a compliance credit? How about the case where the existing window is replaced with a window that has a U-factor of 0.35?

Answer

As explained in Example 9-36, altered components that receive compliance credit must exceed the requirements of Table 150.2-B. Windows in the addition must have a U-factor of < 0.32 and SHGC < 0.25 to receive credit. Replacement windows in the existing house must have a U-factor of < 0.40 and SHGC < 0.35 to receive credit.

A window replacement with a 0.55 U-factor will receive a penalty as compared with a 0.40 U-factor standard design assumption for that window. **Without** third party verification of existing conditions, a 0.35 U-factor window replacement will receive a credit as compared with a 0.40 U-factor standard design assumption for that window. **With** third party verification of existing conditions, a 0.35 U-factor window replacement will receive a credit as compared with a 1.28 U-factor standard design assumption for an operable single pane metal existing window.

Although this example describes a window alteration, the same principles apply to other building systems, such as other building envelope components as well as HVAC and water heating equipment.

Example 9-39

Question

An addition of 590 ft² is being added to a 2,389 ft² single family house. How do you demonstrate compliance using the Existing + Addition + Alterations method?

Answer

The first step is to determine whether alterations to the existing building include at least two components (e.g., upgrading attic insulation and replacing the water heater, or more than one window.) If so, use the E+A+A approach. If not, do not use the performance approach.

Assuming the E+A+A calculation is permissible, the next steps are:

1. Collect accurate envelope and mechanical information about the existing building from scaled drawings (plans, sections, and elevations); determine what components, (HVAC, ducts, water heating, etc.) are being altered as part of the permitted scope of work.
2. Enter the information about the addition and the existing building into the compliance software program, identifying each modeled feature as “existing,” “altered,” or “new” as summarized in Table 9-4. Proper tagging of each of these inputs is critical to correctly and accurately determine compliance.
3. Run the compliance software to determine if the proposed building TDV energy is equal or less than the standard design TDV energy.
4. If it is not, modify the energy features of the addition and/or the existing building until compliance is achieved; print out the compliance report for permit submittal.
5. All projects that include energy measures requiring HERS field verification and diagnostic testing--which represent almost all buildings under the 2016 Energy Standards--must be registered online with a HERS provider as explained in Section 2.3.

Example 9-40

Question

When using the existing-plus-addition performance approach, do the refrigerant charge, access holes (MAH and STMS) or FID, see §150.1(c)7, airflow, watt draw measurement, and static pressure probe (HSPP), or a permanently installed static pressure probe (PSPP) as specified in §150.0(m)13 and need to be met for central split system air conditioners serving an addition?

Answer

If existing equipment is extended to serve the addition, these space conditioning requirements do not need to be met as specified by Exception 4 to §150.2(a). However, Exception 5 to §150.2(a) indicates that the duct system that is to be extended must be sealed, tested, and HERS verified according to §150.2(b)1D.

For performance compliance in climate zones that require a refrigerant charge and airflow measurement in Package A, a hypothetical standard design SEER split system with this credit would be modeled in both the standard and the proposed designs (for example, values from the vintage table, or minimally complying equipment), resulting in neither credit nor penalty related to this feature.

If a new central split system is installed to serve the addition, it must meet the requirements of §150.2(b)1C where installation of a new air conditioner to serve both the existing house and the addition is considered an alteration, and must meet the requirements for diagnostically tested refrigerant charge measurement fan airflow, watt draw, and other requirements described. The duct sealing, testing, and verification requirements of §150.2(b)1E must also be met.

Example 9-41

Question

When using the E+A+A performance method, can compliance credit be gained by sealing the existing ducts when it was not required for prescriptive compliance?

Answer

Yes. Credit can be obtained from sealing, testing, and HERS verification of duct sealing.

However, as shown in Table 150.2-B “Standard Design for an Altered Component,” the base case duct leakage will be the requirements in §150.2(b)1D (i.e., with 15 percent duct leakage or 10 percent leakage to the outside). Sealing below 15 percent can be difficult if the ducts are not readily accessible and large holes are present in the ducts. An alternative approach is to replace the ducted system with a ductless system such as a mini-split.

Example 9-42

Question

When using the existing plus addition performance compliance method, can credit be gained by installing a radiant barrier in the existing house attic? If so, where does the radiant barrier need to be installed?

Answer

Yes, installing a radiant barrier in the existing building will result in a credit relative to the standard design for existing buildings permitted (or constructed) prior to June 1, 2001. The radiant barrier must be installed over the entire attic/roof area including gable walls. If there are roof/ceiling assemblies where it is not possible to reach the underside of the roof, such as roof/ceiling assemblies using enclosed rafters which are not proposed to be exposed as part of the project, the radiant barrier cannot be properly installed and compliance credit is not possible.

Example 9-43

Question

I am adding a room to and altering an existing building in climate zone 12. I am upgrading a single-pane clear glass window with a U-factor of 1.2 and SHGC of 1.0 to a dual-pane window with a U-factor of 0.50 and SHGC of 0.45. Do I receive credit toward the addition compliance for installing this window?

Answer

No. There will be a penalty toward achieving compliance since the window is not as efficient as required by Table 150.2-B for climate zone 12 which requires a U-factor of 0.40 and an SHGC of 0.35. The penalty for the U-factor is based on the difference between 0.40 and 0.50 and for the SHGC is based on the difference between 0.35 and 0.45. If fenestration is installed which exceeds the performance of the values in Table 150.2-B, then credit is available.

Example 9-44**Question**

I am planning on installing R-19 insulation in the attic of an existing house built in 1970. Can I use this added insulation as a credit for trading with the energy features of an addition?

Answer

No. When insulation is added to an attic, it must comply with §150.0(a) which sets a mandatory minimum for attic insulation of R-22. No credit is allowed until the mandatory minimum R-22 is reached.

Example 9-45**Question**

I am planning on installing R-25 insulation in an un-insulated vaulted ceiling without an attic space in an existing house built in 1970. Can I use this added insulation as a credit for trading with the energy features of an addition?

Answer

Yes. Since there is no attic space, the requirements of §150.0(a) require only R-19 or the equivalent between roof rafters. When you install R-25 you are allowed to take credit for the difference between R-25 and R-19 without third party verification of existing conditions. With third party site verification of the existing un-insulated vaulted ceiling prior to construction, you may take credit for the difference between the R-25 and R-0 (no insulation) in the vaulted ceiling.

Appendix A Compliance Documents

NOTE: For Documents and User Instructions, please visit our website at:

<http://energy.ca.gov/title24/2016standards>

#	Doc Type	Doc Category	Category Description	Document Description
CF1R's – Certificate of Compliance				
1	CF1R-	NCB-01-E	Newly Constructed Buildings	Prescriptive Newly Constructed Buildings and Additions Equal to or Greater Than 1,000 ft ²
2	CF1R-	ADD-01-E	Additions	Prescriptive Additions Less Than 1,000 ft ²
3	CF1R-	ADD-02-E	Additions	Prescriptive Additions – Simple NonHERS (paper version)
4	CF1R-	ALT-01-E	Alterations	Prescriptive Alterations
5	CF1R-	ALT-02-E	Alterations	Prescriptive Alterations HVAC
6	CF1R-	ALT-03-E	Alterations-HVAC	Alterations-HVAC for CZ 1, 3-7, 16 (paper version)
7	CF1R-	ALT-04-E	Alterations-HVAC	Alterations HVAC for CZ 2, 8-15 (paper version)
8	CF1R-	ALT-05-E	Alterations	Prescriptive Alterations – Simple NonHERS (paper version)
9	CF1R-	ENV-02-E	Envelope	Area Weighted Average Calculation Worksheet
10	CF1R-	ENV-03-E	Envelope	Solar Heat Gain Coefficient (SHGC) Worksheet
11	CF1R-	ENV-04-E	Envelope	Solar Reflective Index (SRI) Calculation Worksheet
12	CF1R-	PLB-01-E	Plumbing (DHW)	Hydronic Heating System Worksheet
13	CF1R-	SRA-01-E	Solar Ready	Solar Ready Buildings – New Construction
14	CF1R-	SRA-02-E	Solar Ready	Minimum Solar Zone Area Worksheet – New Construction
15	CF1R-	STH-01-E	Solar Thermal	OG 300 Solar Water Heating Worksheet
16	CF1R-	STH-02-E	Solar Thermal	OG 100 Solar Water Heating Worksheet
CF2R's – Certificate of Installation				
17	CF2R-	ADD-02-E	Additions	Prescriptive Additions – Simple NonHERS (paper version)
18	CF2R-	ALT-05-E	Alterations	Prescriptive Alterations – Simple NonHERS (paper version)
19	CF2R-	ENV-01-E	Envelope-NonHERS	Fenestration Installation
20	CF2R-	ENV-03-E	Envelope-NonHERS	Insulation Installation
21	CF2R-	ENV-04-E	Envelope-NonHERS	Roofing – Radiant Barrier
22	CF2R-	ENV-20-H	Envelope-HERS	Building Leakage Diagnostic Test
23	CF2R-	LTG-01-E	Lighting-NonHERS	Lighting - Single Family Dwellings

Appendix A Compliance Documents

#	Doc Type	Doc Category	Category Description	Document Description
24	CF2R-	LTG-02-E	Lighting-NonHERS	Lighting - Multifamily Dwellings
25	CF2R-	MCH-01-E	Mechanical-NonHERS	Space Conditioning Systems
26	CF2R-	MCH-02-E	Mechanical-NonHERS	Whole House Fan
27	CF2R-	MCH-04-E	Mechanical-NonHERS	Evaporative Coolers
28	CF2R-	MCH-20-H	Mechanical-HERS	Duct Leakage Diagnostic Test
29	CF2R-	MCH-21-H	Mechanical-HERS	Duct Location Verification
30	CF2R-	MCH-22-H	Mechanical-HERS	Fan Efficacy
31	CF2R-	MCH-23-H	Mechanical-HERS	Airflow Rate
32	CF2R-	MCH-24-H	Envelope-HERS	Building Envelope Air Leakage Worksheet
33	CF2R-	MCH-25-H	Mechanical-HERS	Refrigerant Charge Verification
34	CF2R-	MCH-26-H	Mechanical-HERS	Rated Space Conditioning System Equipment Verification
35	CF2R-	MCH-27-H	Mechanical-HERS	Mechanical Ventilation
36	CF2R-	MCH-28-H	Mechanical-HERS	Return Duct Design and Air Filter Grille Device Sizing According to Tables 150.0-B or C
37	CF2R-	MCH-29-H	Mechanical-HERS	Duct Surface Area Reduction; R-Value; Buried Ducts Compliance Credit
38	CF2R-	MCH-30-E	Mechanical-HERS	Ventilation cooling compliance credit
39	CF2R-	PLB-01-E	Plumbing-DHW-NonHERS	Multifamily Central Hot Water System Distribution
40	CF2R-	PLB-02-E	Plumbing (DHW)-NonHERS	Single Dwelling Unit Hot Water System Distribution
41	CF2R-	PLB-03-E	Plumbing (DHW)-NonHERS	Pool and Spa Heating Systems
42	CF2R-	PLB-21-H	Plumbing (DHW)-HERS	HERS Verified Multifamily Central Hot Water System Distribution
43	CF2R-	PLB-22-H	Plumbing (DHW)-HERS	HERS Verified Single Dwelling Unit Hot Water System Distribution
44	CF2R-	SPV-01-E	Photovoltaics-NonHERS	Photovoltaic Systems
45	CF2R-	STH-01-E	Solar Thermal	Solar Water Heating Systems
CF3R's – Certificate of Installation				
46	CF3R-	ENV-20-H	Envelope-HERS	Building Leakage Diagnostic Test
47	CF3R-	ENV-21-H	Envelope-HERS	Quality Insulation Installation (QII) - Air Infiltration Sealing - Framing Stage - Batt, Loose Fill, and SPF
48	CF3R-	ENV-22-H	Envelope-HERS	Quality Insulation Installation (QII) - Air Infiltration Sealing - Ceiling/Roof Deck
49	CF3R-	ENV-23-H	Envelope-HERS	Quality Insulation Installation (QII) - Insulation Stage

Appendix A Compliance Documents

#	Doc Type	Doc Category	Category Description	Document Description
50	CF3R-	ENV-24-H	Envelope-HERS	Quality Insulation Installation (QII) - Air Infiltration Sealing - Framing Stage - SIP and ICF
51	CF3R-	EXC-20-H	Existing Conditions	HERS Verification of Existing Conditions for Residential Alterations
52	CF3R-	MCH-20-H	Mechanical-HERS	Duct Leakage Diagnostic Test
53	CF3R-	MCH-21-H	Mechanical-HERS	Duct Location Verification
54	CF3R-	MCH-22-H	Mechanical-HERS	Fan Efficacy
55	CF3R-	MCH-23-H	Mechanical-HERS	Airflow Rate
56	CF3R-	MCH-24-H	Envelope-HERS	Building Envelope Air Leakage Worksheet
57	CF3R-	MCH-25-H	Mechanical-HERS	Refrigerant Charge Verification
58	CF3R-	MCH-26-H	Mechanical-HERS	Rated Space Conditioning System Equipment Verification
59	CF3R-	MCH-27-H	Mechanical-HERS	Mechanical Ventilation
60	CF3R-	MCH-28-H	Mechanical-HERS	Return Duct Design and Air Filter Device Sizing According to Tables 150.0-B or C
61	CF3R-	MCH-29-H	Mechanical-HERS	Duct Surface Area Reduction; R-value; Buried Ducts Compliance Credit
62	CF3R-	PLB-21-H	Plumbing (DHW)-HERS	HERS Verified Multifamily Central Hot Water System Distribution
63	CF3R-	PLB-22-H	Plumbing (DHW)-HERS	HERS Verified High Rise Residential/Hotel/Motel Single Dwelling Unit Hot Water System Distribution
64	NRCV-	MCH-04-H	Mechanical-HERS	Duct Leakage Diagnostic Test
65	NRCV-	PLB-21-H	Plumbing (DHW)-HERS	HERS Verified Multifamily Central Hot Water System Distribution
66	NRCV-	PLB-22-H	Plumbing (DHW)-HERS	HERS Verified High Rise Residential/Hotel/Motel Single Dwelling Unit Hot Water System Distribution

Appendix B

APPLICABLE TABLES AND LANGUAGE FROM THE ENERGY STANDARDS AND RACM

Appendix B is a collection of common used tables and language that are referenced in the *Residential Compliance Manual* which includes excerpts from the *2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings* and the *Appliance Efficiency Regulations*.

FIGURE 100.1-A—CALIFORNIA CLIMATE ZONES

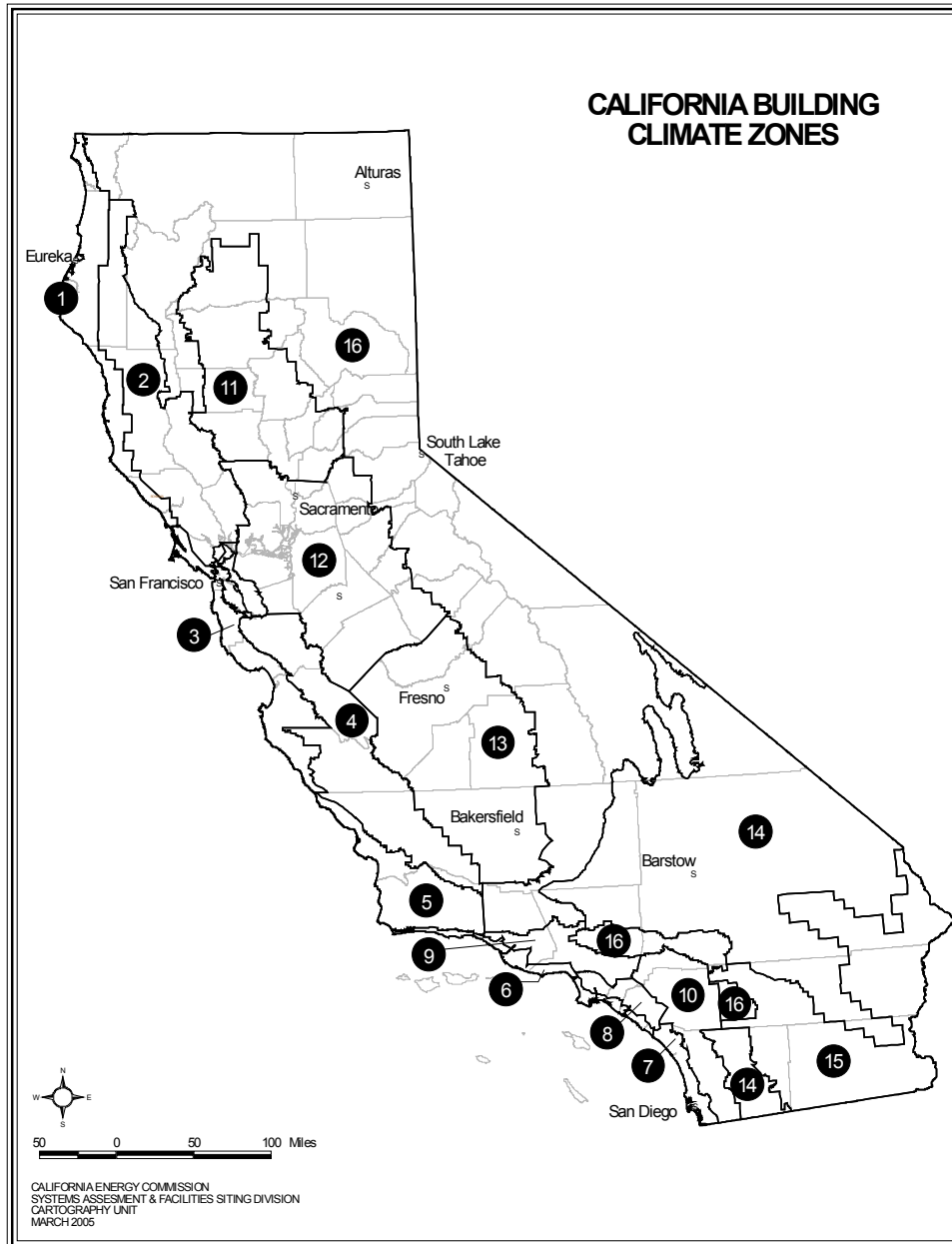


TABLE 100.0-A - APPLICATION OF STANDARDS

Occupancies	Application	Mandatory	Prescriptive	Performance	Additions/ Alterations
General Provisions		100.0, 100.1, 100.2, 110.0			
Nonresidential, High-Rise Residential, And Hotels/Motels	General	120.0	140.0, 140.2	140.0, 140.1	141.0
	Envelope (conditioned)	110.6, 110.7, 110.8, 120.7	140.3		
	Envelope (unconditioned process spaces)	N.A.	140.3(c)		
	HVAC (conditioned)	110.2, 110.5, 120.1, 120.2, 120.3, 120.4, 120.5, 120.8	140.4		
	Water Heating	110.3, 120.3, 120.8, 120.9	140.5		
	Indoor Lighting (conditioned, process spaces)	110.9, 120.8, 130.0, 130.1, 130.4	140.3(c), 140.6		
	Indoor Lighting (unconditioned and parking garages)	110.9, 120.8, 130.0, 130.1, 130.4	140.3(c), 140.6	N.A.	
	Outdoor Lighting	110.9, 130.0, 130.2, 130.4	140.7		
	Electrical Power Distribution	110.11, 130.5	N.A.		
	Pool and Spa Systems	110.4, 110.5, 150.0(p)	N. A.		141.0
	Solar Ready Buildings	110.10	N.A.		141.0(a)
Covered Processes ¹	Envelope, Ventilation, Process Loads	110.2, 120.6	140.9	140.1	120.6, 140.9
Signs	Indoor and Outdoor	130.0, 130.3	140.8	N.A.	141.0, 141.0(b)2H
Low-Rise Residential	General	150.0	150.1(a, c)	150.1(a), 150.1(b)	150.2(a), 150.2(b)
	Envelope (conditioned)	110.6, 110.7, 110.8, 150.0(a), 150.0(b), 150.0(c), 150.0(d), 150.0(e), 150.0(g)			
	HVAC (conditioned)	110.2, 110.5, 150.0(h), 150.0(i), 150.0(j), 150.0(m), 150.0(o)			
	Water Heating	110.3, 150.0(j, n)			
	Indoor Lighting (conditioned, unconditioned and parking garages)	110.9, 130.0, 150.0(k)			
	Outdoor Lighting	110.9, 130.0, 150.0(k)			
	Pool and Spa Systems	110.4, 150.0(p)	N. A.	N.A.	150.2(a), 150.2(b)
	Solar Ready Buildings	110.10	N. A.	N.A.	N.A.
¹ Nonresidential, high-rise and hotel/motel buildings that contain covered processes may conform to the applicable requirements of both occupancy types listed in this table.					

TABLE 110.2-A - ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS – MINIMUM EFFICIENCY REQUIREMENTS

Equipment Type	Size Category	Efficiency ^{a,b}		Test Procedure ^c
		Before 1/1/2016	After 1/1/2016	
Air conditioners, air cooled both split system and single package	≥ 65,000 Btu/h and < 135,000 Btu/h	11.2 EER 11.4 IEER	11.2 EER 12.9 IEER	ANSI/AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	11.0 EER 11.2 IEER	11.0 EER 12.4 IEER	ANSI/AHRI 340/360
	≥ 240,000 Btu/h and < 760,000 Btu/h	10.0 EER 10.1 IEER	10.0 EER 11.6 IEER	
	≥ 760,000 Btu/h	9.7 EER 9.8 IEER	9.7 EER 11.2 EER	
Air conditioners, water cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	12.1 EER 12.3 IEER	12.1 EER 13.9 IEER	ANSI/AHRI 340/360
	≥135,000 Btu/h and < 240,000 Btu/h	12.5 EER 12.5 IEER	12.5 EER 13.9 IEER	ANSI/AHRI 340/360
	≥240,000 Btu/h and < 760,000 Btu/h	12.4 EER 12.6 IEER	12.4 EER 13.6 IEER	ANSI/AHRI 340/360
	≥ 760,000 Btu/h	12.2 EER 12.4 IEER	12.2 EER 13.5 IEER	ANSI/AHRI 340/360
Air conditioners, evaporatively cooled	≥65,000 Btu/h and < 135,000 Btu/h	12.1 EER ^b 12.3 IEER ^b		ANSI/AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	12.0 EER ^b 12.2 IEER ^b		ANSI/AHRI 340/360
	≥240,000 Btu/h and < 760,000 Btu/h	11.9 EER ^b 12.1 IEER ^b		ANSI/AHRI 340/360
	≥ 760,000 Btu/h	11.7 EER ^b 11.9 IEER ^b		ANSI/AHRI 340/360
Condensing units, air cooled	≥ 135,000 Btu/h	10.5 EER 11.8 IEER		ANSI/AHRI 365
Condensing units, water cooled	≥ 135,000 Btu/h	13.5 EER 14.0 IEER		
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.

TABLE 110.2-B - UNITARY AND APPLIED HEAT PUMPS, MINIMUM EFFICIENCY REQUIREMENTS

Equipment Type	Size Category	Efficiency ^{a, b}		Test Procedure ^c
		<u>Before 1/1/2016</u>	<u>After 1/1/2016</u>	
Air Cooled (Cooling Mode) both split system and single package	≥ 65,000 Btu/h and < 135,000 Btu/h	11.0 EER 11.2 IEER	11.0 EER 12.2 IEER	ANSI/AHRI 340/360
	≥ 135,000 Btu/h and < 240,000 Btu/h	10.6 EER 10.7 IEER	10.6 EER 11.6 IEER	
	≥ 240,000 Btu/h	9.5 EER 9.6 IEER	9.5 EER 10.6 IEER	
Water source (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	86°F entering water	13.0 EER	ISO-13256-1
Groundwater source (cooling mode)	< 135,000 Btu/h	59°F entering water	18.0 EER	ISO-13256-1
Ground source (cooling mode)	< 135,000 Btu/h	77°F entering water	14.1 EER	ISO-13256-1
Water source water- to-water (cooling mode)	< 135,000 Btu/h	86°F entering water	10.6 EER	ISO-13256-2
Groundwater source water-to-water (cooling mode)	< 135,000 Btu/h	59°F entering water	16.3 EER	ISO-13256-1
Ground source brine- to-water (cooling mode)	< 135,000 Btu/h	77°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° F db/43° F wb outdoor air	3.3 COP	ANSI/AHRI 340/360
		17° F db/15° F wb outdoor air	2.25 COP	
	≥ 135,000 Btu/h (cooling capacity)	47° F db/43° F wb outdoor air	3.2 COP	
		17° F db/15° F wb outdoor air	2.05 COP	

TABLE 110.6-A - DEFAULT FENESTRATION PRODUCT U-FACTORS

FRAME	PRODUCT TYPE	SINGLE PANE ^{3,} 4 U-FACTOR	DOUBLE PANE ^{1,3,} 4 U-FACTOR	GLASS BLOCK ^{2,3} U-FACTOR
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.
<p>1. For all dual-glazed fenestration products, adjust the listed U-factors as follows:</p> <ol style="list-style-type: none"> Add 0.05 for products with dividers between panes if spacer is less than 7/16 inch wide. Add 0.05 to any product with true divided lite (dividers through the panes). <p>2. Translucent or transparent panels shall use glass block values when not rated by NFRC 100.</p> <p>3. Visible Transmittance (VT) shall be calculated by using Reference Nonresidential Appendix NA6.</p> <p>4. Windows with window film applied that is not rated by NFRC 100 shall use the default values from this table.</p>				

TABLE 110.6-B DEFAULT SOLAR HEAT GAIN COEFFICIENT (SHGC)

FRAME TYPE	PRODUCT	GLAZING	FENESTRATION PRODUCT SHGC		
			Single Pane ^{2,3} SHGC	Double Pane ^{2,3} SHGC	Glass Block ^{1,2} SHGC
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 the default values from this table.

TABLE 150.1-A COMPONENT PACKAGE-A

		Climate Zone																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16					
Building Envelope Insulation	Roofs/Ceilings	Option A (meets §150.1(c)9A)	Continuous Insulation Above Roof Rafter	Roofing Type	No Air Space ¹	NR	NR	NR	R 8	NR	NR	NR	R 8	R 8	R 8	R 8	R 8	R 8	R 8			
			With Air Space ²	NR	NR	NR	R 6	NR	NR	NR	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	R 6	
			Ceiling Insulation	R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38
		Radiant Barrier	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	
		Option B (meets §150.1(c)9A)	Below Roof Deck Insulation ³	Roofing Type	No Air Space	NR	NR	NR	R 18	NR	NR	NR	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18	R 18
			With Air Space	NR	NR	NR	R 13	NR	NR	NR	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13	R 13
	Ceiling Insulation		R 38	R 38	R 30	R 38	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	
	Radiant Barrier	NR	REQ	REQ	NR	REQ	REQ	REQ	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
	Option C (meets §150.1(c)9B)	Ceiling Insulation	R 38	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 30	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	R 38	
		Radiant Barrier	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	

			Climate Zone																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Building Envelope Insulation	Walls	Above Grade	Framed ⁴	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.065	U 0.065	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	U 0.051	
			Mass Wall Interior ⁵	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.059 R 17
			Mass Wall Exterior ⁶	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.125 R 8.0	U 0.1025 R 8.0	U 0.125 R 8.0
		Below Grade	Below Grade Interior ⁷	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.070 R 13	U 0.066 R 15
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			Below Grade Exterior ⁸	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.200 R 5.0	U 0.100 R 10	U 0.100 R 10	U 0.053 R 19
	Floors	Slab Perimeter	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	U 0.58 R 7.0	
		Raised	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	U 0.037 R 19	
		Concrete Raised	U 0.092 R 8.0	U 0.092 R 8.0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.269 R 0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0	U 0.092 R 8.0	U 0.138 R 4.0	U 0.092 R 8.0	
	Building Envelope	Roofing Products	Low-sloped	Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.63	NR	0.63	NR
Thermal Emittance			NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	NR	0.75	NR
Steep Sloped		Aged Solar Reflectance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.20	0.20	0.20	0.20	0.20	0.20	NR	
		Thermal Emittance	NR	NR	NR	NR	NR	NR	NR	NR	NR	0.75	0.75	0.75	0.75	0.75	0.75	NR	
Building Envelope	Fenestration	Maximum U-factor	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32		
		Maximum SHGC	NR	0.25	NR	0.25	NR	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	
		Maximum Total Area	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	
		Maximum West Facing Area	NR	5%	NR	5%	NR	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	

			Climate Zone																
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
HVAC SYSTEM	Space Heating ¹¹	Electric-Resistance Allowed	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	
		If gas, AFUE	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	
		If Heat Pump, HSPF ⁹	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	
	Space cooling	SEER	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	MIN	
		Refrigerant Charge Verification or Fault Indicator Display	NR	REQ	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	
		Whole House Fan ¹⁰	NR	NR	NR	NR	NR	NR	NR	NR	REQ	REQ	REQ	REQ	REQ	REQ	REQ	NR	
	Central System Air Handlers	Central Fan Integrated Ventilation System Fan Efficacy	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	
	Ducts ¹²	Roof/Ceiling Options A & B	Duct Insulation	R-8	R-8	R-6	R-8	R-6	R-6	R-6	R-8	R-8	R-8	R-8	R-8	R-8	R-8	R-8	
			§150.1(c)9A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Roof/Ceiling Option C	Duct Insulation	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6	R-6
			§150.1(c)9B	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ	REQ
	Water Heating	All Buildings	System Shall meet Section 150.1(c)8																

FOOTNOTE REQUIREMENTS TO TABLE 150.1-A:

1. Install the specified R-value with no air space present between the roofing and the roof deck.
2. Install the specified R-value with an air space present between the roofing and the roof deck. Such as standard installation of concrete or clay tile.
3. R-values shown for below roof deck insulation are for wood-frame construction with insulation installed between the framing members.
4. U-factors can be met by cavity insulation alone or with continuous insulation alone, or with both cavity and continuous insulation that results in a U-factor equal to or less than the U-factor shown. Use Reference Joint Appendices JA4 Table 4.3.1, 4.3.1(a), or Table 4.3.4 to determine alternative insulation products to meet the required maximum U-factor.
5. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft². "Interior" denotes insulation installed on the inside surface of the wall.
6. Mass wall has a thermal heat capacity greater than or equal to 7.0 Btu/h-ft². "Exterior" denotes insulation installed on the exterior surface of the wall.
7. Below grade "interior" denotes insulation installed on the inside surface of the wall.
8. Below grade "exterior" denotes insulation installed on the outside surface of the wall.
9. HSPF means "heating seasonal performance factor."
10. When whole house fans are required (REQ), only those whole house fans that are listed in the Appliance Efficiency Directory may be installed. Compliance requires installation of one or more WHFs whose total airflow CFM is capable of meeting or exceeding a minimum 2 cfm/square foot of conditioned floor area as specified by Section 150.1(c)12.
11. A supplemental heating unit may be installed in a space served directly or indirectly by a primary heating system, provided that the unit thermal capacity does not exceed 2 kilowatts or 7,000 Btu/hr and is controlled by a time-limiting device not exceeding 30 minutes.
12. For duct and air handler location: REQ denotes location in conditioned space. When the table indicates ducts and air handlers are in conditioned space, a HERS verification is required as specified by Reference Residential Appendix RA3.1.4.3.8

TABLE 150.2-B AGED SOLAR REFLECTANCE INSULATION TRADE OFF TABLE

Aged Solar Reflectance	Roof Deck Insulation R-value	Aged Solar Reflectance	Roof Deck Insulation R-value
0.62-0.60	2	0.44-0.40	12
0.59-0.55	4	0.39-0.35	16
0.54-0.50	6	0.34-0.30	20
0.49-0.45	8	0.29-0.25	24

Residential Table – Vintage Table Values**TABLE R3-50 – DEFAULT ASSUMPTIONS FOR EXISTING BUILDINGS – VINTAGE TABLE VALUES**

Default Assumptions for Year Built (Vintage)

Conservation Measure	Before 1978	1978 to 1983	1984 to 1991	1992 to 1998	1999 - 2000	2001- 2003	2004- 2005	2006 and 2012	2013 and Later
INSULATION U-FACTOR									
Roof/Ceiling	0.079	0.049	0.049	0.049	0.049	0.049	0.049	0.049	
Wall	0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102	
Raised Floor –Crawl Space	0.099	0.099	0.099	0.046	0.046	0.046	0.046	0.046	
Cool Roof	0.10	0.10	0.10	0.10	0.10	0.10	0.10	Pres Pkg.	
Radiant Barrier	None	None	None	None	None	None	Pres Pkg.	Pres Pkg.	
Raised Floor-No Crawl Space	0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064	
Slab Edge F-factor	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	
Ducts	R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	Pres Pkg.	
LEAKAGE									
Building (SLA)	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9	
Duct Leakage Factor (See Table 4-13)	0.86	0.86	0.86	0.86	0.86	0.89	0.89	0.89	
FENESTRATION									
U-factor	Use Standards Table 110.6-A , §110.6 for all Vintages								
SHGC	Use Standards Table 110.6-B , §110.6 for all Vintages								
Shading Dev.	Use Table R3-27 and R3-28 for all Vintages in the Residential ACM Manual – Performance Approach								
SPACE HEATING EFFICIENCY									
Gas Furnace (Central) AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78	
Gas Heater (Room) AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	
Hydronic/Comb Hydronic	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	
Heat Pump HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4	
Electric Resistance HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413	
Electric Resistance Radiant HSPF	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55	
SPACE COOLING EFFICIENCY									
All Types, SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	13.0	
WATER HEATING									
Energy Factor	0.525	0.525	0.525	0.525	0.575	0.575	0.575	0.575	

Appliance Efficiency Standards from Section 1605.1

Table B-3
Standards for Room Air Conditioners and Room Air-Conditioning Heat Pumps

<i>Appliance</i>	<i>Louvered Sides</i>	<i>Cooling Capacity (Btu/hr)</i>	<i>Minimum Combined EER</i>
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 Packaged Terminal Air Conditioners and Packaged Terminal Heat Pumps

<i>Appliance</i>	<i>Cooling Capacity (Btu/hour)</i>	<i>Minimum Efficiency</i>	
		<i>Minimum EER</i>	<i>Minimum COP</i>
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-3
Standards for Air-Cooled Air Conditioners and Air-Source Heat Pumps Subject to EPA Act
(Standards Effective January 1, 2010 do not apply To Single Package Vertical Air Conditioners)**

Appliance	Cooling Capacity (Btu/hr)	System Type	Minimum Efficiency			
			Effective January 1, 1994 ¹ or January 1, 1995 ²	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	10.0 SEER ¹	13.0 SEER		
	< 65,000 *	Single package	9.7 SEER ¹	13.0 SEER		
	≥ 65,000 and < 135,000	All	8.9 EER ¹		11.2 EER ³ 11.0 EER ⁴	11.0 EER ³ 10.8 EER ⁴
	≥ 135,000 and < 240,000	All	8.5 EER ²		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	6.8 HSPF ¹	7.7 HSPF		
	< 65,000 *	Single package	6.6 HSPF ¹	7.7 HSPF		
	≥ 65,000 and < 135,000	All	3.0 COP ¹		3.3 COP	
	≥ 135,000 and < 240,000	All	2.9 COP ²		3.2 COP	
	≥ 240,000 and < 760,000	All			3.2 COP	
<p>* Three phase models only.</p> <p>³ Applies to equipment that has electric resistance heat or no heating.</p> <p>⁴ Applies to equipment with all other heating-system types that are integrated into the unitary equipment.</p>						

**Table C-4
Standards for Evaporatively-Cooled Air Conditioners**

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 conditioners	< 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 [†]	4.2		
Water-cooled air conditioners and evaporatively cooled air conditioners	≥ 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 conditioners	≥ 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 ^{††}	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

<i>Appliance</i>	<i>Cooling Capacity (BTU/hr)</i>	<i>System Type</i>	<i>Minimum Efficiency</i>	
			<i>Cooling Mode</i>	<i>Heating Mode</i>
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 E-2
Standards for Gas Wall Furnaces, Floor Furnaces, and Room Heaters

<i>Appliance</i>	<i>Design Type</i>	<i>Capacity (Btu per hour)</i>	<i>Minimum AFUE (%)</i>	
			<i>Effective Before April 16, 2013</i>	<i>Effective On or After April 16, 2013</i>
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	
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 and Electric Residential Boilers

<i>Appliance</i>	<i>Minimum AFUE (%)</i>	
	<i>Effective January 1, 1992</i>	
	<i>75</i>	<i>Effective September 1, 2012</i>
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 F-2
Standards for Large Water Heaters Effective October 29, 2003**

<i>Appliance</i>	<i>Input to Volume Ratio</i>	<i>Size (Volume)</i>	<i>Minimum Thermal Efficiency (%)</i>	<i>Maximum Standby Loss^{1,2}</i>
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	$0.67 - (.0019 \times V)$	$0.675 - (0.0015 \times V)$
	> 55		$0.8012 - (0.00078 \times V)$
Oil-fired water heaters (storage and instantaneous)	Any	$0.59 - (.0019 \times V)$	$0.68 - (.0019 \times V)$
Electric storage water heaters (excluding tabletop water heaters)	≤ 55	$0.97 - (.00132 \times V)$	$0.960 - (0.0003 \times V)$
	> 55		$2.057 - (0.00113 \times V)$
Electric tabletop water heaters	Any	$0.93 - (.00132 \times V)$	$0.93 - (.00132 \times V)$
Gas-fired instantaneous water heaters	Any	$0.62 - (.0019 \times V)$	$0.82 - (.0019 \times V)$
Electric instantaneous water heaters (excluding tabletop water heaters)	Any	$0.93 - (.00132 \times V)$	$0.93 - (.00132 \times V)$
Heat pump water heaters	Any	$0.97 - (.00132 \times V)$	$0.97 - (.00132 \times V)$

V = Rated storage volume in gallons.

Appendix C

NATURAL GAS APPLIANCE TESTING (NGAT) STANDARDS

The NGAT standards, "Natural Gas Appliance Testing (NGAT) Standards", are found in Section 24 of the "California Installation Standards" manual; edition dated July 1, 2012. A copy may be obtained from contacting:

James E. O'Bannon

Richard Heath and Associates

1390 Ridgewood Drive, Suite 10

Chico, CA 95973

Phone: (530) 892-2460

Fax: (530) 892-2825

email: jim@rhainc.com

Appendix D – Eligibility Criteria for Radiant Barriers, Section RA4.2.1

Radiant barriers shall meet specific eligibility and installation criteria to be modeled by any approved compliance software and receive energy credit for compliance with the Building Energy Efficiency Standards for low-rise residential buildings.

The emittance of the radiant barrier shall be less than or equal to 0.05 as tested in accordance with ASTM C1371 or ASTM E408.

Installation shall conform to ASTM C1158 (Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Building Construction), ASTM C727 (Standard Practice for Installation and Use of Reflective Insulation in Building Constructions), ASTM C1313 (Standard Specification for Sheet Radiant Barriers for Building Construction Applications), and ASTM C1224 (Standard Specification for Reflective Insulation for Building Applications), and the radiant barrier shall be securely installed in a permanent manner with the shiny side facing down toward the interior of the building (ceiling or attic floor). Moreover, radiant barriers shall be installed at the top chords of the roof truss/rafters in any of the following methods:

- (a) Draped over the truss/rafter (the top chords) before the upper roof decking is installed.
- (b) Spanning between the truss/rafters (top chords) and secured (stapled) to each side.
- (c) Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space shall be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.
- (d) Attached [laminated] directly to the underside of the roof decking. The radiant barrier shall be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.
- (e) In addition, the radiant barrier shall be installed to cover all gable end walls and other vertical surfaces in the attic.

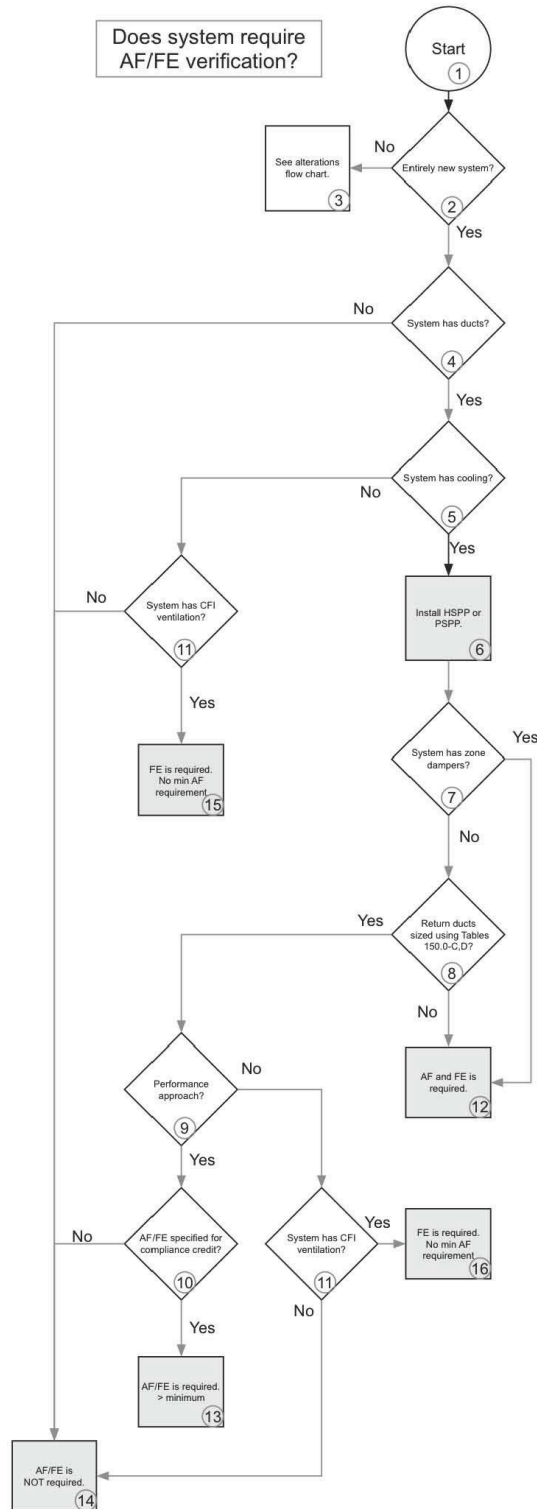
For Prescriptive Compliance: The attic shall be ventilated to:

- (a) Provide a minimum free ventilation area of not less than one square foot of vent area for each 300 ft² of attic floor area.
- (b) Provide no less than 30 percent upper vents.
- (c) Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full airflow to the venting.
- (d) The product shall meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.
- (e) The use of a radiant barrier shall be listed in the Special Features and Modeling Assumptions listings of the Certificate of Compliance and described in detail in the Residential ACM Manual Conform to the radiant barrier manufacturer's instructions.

Appendix E

Requirement Diagrams for Selected Residential HVAC HERS Measures

Flowchart G-1: Determining if a System Requires Airflow and Fan Efficacy Verification

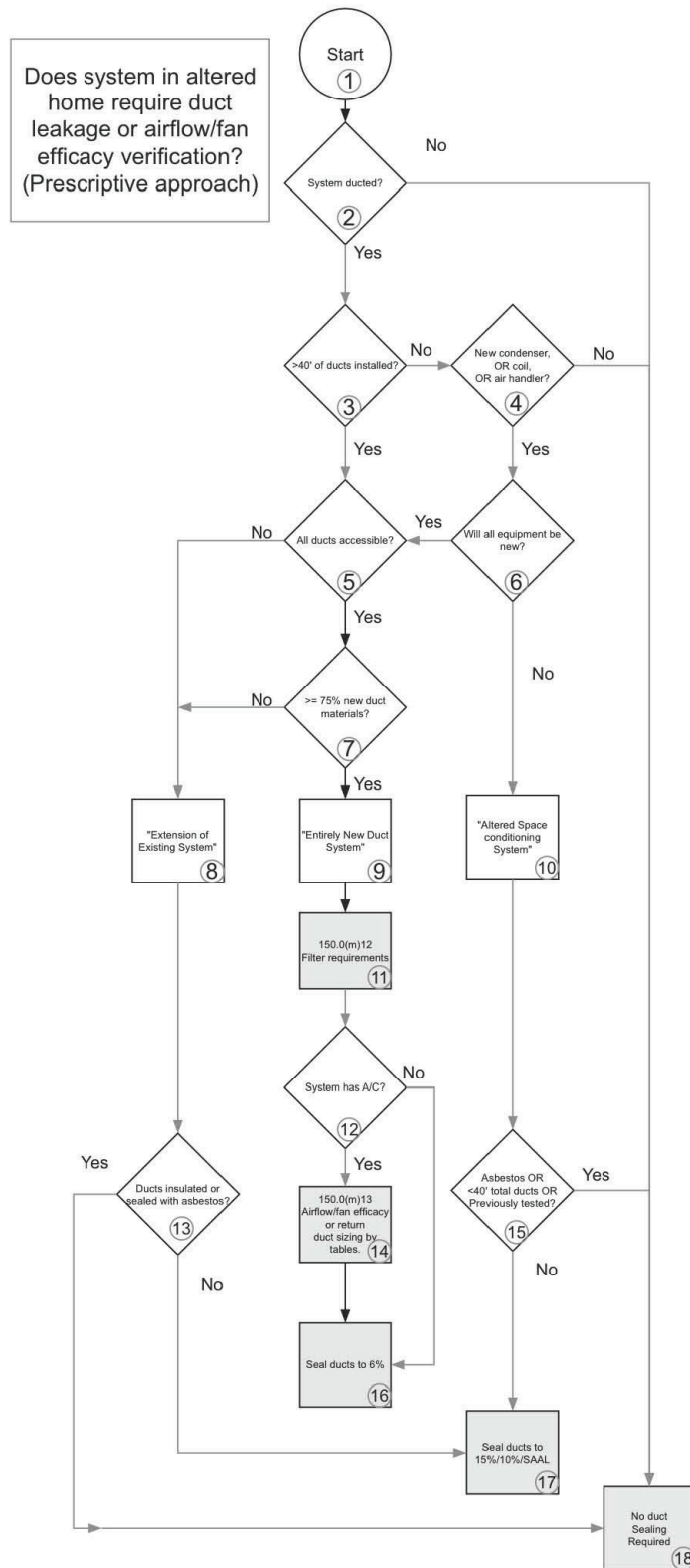


Instructions for Flowchart G-1 - Determining if a System Requires Airflow and Fan Efficacy Verification:

1. Start here to determine if a new or altered system is required to have the airflow and fan efficacy field verified (350 cfm/ton and 0.58 watts/cfm).
2. If the system meets the definition of an Entirely New or Completely Replaced System (refer to Section 9.X in the Residential Compliance Manual), either being installed in a newly constructed home or in an existing home, choose "Yes," otherwise choose "No."
3. If the system is being installed in an existing home and it is an altered system, refer to Flow Chart 9.1.
4. If the system has a central air handler (package or split) connected to supply outlets via ducting of any shape or material, then choose "Yes." Otherwise, choose "No."
5. If they system includes mechanical DX air conditioning (this does not include whole house fans or swamp coolers), choose "Yes." Otherwise, choose "No."
6. Reaching this box means that the system is subject to the requirements of section 150.0(m)13. An HSPP or PSPP must be installed, as required. Refer to section 9.X in the Residential Compliance Manual. Continue to next box.
7. If the system has motorized zone dampers that open and close to send supply air to different parts of the home, then choose "Yes." Otherwise, choose "No."
8. Section 150.0(m)13 requires that the system either meet the airflow and fan efficacy requirements OR have the return ducts sized according to Table 150.0-C or 150.0-D. If the return ducts are sized and installed according to these tables, then choose "Yes." Otherwise choose "No."
9. If the performance compliance approach is used to demonstrate compliance to the energy requirements, then choose "Yes." Otherwise, choose "No."
10. If the performance compliance approach is used to demonstrate compliance to the energy requirements and airflow greater than 350 cfm/ton is specified for compliance credit or a fan efficacy less than 0.58 watts/cfm is specified for compliance credit, then choose "Yes." Otherwise, choose "No."
11. If the system has a central fan integrated ventilation system (refer to section 9.6 of the Residential Compliance Manual), then choose "Yes." Otherwise, choose "No."
12. Reaching this box means that the system is required to demonstrate compliance to the minimum requirements of 350 cfm/ton and 0.58 watts/cfm. Refer to section 9.X of the Residential Compliance Manual. HERS Rater verification is required for these features as well as proper installation of the HSPP/PSPP.
13. Reaching this box means that the system is required to demonstrate compliance to the requirements of 350 cfm/ton or better and 0.58 watts/cfm or better. Refer to section 9.X of the Residential Compliance Manual. HERS Rater verification is required for these features as well as proper installation of the HSPP/PSPP and proper sizing of the return ducts according to Tables 150.0-C or Table 150.0-D.
14. Reaching this box means that the system is not subject to either the airflow or fan efficacy requirements, but if the system is ducted and has cooling, it will be subject to the requirements of having an HSPP/PSPP and return ducts sized according to Tables 150.0-C or 150.0-D.
15. Reaching this box means that the system is required to meet the 0.58 watts/cfm requirement, but not the 350 cfm/ton requirement.

16. Reaching this box means that the system is required to meet the 0.58 watts/cfm requirement, the HSPF/PSFP requirement and proper return duct sizing according to Tables 150.0-C or 150.0-D, but not the 350 cfm/ton requirement. HERS verification is required for all these required features.

Flowchart G-2: Duct Requirements for Altered Systems



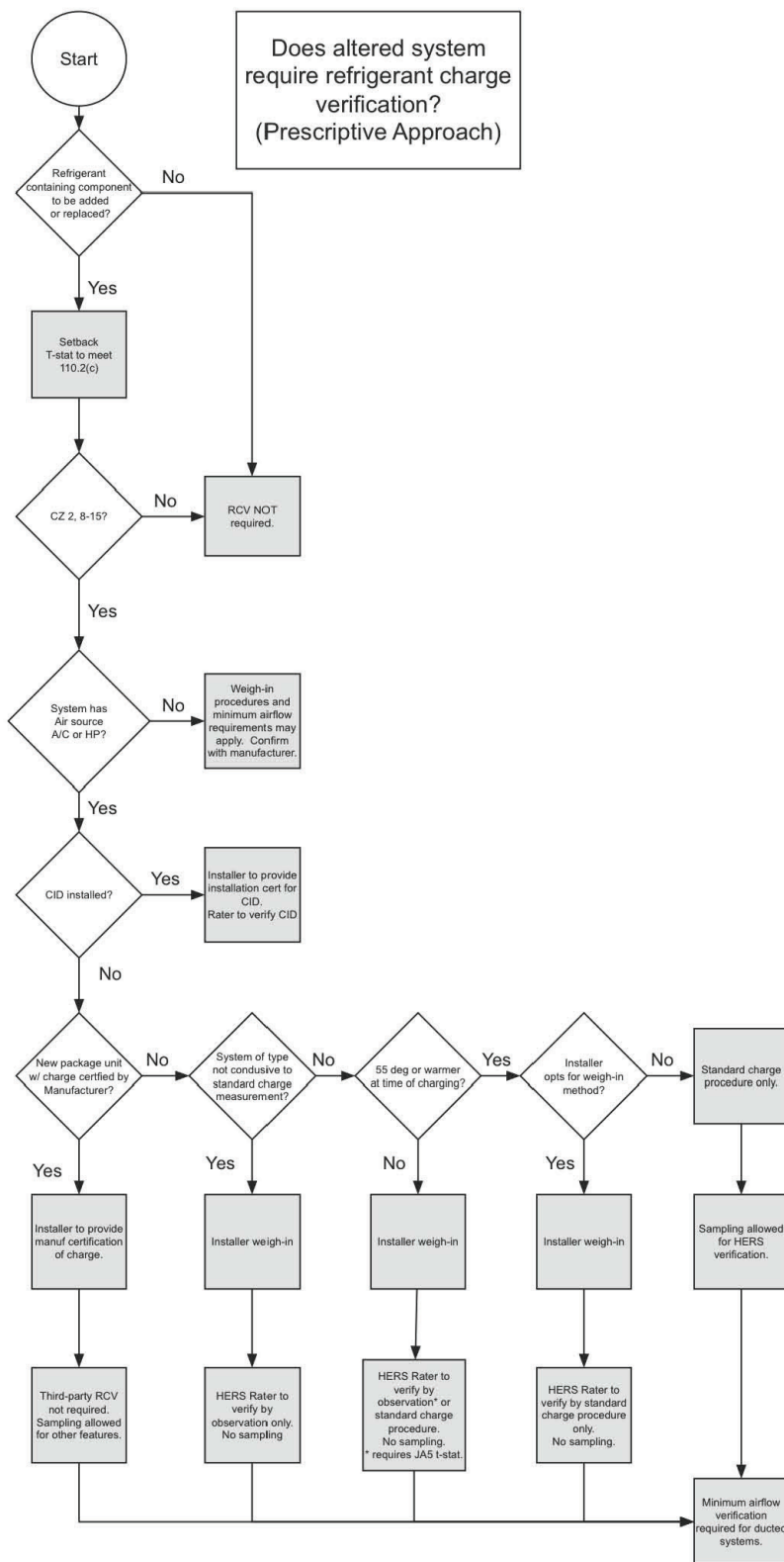
Instructions for Flowchart G-2 – Duct Requirements for Altered Systems

1. Start here to determine if a system being added to or altered in an existing home needs to comply with the requirements for duct sealing and verification of sections 150.2(b)1D or 150.2(b)1E; or with the requirements for filtration, airflow and fan efficacy of sections 150.0(m)12 and 150.0(m)13 via section 150.2(b)Diia.
2. If the system has a central air handler (package or split) connected to supply outlets via ducting of any shape or material, then choose “Yes.” Otherwise, choose “No.”
3. If more than 40 feet of ducting is to be added to the existing system, replaced in the existing system or any combination of these two, then choose “Yes.” Otherwise, choose “No.”
4. If a new condenser, air handler, or evaporator coil is to be installed or replaced in this system, choose “Yes.” Otherwise, choose “No.”
5. If all of the ducts are accessible at some point before, after, or during the alterations to the system, choose “Yes.” (This includes ducts in accessible attics, garages or crawl spaces. Ducts concealed behind sheetrock or other permanent obstructions are not considered accessible. See definition in Chapter 4.X of the Residential Compliance Manual.) Otherwise, choose “No.”
6. If all of the heating and cooling equipment are newly installed or replaced, choose “Yes.” If any heating or cooling equipment component (including air handlers, condensers, and coils, but not including ducts or plenums) will remain from prior to the alteration, choose “No.”
7. Take the estimated length of the ducts to be added or replaced and divide it by the estimated total length of ducts in the system after the alteration work is completed. Include accessible and inaccessible ducts. If the result is 0.75 or greater, choose “Yes.” Otherwise, choose “No.”
8. Reaching this box means that the system meets the definition of an “Extension of Existing System” and is subject to the requirements of section 150.2(b)1Diib. Continue to next box.
9. Reaching this box means that the system meets the definition of an “Entirely New or Replacement Duct System” and is subject to the requirements of section 150.2(b)1Diia. Continue to next box.
10. Reaching this box means that the system meets the definition of an “Altered Space-Conditioning System” and is subject to the requirements of section 150.2(b)1E. Continue to next box.
11. Reaching this box means that the system is subject to the requirements of section 150.0(m)12 – Air Filtration. Refer to Chapter 9.X of the Residential Compliance Manual. Continue to next box.
12. If the system includes mechanical DX air conditioning (this does not include whole house fans or swamp coolers), choose “Yes.” Otherwise, choose “No.”
13. If any of the existing ducts or plenums are insulated or sealed with an asbestos containing material (this includes tapes, insulation wrap, or the duct material itself), choose “Yes.” Otherwise, choose “No.”
14. Reaching this box means that the system is subject to the requirements of section 150.0(m)13 – Duct System Sizing and Air Filter Grille Sizing. Refer to Chapter 9.X of the Residential Compliance Manual. Continue to next box.
15. If any of the existing ducts or plenums are insulated or sealed with an asbestos containing material (this includes tapes, insulation wrap, or the duct material itself); OR if the finished

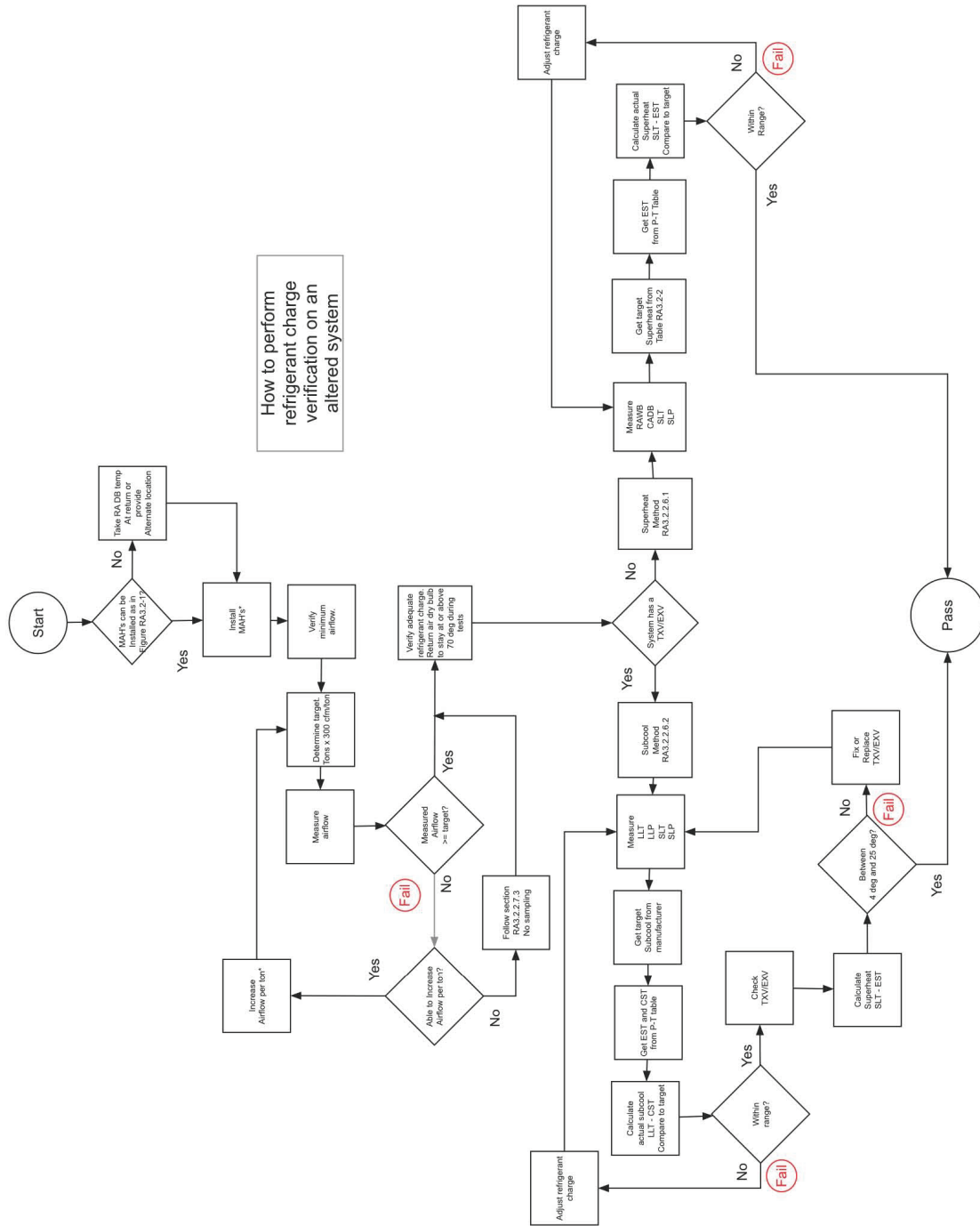
system will have less than 40 feet of ducts; OR if the system was previously tested for duct leakage and a certificate of verification can be provided from an earlier permit showing that the system passed, choose “yes.” Otherwise, choose “No.”

16. Reaching this box means that the system requires duct sealing similar to a new system: 6% or one of the appropriate targets for “new duct systems” from Table RA3.1-2. If the air handler is not new (left from the original system that was altered), an attempt must be made to seal it to 6% leakage. If it cannot obtain this target, smoke may be used to show that excessive leakage is coming from the old air handler. Refer to sections RA3.1. Note: if the answer to box #6 is “Yes,” then the system meets the definition of an “Entirely New or Complete Replacement Space Conditioning System” and is subject to the requirements of section 150.2(b)1C.
17. Reaching this box means that the system requires duct sealing using one of the appropriate targets for “altered existing duct systems” from Table RA3.1-2. Refer to sections RA3.1.
18. Reaching this box means that the system is not subject to any duct sealing requirements.

Flowchart G-3: Refrigerant Charge Prescriptive Approach



Flowchart G-4: Refrigerant Charge on Altered Systems



Appendix F - Field Verification of Zonally Controlled Systems

References: §150.0(m)13C, §150.1(c)13, JA1:Glossary: **ZONAL CONTROL**, RA 3.1.4.6

F1.1 Introduction/Scope

Zonally controlled systems are usually installed primarily for improved comfort, not improved energy consumption. Recent studies have shown that zonally controlled cooling systems that utilize bypass ducts or that substantially reduce the airflow across the coil when zone dampers close can actually use more energy. Because of this, HERS raters are required to evaluate these systems to ensure that it is consistent with what was modeled and what appears on the CF1R form.

One type of zonally controlled forced air system utilizes motorized zone dampers in the supply ducts to send supply air from a single air handler to different zones, as needed, rather than sending air to the entire area served by that system. These require multiple thermostats or temperature sensors in each of the zones. The number of zones can be two or more. Two-zone systems are by far the most common. The most common application of this type of system is in two story homes served by a single forced air system. The tendency for air to stratify, along with substandard duct design, causes comfort issues that can often be overcome by zonal control.

Note that dampers may also be installed on the return ducts, but are not required for the system to be considered a zonally controlled system.

Problems with this type of zonally controlled systems arise from the excess air pressure that occurs at the air handler fan when one or more of the zone dampers close and restrict airflow to just a portion of the supply duct system. One strategy is to simply let the pressure increase, which substantially reduces airflow across the cooling coil or heat exchanger. Another is to install a bypass duct that allows the excess air to “short circuit” from the supply side back to the return side. This causes problems by sending excessively hot air (heating mode) or excessively cold air (cooling mode) back into the system.

An alternative approach is to send the “excess air” back into conditioned space rather than directly back into the return air. These are not considered bypass ducts if the air has a chance to mix with house air in a way that does not substantially change the return air temperatures. The area in the home where the excess air is sent to is referred to as a “dump zone”. These dump zones will generally be over conditioned by this excess air and are usually unoccupied portions of the home, such as hallways or vaulted ceiling areas above the occupied zones. This design may lose some of the comfort benefits of a zonally controlled system.

Note that zonal control can be also achieved by using two separate systems, sized appropriately for each zone. These act independently and do not need zone dampers. These also do not require bypass dampers or other strategies to handle the excess air. For example, zonal control can be achieved in a two story home by installing a single system with zone dampers that separately control air to the upstairs and downstairs; or it can be achieved by installing two small systems, one dedicated to the first floor and one to the second floor. Assuming that the house can be adequately served by a single large system, the first approach generally costs less.

If it is discovered that a zonally controlled forced air system is installed but not claimed for credit, it needs to be reported to the HERS provider (registry). Because zonally controlled systems can be an energy penalty, they need to be correctly modeled when installed.

F1.2 Summary of Requirements:

Prescriptive compliance approach –

1. Zonally controlled systems are not required, but if installed must meet mandatory AF/FE requirements (slightly different test methods for single speed and variable speed compressors)
2. Bypass ducts/dampers are NOT allowed.

Performance compliance approach –

1. Zonally controlled systems must be modeled if installed.
2. Bypass dampers allowed only if modeled.
3. Dual speed/multi speed condensers may also qualify for a credit (reduced penalty) and if modeled, must be installed.

Note: when a feature is “modeled” using the performance compliance approach it will appear on the certificate of compliance.

F1.3 Identifying Zonally Controlled Systems in the Field

The following are characteristics of most zonally controlled systems that utilize dampers. Not all of these items need to be apparent for the system to be considered zonally controlled. Final determination may require consulting with the installer, designer and system manufacturer.

1. Motorized or actuated zone dampers on the supply ducts. These can be one or more large dampers in or near the supply plenum or they can be one damper for each supply outlet (register). See diagrams below.
2. Multiple thermostats or temperature sensors in area served by a single system. The most common two zone systems utilize ordinary thermostats for each zone. Some systems have a single master thermostat with small temperature sensors in each zone.
3. A control board on or near the air handler with low voltage wires going to the thermostats/temperature sensors and to each damper. Low voltage wires will also connect the control board and the main air handler control board. See photos below.
4. Bypass duct and damper. This will be a duct connecting the supply end directly to the return end. On the supply side it will connect after the coil and before the zone damper(s), usually off of the supply plenum. On the return side, it can either connect directly to the side of the return end of the furnace, near the return end of the furnace in a return plenum, or as far away as a return grill boot. Some sort of automatic damper will control airflow through this duct. When all zones are calling for cooling (all zone dampers open), the bypass damper should be fully closed. When one or more zone dampers close, the damper should open partially or fully as needed to reduce the supply plenum pressure. This is commonly achieved by a barometric bypass damper. Barometric dampers are held closed by an adjustable weight. When enough pressure builds up on one side of the damper, it overpowers the weight and opens the damper. See diagram below. Another strategy is to use a motorized damper.

F1.4 Identifying Multi-Speed/Variable-Speed Condensers

Most condensers operate at a single speed and capacity and either run for longer or shorter periods of time during hotter or cooler weather, respectively. Short run times (aka, short cycling) reduce efficiency. Multi-speed condensers typically have a high and low speed. This can be accomplished by two separate compressors inside a single condenser, or by a single dual-stage compressor. During cooler weather (aka, part load times) the condenser will run in low speed for longer run periods. When needed, the condenser can run in high speed.

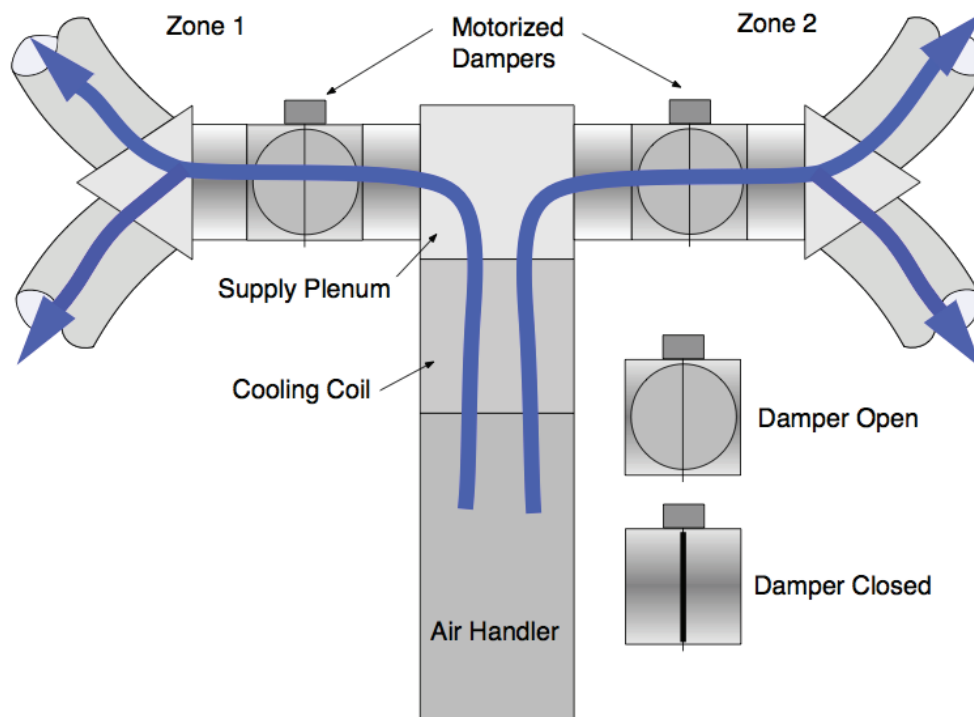
Variable-speed condensers are not limited to just high and low speeds. They can gradually ramp from lowest to highest speeds as needed.

There are several features that can indicate that a condenser is multi-speed. These include:

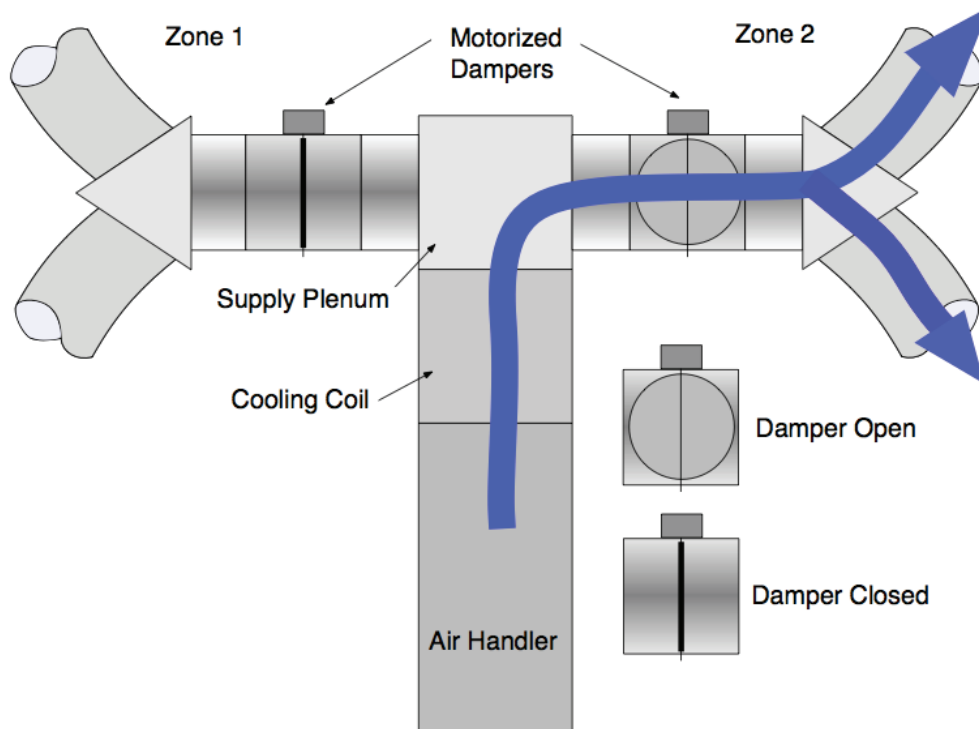
1. Product tags, labels and marketing names that indicate two-stage, dual-stage, multi-stage, etc.

2. Two compressors observed by looking down through the condenser fan.
3. High and low capacities or nominal tonnages indicated on nameplate.

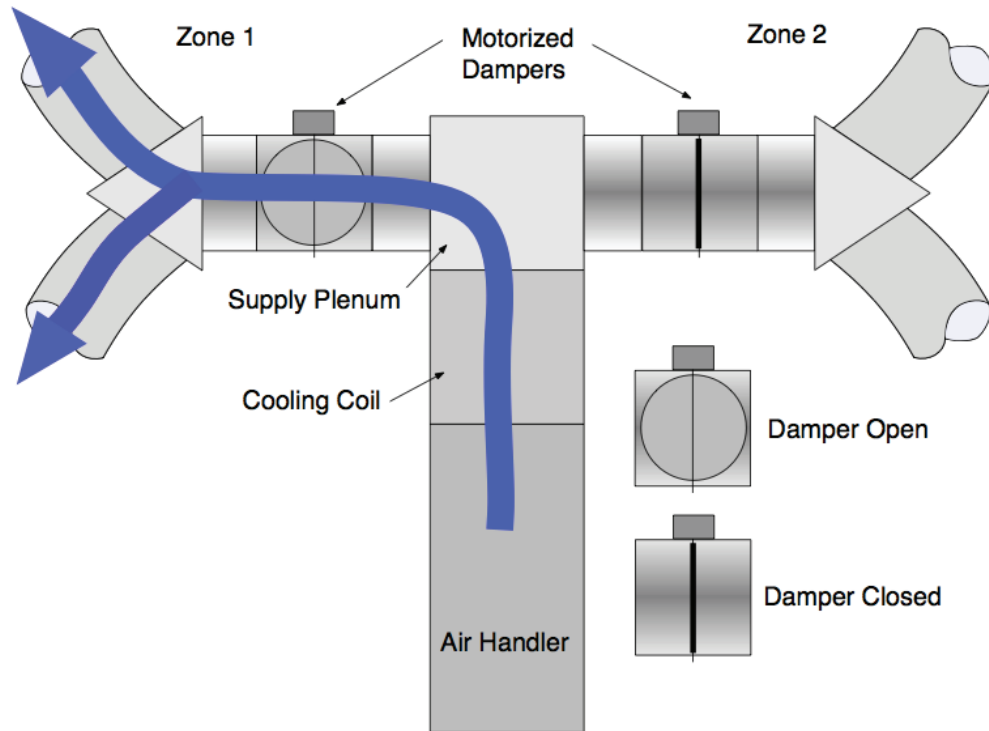
The only definitive way to determine if the condenser is multi-speed or variable speed is to record the make and model number and find the manufacturer's specifications.



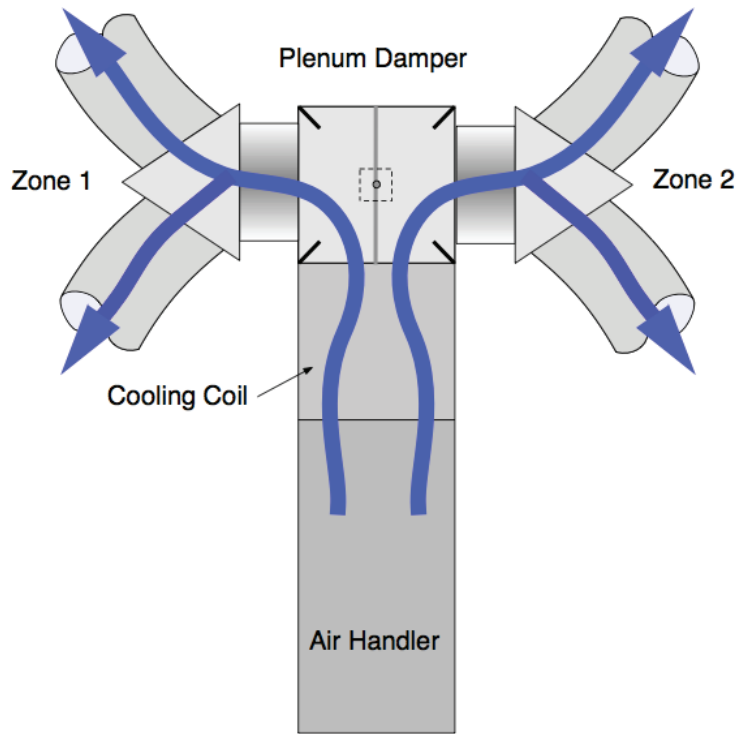
This diagram shows a common two-zone, two-damper system with both zones open (i.e., both zones are calling for cooling).



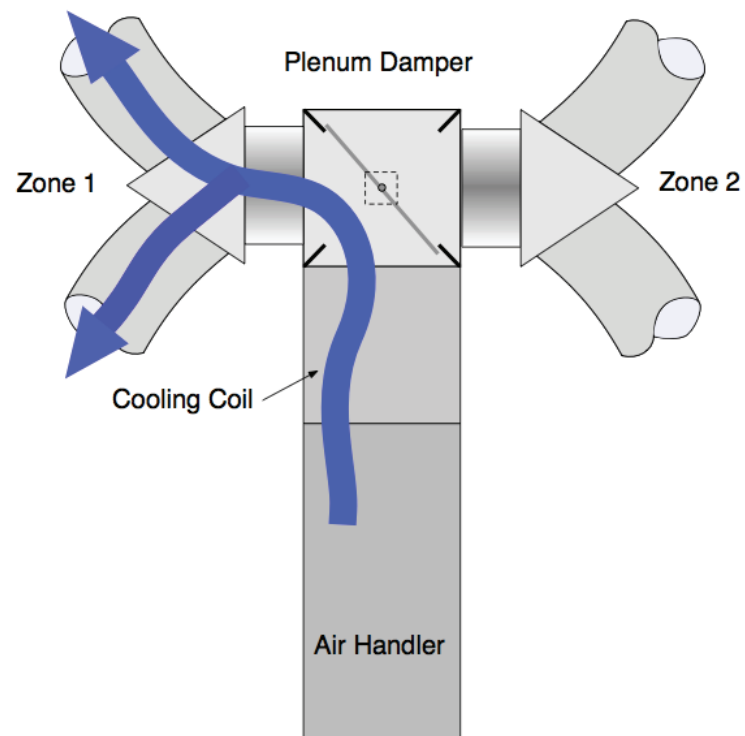
This diagram shows a common two-zone, two-damper system with zone 2 open (i.e., only zone 2 is calling for cooling).



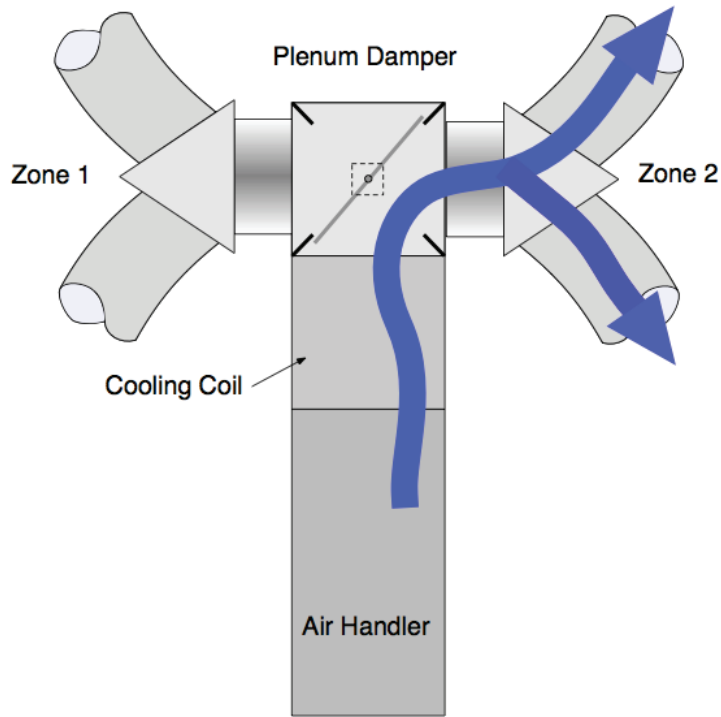
This diagram shows a common two-zone, two-damper system with zone 1 open (i.e., only zone 1 is calling for cooling).



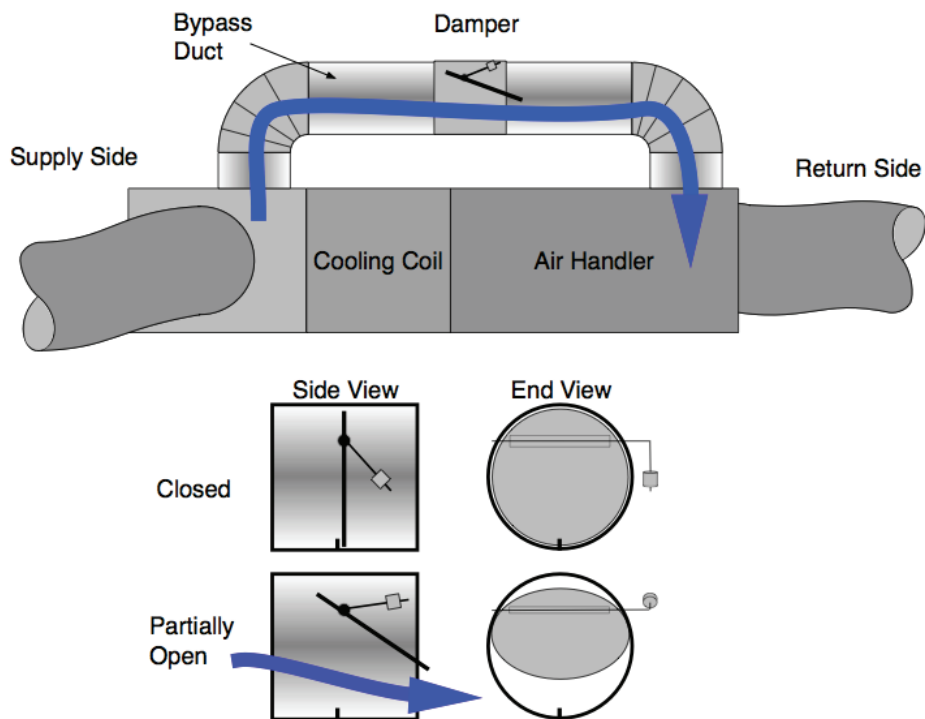
This diagram shows a common two-zone, single-damper system with both zones open (i.e., both zones are calling for cooling).



This diagram shows a common two-zone, single-damper system with zone 1 open (i.e., only zone 1 is calling for cooling).

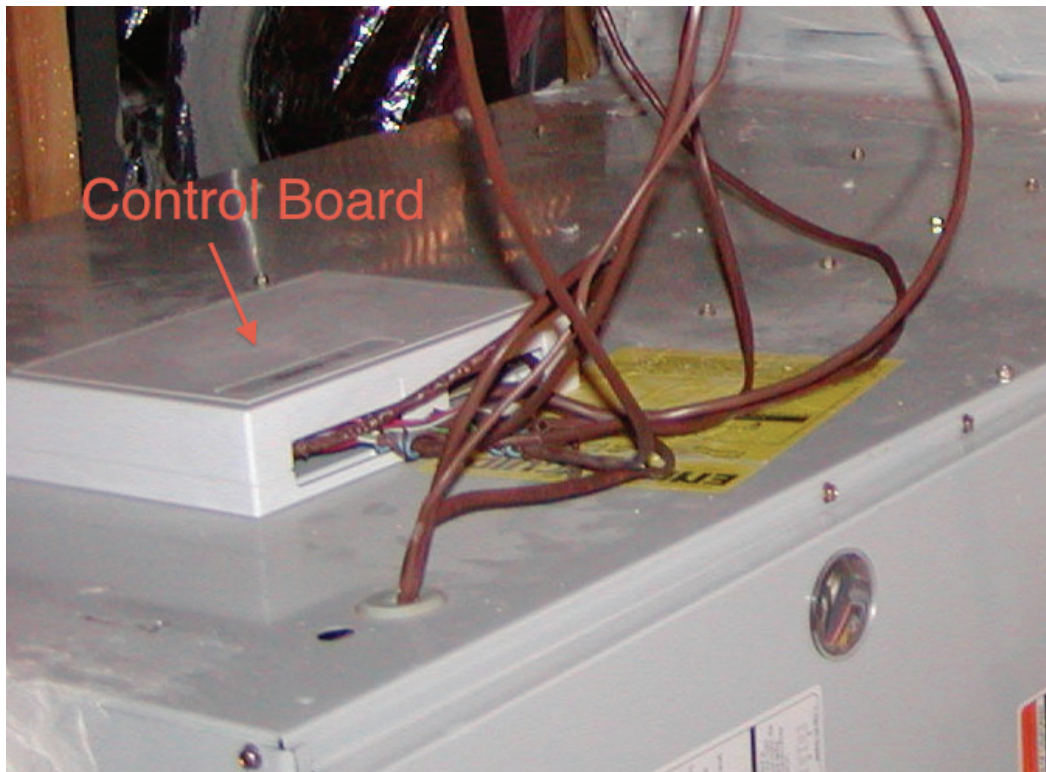


This diagram shows a common two-zone, single-damper system with zone 2 open (i.e., only zone 2 is calling for cooling).



This diagram shows a common bypass duct/damper strategy. The bypass duct is sheet metal (which should always be insulated) and the damper is a barometric type. The details show how the damper opens when air pressure builds up against the adjustable weight. Sending heated or cooled air back into the space conditioning equipment can cause problems and reduce efficiency.

These photos show two examples of zonal control control-boards.



F1.5 References:

JA1: Glossary

ZONAL CONTROL is the practice of dividing a residence into separately controlled HVAC zones. This may be done by installing multiple HVAC systems that condition a specific part of the building, or by installing one HVAC system with a specially designed distribution system that permits zonal control. The Energy Commission has approved an alternative calculation method for analyzing the energy impact of zonally controlled space heating and cooling systems. To qualify for compliance credit for zonal control, specific eligibility criteria specified in the Residential ACM Manual must be met.

§150.0(m)15. **Zonally Controlled Central Forced Air Systems.** Zonally controlled central forced air cooling systems shall be capable of simultaneously delivering, in every zonal control mode, an airflow from the dwelling, through the air handler fan and delivered to the dwelling, of greater than 350 CFM per ton of nominal cooling capacity, and operating at an air-handling unit fan efficacy of less than 0.58 W/CFM as confirmed by field verification and diagnostic testing in accordance with the procedures specified in Reference Residential Appendix RA3.3.

EXCEPTION to 150.0(m)15: Multi-speed compressor systems or variable speed compressor systems shall demonstrate compliance for airflow (cfm/ton) and fan efficacy (Watt/cfm) by operating the system at maximum compressor capacity and maximum system fan speed and with all zones calling for conditioning.

§150.1(c)13. **HVAC System Bypass Ducts.** Unless otherwise specified on the Certificate of Compliance, bypass ducts that deliver conditioned supply air directly to the space conditioning system return duct airflow shall not be used. All zonally controlled forced air systems shall be verified by a HERS Rater utilizing the procedure in Reference Residential Appendix Section RA3.1.4.6 to confirm compliance with 150.1(c)13.

RA 3.1.4.6 Verification of Prescriptive Bypass Duct Requirements for Zonally Controlled Forced Air Systems

When a zonally controlled forced air system is installed, the following shall be verified to determine compliance as required by Energy Standards §150.1(c)13:

1. A visual inspection shall confirm that bypass ducts that deliver conditioned supply air directly to the space conditioning system return duct airflow are not used; or
2. If the Certificate of Compliance indicates an allowance for use of a bypass duct, the bypass duct shall conform to the specifications given on the Certificate of Compliance.

If the zonally controlled system meets one of these criteria, the system complies. Otherwise the system does not comply

Appendix G

Verification of the Existing Features of a Home for Existing + Addition + Alteration Performance Approach

When adding to or altering an existing home, compliance credit can be taken for upgrading existing features by using the performance approach when the existing features are verified by a qualified HERS rater prior to registration of the certificate of compliance.

The performance approach provides for a means to trade off against features that may not meet the prescriptive requirements, such as exceeding the allowed maximum glass area, by demonstrating that the house to be built (proposed design) achieves the same level of efficiency as it would if it were built to the prescriptive requirements (standard design). The standard design is the hypothetical house that sets the target energy budget for the proposed house.

The Existing + Addition + Alteration approach gives further credit for upgrading existing features. It does this by lowering the standard design for an altered building feature down to match the existing energy efficiency of the building feature before it is altered. The greater the efficiency of the altered building feature is relative to the existing energy efficiency, the greater the compliance credit will be. Third-party verification of the features prior to the construction is required to receive this compliance credit. The credit level depends on whether defaults are used or actual values (that are less efficient than defaults) are used.

The proposed design is calculated using the actual energy efficiency values of the existing unaltered components of the existing house, as well as the proposed values of the altered components, plus the proposed features of the addition. Each building component must be modeled correctly as one of the following classifications below in order to determine the proposed design:

1. “Existing” – these building components remain unchanged by the alterations or additions (e.g., insulated exterior walls in the existing portion of the home that will not be touched).
2. “Altered” – these building components exist prior to the remodel, but are being changed (e.g., roof insulation that will be added as part of the construction work, or a furnace that is being replaced as part of the construction work).
3. “New” – these building components do not exist prior to the construction work. (e.g., new walls added to create the addition).

All of these building components will determine how the standard design is calculated. Existing features will be modeled the same in both the proposed and standard designs. New features will be modeled in the standard design according to prescriptive package A, Table 150.1-A. Altered features will be modeled in the standard design according to Table 150.2-C.

There are two columns in Table 150.2-C. One column details how the standards design is calculated for altered components when the existing features are not verified by a HERS rater. The other column details how the standards design is calculated for altered components when the existing features are verified by a HERS rater prior to construction. Without HERS verification, the standard design for existing features is calculated using the prescriptive or mandatory measures according to Table 150.2-C.

In order for the building to comply, the proposed design (proposed house) must be equal to or less than the standard design (standard house) in order to comply. The existing portions of the proposed house will be compared to the existing portions of the standard house, the efficiencies of which are determined by Table 150.2-C. When a feature in the proposed house is better than the standard house, it is referred to as a compliance credit, and it can be used to trade off against features that are less efficient than the standard house. For example, without third-party verification, attic insulation is assumed to be R-30 in the standard house. With HERS verification, attic insulation for the standard house is calculated using the existing attic insulation value, even if it is R-0. If the actual attic insulation value is substantially less than R-30, more compliance credit can be obtained by having it HERS verified.

Example:

Consider the house in Figure G-1 in climate zone 12. The shaded area is the addition. Some windows and walls were removed to build the addition, but these are ignored.

The existing home has the following features:

1. Single-pane metal framed windows
2. 2x4 R-11 walls, and R-19 attic insulation
3. AFUE 75 furnace

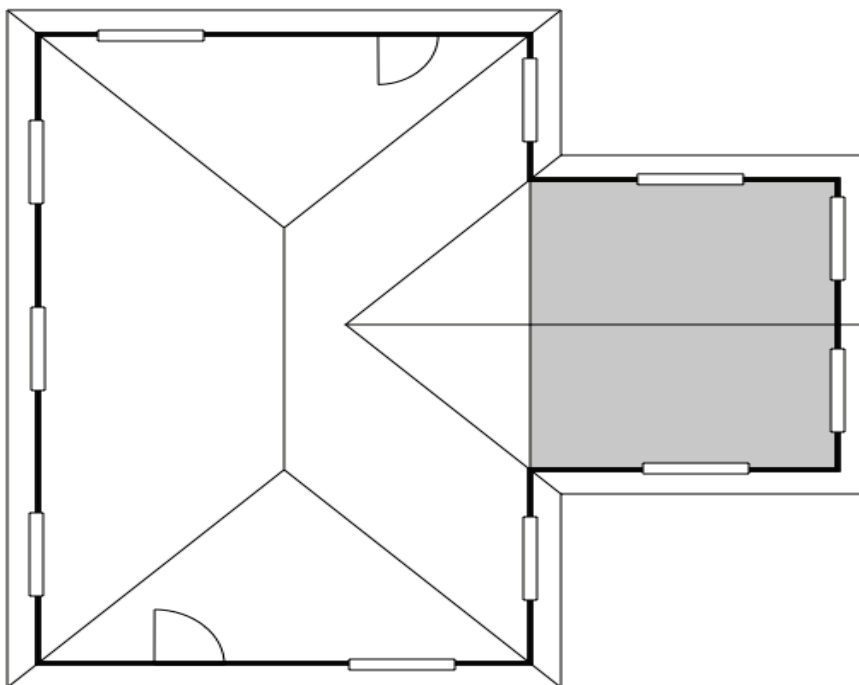


Figure G-1 – The Proposed Addition and Alterations

Component	Status	Proposed House	Standard Design w/o verification	Standard Design w/verification
Attic	Existing Altered New	R-38 R-38	R-30 R-38	R-19 R-38
Walls	Existing Altered New	R-13	R-11 R-15+4	R-11 R-15+4
Window	Existing Altered New	0.30/0.30 0.30/0.30	0.40/0.35 0.32/0.25	1.28/0.80 0.32/0.25
Furnace	Existing Altered New	0.92	0.78	0.75
Attic	Existing Altered New	R-38 R-38	R-30 R-38	R-19 R-38

Part of the construction work includes replacing all of the windows with low-E vinyl windows to match the new windows in the addition, adding R-19 to the existing attic and reroofing the entire house with cool roof shingles. The existing furnace will be replaced with a new high efficiency furnace.

For the proposed design, none of the attic is modeled as “existing” because insulation is being added to the existing part of home, and the attic in the addition is new, so the attic will be modeled as “new” for the addition and “altered” for the existing home. Similarly, none of the roof or windows are modeled as “existing” because the all windows and the roof are being replaced on the existing home, and new ones are installed in the addition, so windows and the roof will be modeled as “new” for the addition and “altered” for the existing home. On the other hand, none of the existing walls are being altered, so they are either “existing” or “new”. The furnace, even though it is new, is modeled as “altered” because it is replacing an existing furnace. Note that the walls, windows, and other components that are removed as part of the addition and alterations are ignored and not modeled

Table G-1 illustrates how the proposed house features and the standard house features are calculated with and without HERS verification of the existing conditions. The values in **bold face** indicate where there is substantial compliance credit is gained by having HERS verification.

The HERS rater must visit the home to verify the assumptions of the existing conditions in the building, prior to registration of the certificate of compliance.

HERS raters are to follow the protocols for a Whole House Home Energy Rating (WHHER) when verifying existing conditions. The HERS rater must be trained by the providers to verify the existing conditions of the home consistent with Energy Commission approved HERS provider training for the verification requirements specified in Table 150.2-C. The Data Registry will generate a CF3R-EXC-20-H compliance document based upon the output from the Performance Compliance Software. The CF3R-

EXC-20-H will list the features of the existing conditions that must be field verified by the HERS rater. A registered CF3R-EXC-20-H that agrees with the existing conditions input for the proposed building for the performance compliance calculation will be required by the HERS Registry as a prerequisite to completion of the registration of the CF1R for the project.

The Whole House Home Energy Rating protocols are established by the HERS Technical Manual (CEC-400-2008-012). Appendix A of that document details the protocols for verification of each component. Raters must follow all Energy Commission approved procedures established by the HERS provider. The HERS Technical Manual can be downloaded from:

<http://www.energy.ca.gov/2008publications/CEC-400-2008-012/CEC-400-2008-012-CMF.PDF>