# 2013 Residential Alternative Calculation Method (RACM) – Reference Manual (Draft)

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# 1. Overview

## 1.1 Purpose

This document is the California Residential ACM Approval Manual. It explains the requirements for approval of residential compliance and rating software in California.

### 1.1.1 Modeling Assumptions

When calculating annual energy use, it is necessary to make assumptions about how the proposed building is operated. Operating assumptions include thermostat settings, number of occupants, receptacle loads, process loads, hot water loads as well as schedules of operation for HVAC systems, lighting systems and other systems. Sometimes these data are known with some certainty and other times (for instance for speculative buildings), it is necessary to make estimates. These inputs are prescribed (they are fixed for both the proposed design and for the baseline building and can't be changed) for California Compliance.

## 1.2 Scope

This manual is intended to be used for residential buildings that are seeking a building permit for new construction.

The long-term goal of this manual is to define modeling rules and procedures for all conceivable design features that may be incorporated in buildings. The authors recognize, however, that this goal cannot be fully achieved due to limitations in energy simulation algorithms, and due to the natural lag time between the introduction of an advanced energy efficiency measure or device and the development of algorithms to simulate its performance,

The goal of the manual is to provide methods that are as flexible and accurate as possible. This goal can best be achieved if the manual is a 'living document,' changing and growing as increasing amounts of information and better modeling methods become available.

## 1.3 Minimum Modeling Capabilities

Minimum modeling capabilities shall be included in all compliance software. If candidate compliance software does not have all of these capabilities, then it cannot be approved for compliance. The minimum modeling capabilities are summarized below:

- Conduction gains and losses through opaque and fenestration surfaces
- Slab edge gains and losses
- Infiltration gains and losses
- Solar gains through glazing including the effects of internal shading devices.
- Natural ventilation cooling
- Mechanical Ventilation for Indoor Air Quality (IAQ)
- Thermal mass effects to dampen temperature swings

- Space conditioning equipment efficiency and distribution systems
- Water heating equipment efficiency and distribution systems
- Building additions
- Attic Modeling (UZM)
- Maximum Cooling Capacity

### *1.4 Optional Modeling Capabilities*

Candidate compliance software may have more capabilities than the minimum required. Compliance software can be approved for use with none, a few, or all of the optional capabilities. The following optional capabilities are recognized for residential compliance software:

- Raised floors with automatically operated crawl space vents
- Zonal control or multi-zone modeling of the sleeping and living areas of the house
- Attached sunspaces for collection and possible storage of heat for transfer to the main house
- Exterior mass walls
- Overhangs and Side Fin Shading
- Combined hydronic space and water heating
- Building alterations
- Solar water heating
- Gas fired and Absorption Cooling
- Evaporatively cooled condensing units
- Ice storage air conditioner
- Evaporative coolers
- Photovoltaic performance modeling

Many of the optional modeling capabilities have been previously approved by the Commission through the exceptional methods process. The approval tests for optional modeling capabilities are included in Chapter 5.

# 2. Standard Reports

### *2.1 General*

For consistency and ease of enforcement, the manner in which building features are reported by compliance software is standardized. This and the subsequent chapter of the compliance software Approval manual describe the required standard reports. All residential compliance software shall automatically produce standardized compliance reports. These *Standard Reports* are required to enable building officials to evaluate the results without having to learn each computer program. Included in every compliance package will be reports CF-1R and other related forms, which are described in detail in this manual.

The Certificate of Compliance (CF-1R) is the principal compliance report. The CF-1R shall indicate the features and performance specifications needed to comply with Part 6 of Title 24 and shall be approved by the local enforcement agency by stamp or authorized signature. The CF-1R and supporting documentation shall be readily legible and of substantially similar format and informational order and content to the CF-1R model provided in the appropriate Residential Compliance Manual and as approved by the CEC Executive Director. .

At the beginning of the CF-1R, notification of the use of HERS or NSHP shall be prominently displayed.

The CF-1R shall have two highly visible sections, one for Special Features Inspection Checklist and a second for features requiring *Hers Required Verification*. These two sections serve as "punch lists" during compliance verification by the local building department. Items listed in the *Special Features Inspection Checklist* section indicate the use for compliance of unusual features or assumptions, and call for special care by the local building department. Items listed in the *Hers Required Verification* section are for features that require diagnostic testing or *independent* verification to insure proper field installation in addition to local building department inspection.

Only user inputs are described and included in the standard reports. The fixed and restricted inputs are not included in the standard reports since compliance software shall be designed so that the fixed and restricted inputs and default values are automatically used in the absence of specific user input.

Deviations from the standard reports will be approved by the Commission on a case-by-case basis when they are necessary because of conceptual differences between compliance software or because of special modeling features. However, the categories of information represented in the tables and the standard headings shall not be changed. Additional columns or additional tables may be added when necessary and column headings may be abbreviated, and reports may be reformatted with different character spacing, line spacing, row heights or column widths to permit better readability or paper conservation. Compliance software may also provide additional customized information at the bottom of the standard reports, separated from the standard report by a line.

Some of the information in the standard reports may not be applicable for all buildings. When information is not applicable for a particular building, it should be omitted. When a feature exists, however, all the information about that feature should be included, even if some of the detail is not applicable to the proposed design.

The Standard Reports are designed to accommodate the optional modeling capabilities included in this manual. Approval of additional optional modeling capabilities may require modification of the standard report format.

## *2.2 Certificate of Compliance – Residential Computer Method (CF-1R)*

The Certificate of Compliance (report CF-1R) is the principal standard report that shall be produced. The Certificate of Compliance is required by the Administrative Regulations (Title 24, Part 1, §10-103).

The CF-1R (Residential Computer Method) shall include all information provided by the program user. If the standard report does not fully document all user inputs, additional tables or notes shall be added by the program vendor to fully document all user inputs.

Information on the Certificate of Compliance is provided below to illustrate the use of all the standard tables.

### 2.2.1 Report Headings

The following heading shall appear on the first page and contain the following information:

- Date

- Project Title
- Project address
- Documentation author, telephone, email and address
- A box for use by the building department containing the building permit number, the plan check date, the field check date and other information to be specified by the CEC Executive Director.
- Information to verify the compliance run such as the computer simulation file name, a run code, the run title, the run date, etc.

The filename and computer run information shall appear as part of the header information for all pages of the Certificate of Compliance.

### 2.2.2 Energy Use Summary

This section compares the energy use of the proposed building to the energy budget of the standard design building. All units in this table are TDV (time dependent valuation) energy (kTDV/ft²-yr). Energy shall be separated for space heating, space cooling, hot water, ventilation, and other uses. The energy budgets are determined from the standard design using the custom budget method. The water heating budget is calculated from the custom budget water heating calculation methods described in this document. Compliance software vendors may add additional columns or rows to this report when appropriate, such as for multi-zone building analyses or breaking out energy use components such as HVAC fans.

### 2.2.3 Building Features

The features and characteristics of the proposed design shall be described in a series of tables that are described in the subsequent chapter.

### 2.2.4 Special Features Inspection Checklist

This listing shall **stand out and command the attention** of anyone reviewing the CF-1R to emphasize the importance of verifying these Special Features and the aspects of these features that were modeled to achieve compliance or the energy use results reported. This listing in the Certificate of Compliance shall include any special features of the building that affect the building’s compliance with the standards. The use of certain non-default values shall also be included in this list. These special default values are indicated in the subsequent text. Statements in this section shall use the special feature statements listed in Appendix C of this manual, unless other text is approved.

This is a free format section for the CF-1R report to note any special features about the building that are needed to verify compliance. The following is an example of the type of information to include in the special features and modeling section of the CF-1R.

*Table R2-1 – CF-1R Report – SPECIAL FEATURES INSPECTION CHECKLIST: (Example Listing)*

| | |
|---|---|
| High mass building features | High-mass building features are described in the THERMAL MASS FOR HIGH MASS DESIGN table of compliance form CF-1R. |
| Non-standard Ventilation Height Difference | Non-standard ventilation height difference must be verified according to the rules in Residential ACM Chapter 3 under Building Zone Information. |
| Higher U-factors are specified than the vintage defaults. | Field verification of U-factors as specified is required. |
| Non-NAECA large storage gas water heater | A non-NAECA large storage gas water heater is specified for this building. System specifications are shown in the SPECIAL WATER HEATER/BOILER DETAILS table of compliance form CF-1R. |

## 2.3 HERS Required Verification

This listing shall **stand out and command the attention** of anyone reviewing this form to emphasize the importance of HERS Required Verification and to call attention to the building features that require such verification and testing.

All items in the *Hers Required Verification* listings shall also report that the installer and HERS rater shall both provide the appropriate CF-6R and CF-4R documentation, respectively, for proper installation, testing, and test results for the features that require verification by a HERS rater. The installer shall document and sign the CF-6R to verify compliance with design and installation specifications. The HERS rater shall document and sign the CF-4R to confirm the use of proper testing procedures and protocol to report test results, and to report field verification of installation consistent with the design specifications needed to achieve these special compliance efficiency credits.

The following table is an example of the type of information to be included:

*Table R2-2 – CF-1R Report – HERS REQUIRED VERIFICATION*

| |
|---|
| This house is using reduced duct leakage to comply and shall have diagnostic site testing of duct leakage performed by a certified HERS rater under the supervision of a CEC-approved HERS provider. The results of the diagnostic testing shall be reported on a CF-4R form and list the target and measured CFM duct leakage at 25 pascals. |
| This house has tight construction with reduced infiltration and a target blower door test range between 586 and 1250 CFM at 50 pascals. The blower door test shall be performed using the ASTM *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, ASTM E 779-03. |
| This house is using an HVAC system with all ducts and the air handler located within the conditioned space. This results in a higher distribution efficiency rating due to elimination of conduction losses (losses due to leakage are not changed) and shall be visually confirmed by a certified HERS rater under the supervision of a CEC-approved HERS provider. This verification shall be reported on a CF-4R form. |
| WARNING: If this house tests below 586 CFM at 50 pascals, the house shall either be provided with a ventilation opening that will increase the tested infiltration to at least 586 CFM at 50 pascals (SLA = 1.5) OR mechanical supply ventilation shall be provided that can maintain the house at a pressure of at least -5 pascals relative the outside average air pressure while other continuous ventilation fans are operating. Note also that the Commission considers an SLA≤1.5 to be "unusually tight" per the California Mechanical Code. |

## 2.4 Compliance Statement and Signatures

The CF-1R also requires a signature block, as required by §10-103(a)1 of the Administrative Regulations (Title 24, Part 1). The following is an example of the type information to be included with the compliance statement and signature block.

*Table R2-3 – CF-1R Report – COMPLIANCE STATEMENT*

| This certificate of compliance lists the building features and performance specifications needed to comply with the Energy Standards in Title 24, Parts 1 and 6, of the California Code of Regulations, and the Administrative regulations to implement them. This certificate has been signed by the individual with overall design responsibility. | | | |
|---|---|---|---|
| Designer or Owner (per Business & Professions Code) | | Documentation Author | |
| Name | ______________________________ | Name | ______________________________ |
| Title/Firm | ______________________________ | Title/Firm | ______________________________ |
| Address | ______________________________ | Address | ______________________________ |
| City & Zip Code | ______________________________ | City & Zip Code | ______________________________ |
| Telephone | ______________________________ | Telephone | ______________________________ |
| License Number | ______________________________ | Signature/Date | ______________________________ |
| Signature/Date | ______________________________ | | |
| Enforcement Agency | | | |
| Name | ______________________________ | | |
| Title | ______________________________ | | |
| Agency | ______________________________ | | |
| City | ______________________________ | | |
| Telephone | ______________________________ | | |
| Signature/Date | ______________________________ | | |

# 3. The Proposed Design and Standard Design

## *3.1 Overview*

The space conditioning energy budget for the residential Standards is a custom budget, that is, the energy that would be used by a building similar to the proposed design, but that is modified to just meet the requirements of the prescriptive standards. The building that is modeled to create the custom budget is the standard design. This chapter describes how the proposed design and standard designs are defined and describes the algorithms that are used to implement these modeling assumptions.

For the proposed design*,* the user enters information to describe the thermal characteristics of the proposed building envelope including its surface areas, air leakage, shading structures and attachments, thermal mass elements, heating and cooling equipment and distribution systems, and water heating equipment and distribution systems. These inputs are subject to a variety of restrictions which are defined in this section.

The process of generating the standard design and calculating the custom budget shall be performed automatically by the compliance software, based on the allowed and default inputs for the proposed design as well as the fixed and restricted inputs and assumptions for both designs. The process of custom budget generation shall not be accessible to program users for modification when the program is used for compliance purposes or when compliance forms are generated by the program. The standard design generator shall automatically take user input about the proposed design and create the standard design, using all the applicable fixed and restricted inputs and assumptions described in this Chapter. All assumptions and algorithms used to model the proposed design shall also be used in a consistent manner in the standard design building.

The basis of the standard design is prescriptive Package D, which is contained in §151(f) of the Standards. The Package D prescriptive requirements are not repeated here. However, the following sections present the details on how the standard design is to be developed. Defining the standard design building involves two steps.

- First, the geometry of the proposed building is modified from the description entered for the proposed design.
- Second, building features and performance characteristics are modified to meet the minimum requirements of compliance with Package D.

The fixed and restricted modeling assumptions apply to both the standard design run and to the proposed design run. The standard fixed and restricted modeling assumptions always apply to the standard design run and are the *default* for the proposed design. In some cases, the CEC has approved *alternate* fixed and restricted modeling assumptions that may be used in the proposed design run, when qualifying energy efficiency measures are provided. This chapter specifically identifies when the modeling assumptions differ between the standard design and the proposed design, otherwise they are assumed to be the same. The alternate modeling assumptions may only be used when the proposed design run has a special building feature (e.g. zonal control) that is recognized for credit, and the compliance software has been approved with this modeling capability. The modeling of such building features for compliance purposes shall always be documented in the *Special Features Inspection Checklist* on the Certificate of Compliance.

While this manual describes the algorithms and calculation methods used by the reference method, compliance software may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the standard design and the proposed design and provided that the compliance software passes the applicable tests described in Chapters 4 and 5.

## 3.2 General Modeling Assumptions

### 3.2.1 Weather Data

All compliance software shall use standard hourly weather data for compliance runs. The same hourly weather data and weather data format shall be used for both the standard design and the proposed design calculations.

Reference Joint Appendix JA2 contains information on the official CEC weather data. There are 16 standard climate zones with a complete year of 8,760 hourly weather records. Each standard climate zone is represented by a particular city. As an alternative, compliance software may use weather files provided by the Commission which have been customized for each city in Reference Joint Appendix JA2 for which design day data is provided using procedures described in Reference Joint Appendix JA2.

### 3.2.2 Time Dependent Valuation

Time Dependent Valuation (TDV) energy is the parameter used to compare the energy consumption of proposed designs to energy budgets. TDV replaces the source energy multipliers of one for natural gas and 3 for electric. TDV is explained in Reference Joint Appendix JA3 in more detail. The TDV data is based on 1991 which means that the year starts on a Tuesday.

### 3.2.3 Ground Reflectivity

Compliance software shall assume that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter. This applies to both the standard design and proposed design.

### 3.2.4 Building Physical Configuration

***Proposed Design.*** The building configuration is defined by the user through entries for floor areas, wall areas, roof and ceiling areas, fenestration areas, and door areas. Each are entered along with performance characteristics such as U-factors, SHGC, thermal mass, etc. Information about the orientation and tilt is required for walls, fenestration and other elements. The user entries for all of these building elements shall be consistent with the actual building design and configuration. If the compliance software models the specific geometry of the building by using a coordinate system or graphic entry technique, the data generated shall be consistent with the actual building design and configuration. Attics and crawlspaces shall be specifically defined in the compliance software. Inputs for these are defined in greater detail below. Attached garages are not explicitly modeled, but rather the wall that separates conditioned space from the garage is modeled with no solar gains.

***Standard Design.*** The standard design building has the same floor area, volume, and configuration as the proposed design, except that wall and window areas are distributed equally between the four main compass points, North, East, South, and West. For alterations, the standard design shall have the same wall and fenestration areas and orientations as the proposed building. The details are described below.

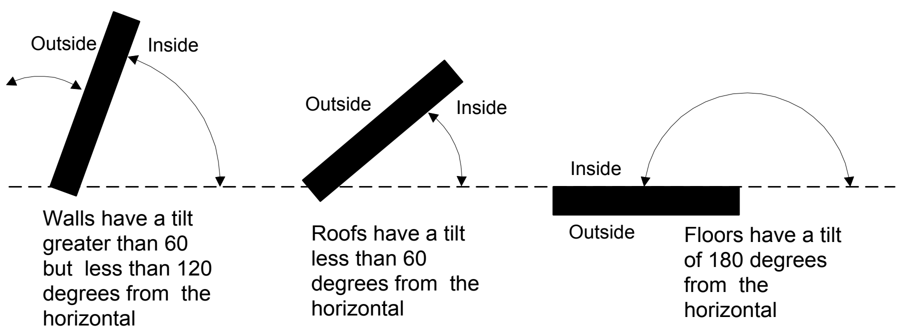



*Figure R3-1 – Surface Definitions*

### 3.2.5 Thermostats

The *standard* thermostat settings are shown in Table R3-1 below. The values for the "Whole House" apply to the standard design run and are the default for the proposed design run. See the explanation later in this section regarding the values for Zonal Control.

*Table R3-1 – Hourly Thermostat Set Points*

| | Whole House | | Zonal Control Living Areas | | Zonal Control Sleeping Areas | | |
|---|---|---|---|---|---|---|---|
| Hour | Heating | Cooling | Heating | Cooling | Heating | Cooling | Venting |
| 1 | 65 | 78 | 65 | 83 | 65 | 78 | Off |
| 2 | 65 | 78 | 65 | 83 | 65 | 78 | Off |
| 3 | 65 | 78 | 65 | 83 | 65 | 78 | Off |
| 4 | 65 | 78 | 65 | 83 | 65 | 78 | Off |
| 5 | 65 | 78 | 65 | 83 | 65 | 78 | Off |
| 6 | 65 | 78 | 65 | 83 | 65 | 78 | 68 |
| 7 | 65 | 78 | 65 | 83 | 65 | 78 | 68 |
| 8 | 68 | 83 | 68 | 83 | 68 | 83 | 68 |
| 9 | 68 | 83 | 68 | 83 | 65 | 83 | 68 |
| 10 | 68 | 83 | 68 | 83 | 65 | 83 | 68 |
| 11 | 68 | 83 | 68 | 83 | 65 | 83 | 68 |
| 12 | 68 | 83 | 68 | 83 | 65 | 83 | 68 |
| 13 | 68 | 83 | 68 | 83 | 65 | 83 | 68 |
| 14 | 68 | 82 | 68 | 82 | 65 | 83 | 68 |
| 15 | 68 | 81 | 68 | 81 | 65 | 83 | 68 |
| 16 | 68 | 80 | 68 | 80 | 65 | 83 | 68 |
| 17 | 68 | 79 | 68 | 79 | 65 | 83 | 68 |
| 18 | 68 | 78 | 68 | 78 | 65 | 83 | 68 |
| 19 | 68 | 78 | 68 | 78 | 65 | 83 | 68 |
| 20 | 68 | 78 | 68 | 78 | 65 | 83 | 68 |
| 21 | 68 | 78 | 68 | 78 | 65 | 83 | 68 |
| 22 | 68 | 78 | 68 | 78 | 68 | 78 | 68 |
| 23 | 68 | 78 | 68 | 78 | 68 | 78 | 68 |
| 24 | 65 | 78 | 65 | 83 | 65 | 78 | Off |

*Determining Heating Mode vs. Cooling Mode*. When the building is in the heating mode, the heating setpoints for each hour are set to the "Heating" values in Table R3-1, the cooling setpoint is set to a constant 78°F and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode, the "Cooling" values are used. The heating setpoint is set to a constant 60°F, and the cooling and venting setpoints are set to the values in Table R3-1.

The state of the building's conditioning mode is dependent upon the outdoor temperature averaged over hours 1 through 24 of day 8 through day 2 prior to the current day (e.g., if the current day is June 21, the mode is based on the average temperature for June 13 through 20). The compliance software shall calculate and update daily this 7-day running average of outdoor air temperature. When this running average temperature is equal to or less than 60°F the building shall be set in a heating mode and all the thermostat set points for the heating mode shall apply. When the running average is greater than 60°F the building shall be set to be in a cooling mode and the cooling mode set points shall apply.

*Zonal Control*: The alternative thermostat schedules listed in Table R3-1 above may be used for the proposed design when it meets the eligibility criteria for zonal control as defined in Chapter 5, Section 5.9.1.

*Setback Thermostat Exceptions:* Certain types of heating and/or cooling equipment are exempt from the mandatory requirement for setback thermostats, including wall furnaces and through-the-wall heat pumps. If setback thermostats are not installed, then the compliance software shall model the proposed design with the standard thermostat schedule, except that the heating mode setback set point shall be 66°F. In cases where setback thermostats are not mandatory but nonetheless are installed by the builder, the compliance software shall model the proposed design using the standard heating setback set point of 65°F. The standard design always assumes the setback schedule shown in Table R3-1.

## 3.3 Internal Gains

***Basic Allocation***

Internal gain from lights, appliances, people and other sources shall be set to 20,000 Btu/day for each dwelling unit plus 15 Btu/day for each square foot of conditioned floor area (CFA) as shown in Equation R3-1. Identical inputs shall be used for both the proposed design and the standard design.

Equation R3-1

$$IntGain_{total} = (20{,}000 \times N) + \left(15 \times \sum_{i=1}^{N} CFA_i\right)$$

Where

N= Number of dwelling units

$CFA_i$= Conditioned Floor Area of $i^{th}$ dwelling unit

***Additions***

For addition-alone compliance (single-zone), the internal gains are apportioned according to the fractional conditioned floor area, referred to as the Fractional Dwelling Unit (FDU). For zone j, the internal gain is determined by Equation R3-2. Identical inputs shall be used for both the proposed design and the standard design.

Equation R3-2

$$IntGainZone_j = IntGain_{tot} \times FDU_j$$

where

$FDU_j$ = Fractional Dwelling Unit of $j^{th}$ zone, calculated from Equation R3-3

Equation R3-3

$$FDU_j = \frac{CFA_j}{CFA_{total}}$$

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Chapters 4 and 5). When modeled together the number of dwelling units for the proposed dwelling ($NDU_{proposed}$) remains equal to the number of dwelling units for the existing structure ($NDU_{existing}$), while the conditioned floor area ($CFA_{proposed}$) is increased to include the contribution of the addition ($CFA_{addition}$). When modeled separately, the internal gain of the addition ($IntGain_{addition}$)is based on the value of the addition's fractional dwelling unit ($FDU_{addition}$), as expressed in Equation R3-4 and Equation R3-5.

Equation R3-4

$$IntGain_{addition} = IntGain_{total} \times FDU_{addition}$$

Equation R3-5

$$FDU_{addition} = \frac{CFA_{addition}}{CFA_{existing} + CFA_{addition}}$$

***Hourly Schedules***

The standard hourly internal gain schedule is shown in Table R3-2. “Hour one” is between midnight and 1:00 am. The whole building schedule shall always be used for the standard design run. The whole building is also used for the proposed design unless the proposed design has zonal control. For zonal control, the Living Areas schedule is used for the living areas and the Sleeping Areas schedule is used for sleeping areas.

*Table R3-2 – Hourly Internal Gain Schedules*

| | Percent of Daily Total Internal Gains (%) | | |
|---|---|---|---|
| Hour | Whole House | Living Areas | Sleeping Areas |
| 1 | 2.40 | 1.61 | 4.38 |
| 2 | 2.20 | 1.48 | 4.02 |
| 3 | 2.10 | 1.14 | 4.50 |
| 4 | 2.10 | 1.13 | 4.50 |
| 5 | 2.10 | 1.21 | 4.32 |
| 6 | 2.60 | 1.46 | 5.46 |
| 7 | 3.80 | 2.77 | 6.39 |
| 8 | 5.90 | 5.30 | 7.40 |
| 9 | 5.60 | 6.33 | 3.76 |
| 10 | 6.00 | 6.86 | 3.85 |
| 11 | 5.90 | 6.38 | 4.70 |
| 12 | 4.60 | 5.00 | 3.61 |
| 13 | 4.50 | 4.84 | 3.65 |
| 14 | 3.00 | 3.15 | 2.63 |
| 15 | 2.80 | 2.94 | 2.46 |
| 16 | 3.10 | 3.41 | 2.32 |
| 17 | 5.70 | 6.19 | 4.47 |
| 18 | 6.40 | 7.18 | 4.45 |
| 19 | 6.40 | 7.24 | 4.29 |
| 20 | 5.20 | 5.96 | 3.30 |
| 21 | 5.00 | 5.49 | 3.75 |
| 22 | 5.50 | 6.20 | 3.75 |
| 23 | 4.40 | 4.38 | 4.45 |
| 24 | 2.70 | 2.35 | 3.59 |
| Total | 100.00 | 100.00 | 100.00 |

***Seasonal Adjustments***

Daily internal gain shall be modified each month according to the multipliers shown in Table R3-3. These multipliers are derived from the number of daylight hours for each month. Identical inputs shall be used for both the proposed design and the standard design.

*Table R3-3 – Seasonal Internal Gain Multipliers*

| Month | Multiplier | Month | Multiplier | Month | Multiplier |
|---|---|---|---|---|---|
| Jan | 1.19 | May | 0.84 | Sep | 0.98 |
| Feb | 1.11 | Jun | 0.80 | Oct | 1.07 |
| Mar | 1.02 | Jul | 0.82 | Nov | 1.16 |
| Apr | 0.93 | Aug | 0.88 | Dec | 1.21 |

### 3.3.2 Joint Appendix JA4

Thermal resistances (R-values) and thermal transmittance values (U-factors) shall be determined from Reference Joint Appendix JA4. Standard framed (wood and metal) walls with studs 16 in. on center shall be modeled to have 25 percent framing, and standard framed walls with studs located at 24 in. centers shall be modeled to have 22 percent framing.

Degree of Precision: The total R-value shall be entered, stored, displayed, and calculated to at least three significant figures, or, alternatively to two decimal places, and the total U-factor to two significant figures or three decimal places whichever is more precise.

Data from Reference Joint Appendix JA4 shall be used in compliance calculations unless the Energy Commission approves alternate values through the exceptional methods process. Reference Joint Appendix JA4 also includes pre-calculated assemblies that meet the default U-factors using a combination of batt and rigid insulation. Steel framing assemblies are also included.Reference Joint Appendix JA4 has R-values for common materials; information on a variety of masonry wall assemblies; and other data useful in determining the U-factor of an assembly.

### 3.3.3 Quality Insulation Installation

***Proposed Design***. The compliance software user may specify either *Standard* or *Improved* insulation installation quality for the proposed design. The presence of *Improved* insulation installation quality shall be reported in the *HERS Required Verification* listings on the CF-1R. *Improved* insulation installation quality shall be certified by the installer and field verified. Credit for improved insulation installation is applicable to ceililngs/attics, knee walls, exterior walls and exterior floors.

***Standard Design***. The standard design shall be modeled with *Standard* insulation installation quality.

Compliance credit is available for low-rise residential buildings if field verification is performed to ensure that quality insulation and air barrier installation procedures are followed (see Reference Residential Appendix RA4). All newly insulated opaque surfaces in a building must be field verified to receive this credit. Compliance reports and user interfaces shall identify the building as having either *Standard* or *Improved* insulation installation quality. As discussed in Section 3.2.8, the standard design shall have standard insulation installation quality. Approved compliance software must be able to model both *Standard* and *Improved* insulation installation quality (see Table R3-4).

*Table R3-4 – Modeling Rules for insulation installation Quality*

| | | Insulation Installation Quality | |
|---|---|---|---|
| Component | Mode | Standard | Improved |
| Walls | Both | Increase heat gains and losses by 19%, i.e., multiply all wall U-factors by 1.19. | Increase heat gains and losses by 5%, i.e., multiply all wall U-factors by 1.05. |
| Non-Attic Ceilings/Roofs | Heating | Add 0.020 times the area to the UA of each ceiling surface i.e., add 0.02 to the U-factor. | Add 0.01 times the area to the UA of each ceiling surface i.e., add 0.01 to the U-factor. |
| | Cooling | Add 0.005 times the area to the UA of each ceiling surface i.e., add 0.005 to the U-factor. | Add 0.002 times the area to the UA of each ceiling surface i.e., add 0.002 to the U-factor. |
| Attic Ceilings/Roofs | Both | Handled through adjustments to coefficients in the reference method's unconditioned zone model. | Handled through adjustments to coefficients in the reference method's unconditioned zone model. |

When credit is taken for Improved insulation installation quality, the CF-1R shall show that field verification is required and the Installation Certificate (CF-6R) and the Field Verification and Diagnostic Testing Certificate (CF-4R) must be completed and signed by the installer and HERS Rater, respectively.

For alterations of pre-1978 houses, no wall degradation shall be assumed for the existing wall since this construction is assumed to have no insulation to degrade (see Table R3-1).

### 3.3.4 Reporting Requirements on CF-1R

The Certificate of Compliance shall provide basic information about the building, including:

- *HERS Measures (yes or no).* At the very beginning of the Certificate of Compliance, this provides a prominent notification when compliance with the performance standards requires HERS Rater field verification or diagnostic testing
- *NSHP Tier Compliance Margin -Tier 1 or Tier 2 - percent above the standards design budget. List the percent difference of the proposed design above the standard with the designation of which tier is exceeded. If this note is listed on the CF-1R, then the* CF-1R-PV must be attached and the HERS field verification statement should be YES and also appear on the certificate.
- *Conditioned Floor Area.* The conditioned floor area of all building zones modeled in the computer run.
- *Building Type.* The type of building. Possible types are single-family and multi-family.
- *Construction Type:* The type of construction. Possible types are new, existing, addition alone and existing plus addition plus alteration.
- *Building Front Orientation.* The azimuth of the front of the building. This will generally be the side of the building where the front door is located. A typical reported value would be "290° (west)". This would indicate that the front of the building faces north 70° west in surveyors terms. The closest orientation on 45° compass points should be verbally reported in parenthesis, e.g. north, northeast, east, southeast, south, southwest, west or northwest. When compliance is shown for multiple orientations, "all orientations" may be reported. When "all orientations" is reported it shall be included in the *Special Features Inspection Checklist*.
- *Number of Dwelling Units.* The total number of dwelling units in the building. This number may be a fraction for cases of addition alone.
- *Number of Stories*. The number of building stories as defined by the *California Building Code*.
- *Floor Construction Type.* The ground floor construction type is one of the factors considered when determining the amount of thermal mass in the standard design.
- *Number of Conditioned Zones.* The number of conditioned zones modeled in the computer run.
- *Total Conditioned Volume.* The total volume of conditioned space within the building.
- *Conditioned Slab Floor Area.* The total area of slab floor (on grade or raised) with conditioned space above and the ground or unconditioned space below. This is used to determine the standard design mass requirement for buildings and the default values of the thermal mass requirements for the proposed design.
- *Total Conditioned Floor Area.* The total floor area of conditioned space in the building to be permitted. This area shall be no less than the *Conditioned Slab Floor Area* specified above. The conditioned non-slab floor area is the difference between the *Total Conditioned Floor Area* and the *Conditioned Slab Floor Area* and is used to determine the thermal mass for the standard design, the default value of thermal mass for the standard design, and the threshold thermal mass requirement for thermal mass credit in the proposed design. The conditioned non-slab floor area includes any non-slab floors, raised or not, and raised slab floors with conditioned space above and below the floor.

## 3.4 Zone Level Data

### 3.4.1 Building Zone Information

***Conditioned Floor Area***

***Proposed Design.*** The compliance software shall require the user to enter the total conditioned floor area of the proposed design as well as the conditioned slab floor area. The conditioned slab floor area is the area of a slab floor with a minimum slab thickness of 3.5 inches or a minimum heat capacity of 7.0 Btu/ºF-ft² and conditioned space above and unconditioned space or the ground/gravel below. The non-slab conditioned floor area is the total conditioned floor area minus the conditioned slab floor area. Stairwell floor area shall be included in conditioned floor area as the horizontal area of the stairs and landings between two floors of each story of the house. The conditioned slab floor area may be either on-grade or a raised slab.

***Standard Design.*** The total conditioned floor area and the conditioned slab floor area of the standard design building is the same as the proposed design.

***Note.*** Compliance software shall keep track of the conditioned floor area and shall at least be able to keep separate track of the total conditioned floor area and conditioned slab floor area. These areas are used to determine the default thermal mass for the proposed design and the thermal mass for the standard design.

***Conditioned Volume***

***Proposed Design.*** The volume of the proposed design is the conditioned volume of air enclosed by the building envelope. The volume shall be consistent with the air volume of the actual design and may be determined from the total conditioned floor area and the average ceiling height or from a direct user entry for volume.

***Standard Design.*** The volume of the standard design building is the same as the proposed design.

***Free Ventilation Area***

Free ventilation area is the adjusted area taking into account bug screens, window framing and dividers, and other factors.

***Proposed Design***: Free ventilation area for the proposed design is calculated by the compliance software based on the types and areas of windows specified in the proposed design. The free ventilation area is modeled as 20 percent of the fenestration area for hinged type windows such as casements, awnings, hoppers, patio doors and French doors that are capable of a maximum ventilation area of approximately 80 percent of the rough frame opening. If the compliance software user increases the ventilation area for hinged type windows, the compliance software shall also consider the possible effect of fixed glazing in the building which has no free ventilation area (window opening type *Fixed*). The compliance software user may account for additional free ventilation area by entering the total area for sliding windows, the total area for hinged windows, and the total area of fixed windows. The compliance software shall verify that the total area entered for these three types is the same as the total area of windows calculated elsewhere or the compliance software may determine the area of fixed windows by subtracting the slider window area and the hinged window area from the total window area if it is less than the total window and skylight area. If the total window and skylight area is less than the area specified for sliding windows and hinged windows the compliance software shall reduce the area of hinged windows by the difference. The total ventilation area is calculated from the areas of the three possible fenestration opening types, as shown in Equation R3-6 below:

Equation R3-6 $$Vent_{Area} = (Area_{Slider} \times 0.1) + (Area_{Hinged} \times 0.2) + (Area_{Fixed} \times 0.0)$$

The compliance software’s ability to accept a customized ventilation area is an optional capability. When this optional capability is used, the fact that the user entered a customized free ventilation area and the total areas of each of these three fenestration opening types shall be reported in the *Special Features Inspection Checklist* on the CF-1R. Note that the maximum free ventilation area that may be modeled by any compliance software for compliance purposes is 20 percent of the total area of windows and skylights assuming that all windows and skylights are hinged.

***Standard Design***: The standard design value for free ventilation area is 10 percent of the fenestration area (rough frame opening). This value assumes that all windows are opening type *Slider*. The approved compliance software compliance manual shall note that fenestration-opening type *Slider* also may be selected by the user or automatically used by the compliance software as a default or “*Standard*” opening type.

***Ventilation Height Difference***

***Proposed Design***: The default assumption for the proposed design is 2 feet for one story buildings and 8 feet for two or more stories. Greater height differences may be used with special ventilation features such as high, operable clerestory windows. In this case, the height difference entered by the user is the height between the average center height of the lower operable windows and the average center height of the upper operable windows. Such features shall be fully documented on the building plans and noted in the *Special Features Inspection Checklist* of the CF-1R.

***Standard Design***: The standard design modeling assumptions for the elevation difference between the inlet and the outlet is 2 feet for one story buildings and 8 feet for two or more stories.

***Reporting Requirements on CF-1R***

The CF-1R shall include the following information:

- *Zone Name.* Each zone is given a name that is used to categorize information in subsequent tables.
- *Floor Area ($ft^2$).* The floor area of the zone measured to outside wall. The sum of the floor area of all conditioned zones shall equal the conditioned floor area reported under "General Information".
- *Volume ($ft^3$).* The volume of the zone. The sum of the volume of all conditioned zones shall equal the total volume reported under "General Information".
- *# of Units.* The number of dwelling units in the zone. This number may be a fraction for cases of addition alone or a building in which there are more zones than dwellings.
- *Zone Type.* This description controls some modeling restrictions, such as infiltration, internal and solar gains, etc. Possible conditioned zone entries are Conditioned, Living and Sleeping. Possible unconditioned zone entries include Unconditioned, CVCrawl and Sunspace.
- *Thermostat Type*. Possible conditioned zone entries are Setback, NoSetback, LivingStat, SleepingStat. Additional thermostat types may be allowed for optional modeling capabilities.
- *Vent Area ($ft^2$)*. For conditioned zones, these entries are either one half of the default vent area each, for high and low based on entries in the Fenestration Surfaces table or some other value entered by the user. A Vent Area value greater than 10 percent of the total rough-out opening area (all windows treated as opening type: “slider”) of all fenestration shall be reported in the *Special Features Inspection Checklist* for special verification. For unconditioned zones, the high and low ventilation areas will either default to the UBC minimum values for attic vent area, otherwise the values entered by the user shall be reported.
- *Vent Height (ft)*. The height difference between the "inlet" ventilation area and the "outlet" ventilation area. The default ventilation height is determined by the number of stories: one story is 2 feet, and two or more

stories is 8 feet. Different vent heights may be modeled but a non-default vent height is considered a special feature or special modeling assumption that shall be reported in the *Special Features Inspection Checklist* for special verification. The ventilation height for other windows is the average height difference between the centers of the lower operable window openings and the centers of the upper operable window openings.

### 3.4.2 Thermal Mass

Prescriptive Package D, the basis of the standard design, has no thermal mass requirements. Package D and the performance approach assume that both the proposed design and standard design building have a minimum mass as a function of the conditioned area of slab floor and non-slab floor.

Compliance software shall be capable of modeling thermal mass in buildings. Thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. There are two types of thermal mass, *Light Mass* which reacts very quickly to absorb or release heat, and *Heavy Mass* which reacts more slowly. *Light Mass* is modeled in the same way for both the proposed design and the standard design. The modeled mass includes common elements such as framing, furniture, ½ in. gypsum board, and household appliances. Light mass is modeled through an input in the reference program called building heat capacity and is assumed to be fixed at 3.5 Btu/ºF-ft² of conditioned floor area for both the proposed design and the standard design. Other values may be used for unconditioned zones.

“Heavy” mass includes elements such as concrete slab floors, masonry walls, double gypsum board and other special mass elements. When the proposed design qualifies as a high mass building then each element of heavy mass is modeled in the proposed design, otherwise, the proposed design is modeled with the same heavy thermal mass as the standard design. See belowfor details on what qualifies as a high mass building.

***Proposed Design***

The proposed design will be modeled with the same thermal mass as the Standard design unless the proposed design is a high mass building as defined below. The default thermal mass for the proposed design and the fixed thermal mass for the standard design is based on 20 percent of the slab floor being exposed and 80 percent covered with carpet or casework. In addition 5 percent of the non-slab floor is exposed with a topping of 2 in. of concrete.

***Standard Design***

The conditioned slab floor in the standard design is assumed to be 20 percent exposed slab and 80 percent slab covered by carpet or casework. The non-slab floor in the standard design is assumed to be 5 percent exposed with two inch thick concrete with the remainder low-mass wood construction. No other mass elements are modeled in the standard design. The standard design mass is modeled with the following characteristics.

- The conditioned slab floor area (slab area) shall have a thickness of 3.5 inches; a volumetric heat capacity of 28 Btu/ft$^3$-°F; a conductivity of 0.98 Btu-in/hr-ft$^2$-°F. The exposed portion shall have a surface conductance of 1.3 Btu/hr-ft$^2$-°F (no thermal resistance on the surface) and the covered portion shall have a surface conductance of 2.0 Btu/hr-ft$^2$-°F, typical of a carpet and pad.
- The “exposed” portion of the conditioned non-slab floor area shall have a thickness of 2.0 inches; a volumetric heat capacity of 28 Btu/ft$^3$-ºF; a conductivity of 0.98 Btu-in/hr-ft$^2$-ºF; and a surface conductance of 1.3 Btu/hr-ft$^2$-°F (no added thermal resistance on the surface). These thermal mass properties apply to the “exposed” portion of non-slab floors for both the proposed design and standard design. The covered portion of non-slab floors is assumed to have no thermal mass.

***Definition of High Mass Building***

Additional thermal mass in the proposed design may only be modeled when the proposed design is a high mass building. A high mass building has mass equivalent to 30 percent of the conditioned slab floor area being exposed slab and 70 percent slab covered by carpet or casework, and 15 percent of the conditioned non-slab floor area being exposed with two inch thick concrete with the remainder low-mass wood construction. Compliance software may let users indicate a high mass design before entering mass elements for the proposed design, or compliance software can let users enter mass elements, but only consider them in the proposed design if the building qualifies as a high mass building. Thermal mass equivalency is determined through the concept of the Unit Interior Mass Capacity (UIMC) calculation described in Reference Residential Appendix RA4. The thermal mass of the proposed design, other than the default standard design mass is only modeled and displayed on compliance output if the proposed design qualifies as a high mass building.

***Reporting Requirements on CF-1R***

*Conventional Mass Designs*

When the building has slab surfaces but does not qualify as a high mass design (see Thermal Mass in Section 3.3.2), the CF-1R shall report:

- *Mass Name.* The name of the mass element.
- *Area (ft²).* The area of the mass in square feet.

*High Mass Designs*

When the proposed design qualifies as a high mass building the features shall be reported in the *Special Features Inspection Checklist* on the CF-1R. The CF-1R must provide details about the thermal mass elements that qualify the building as a high mass building.

Thermal mass elements may be located within a single zone, they may separate zones, or they may be located on an exterior wall. Mass elements in each of these categories shall be grouped and labeled accordingly. The CF-1R shall include the following information:

- *Mass Name.* The name of the mass element. This name may be referenced from the optional solar gains targeting section of the fenestration surfaces table.
- *Area (ft²).* The area of the mass in square feet.
- *Thickness.* The mass thickness in inches.
- *Heat Capacity.* The volumetric heat capacity of the mass material in Btu/ºF-ft³.
- *Conductivity.* The conductivity of the mass material in Btu-in/h-ft² -°F.
- *Reference Joint Appendix JA4* A reference to a lookup from ReferenceJoint Appendix 4..
- *Inside Surface R-value.* The thermal resistance of any material (such as carpet or tapestry) that may exist on the inside surface of the thermal mass excluding air films. For instance, if a mass element is carpeted, a surface R-value of 2 is the fixed input. For mass elements that separate thermal zones, the surface R-value may be reported separately for each side of the mass.
- *Location/Comments.* User provided information on the location of the mass element or other relevant information.

***Thermal Mass Calculations***

The following calculation method shall be used to determine the impact of thermal mass.

*Solar Gain Targeting*

Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the standard design run and the proposed design run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Chapter 5.

*Unconditioned Sunspaces*
For compliance purposes, when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25 percent of the solar gains from these surfaces to *Heavy* mass elements located within the unconditioned space. Unassigned solar gain is targeted to the air or the combined air/lightweight mass or to high surface area lightweight mass in the unconditioned space. At least 25 percent of the solar gain from any sunspace fenestration surface shall be targeted to high surface area lightweight mass and/or the air. At most 60percent of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. For compliance purposes, a compliance software shall automatically enforce these limits and inform the user of any attempt to exceed these limits.

### 3.4.3 Ventilation and Infiltration

This section of the manual describes how natural ventilation and infiltration are modeled for the proposed design and the standard design. Treatment of mechanical ventilation, which is a mandatory measure is addressed in a subsequent section.

***Infiltration***
The intentional or unintentional replacement of conditioned indoor air by unconditioned outdoor air creates heat gains or heat losses for a conditioned building. This exchange of indoor and outdoor air occurs for all buildings to a greater or lesser extent.

*Proposed Design*
As a default, compliance software shall not require the user to enter any values related to infiltration and shall set the infiltration level to an SLA of 4.3 for ducted HVAC systems without sealed ducts, an SLA of 3.8 for ducted HVAC systems with sealed ducts, and an SLA of 3.2 for non-ducted HVAC systems. However, specific data on infiltration may be entered if the building will be diagnostically tested during building construction or if a qualifying air-retarding wrap is specified.

- *Air Retarding Wrap*. An air retarding wrap can qualify for a default reduction in Specific Leakage Area (SLA) of 0.50 without confirmation by diagnostic testing. The air retarding wrap shall be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or system for Low-Rise Framed Building Walls* and have a minimum perm rating of 10. The air-retarding wrap shall be installed per the manufacturer's specifications that shall be provided to comply with ASTM E1677-95 (2000). The air retarding wrap specifications listed above shall also be reported in the *Special Features Inspection Checklist* when an air retarder is modeled by the compliance software.
- *Reduced Infiltration Due to Duct Sealing*. The default infiltration (no diagnostic testing and measurement of infiltration) credit for reduced duct leakage is also an SLA reduction of 0.50. The compliance software shall automatically apply this credit when the proposed design has sealed and tested ducts. The use of this SLA reduction credit for Low-leakage HVAC ducts shall be listed in the *Special Features Inspection Checklist* of the CF-1R. This credit may be combined with the air retarding wrap credit.
- *Diagnostic Testing for Reduced Infiltration*. Neither of the above credits shall be taken if the user chooses a diagnostic testing target for reduced infiltration. When the user chooses diagnostic testing for reduced infiltration, the diagnostic testing shall be performed using fan pressurization of the building in accordance with ASTM E 779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and

the equipment used for this test shall meet the instrumentation specifications found in Reference Residential Appendix RA-3. The specifications for diagnostic testing and the target values specified above shall be reported in the *HERS Required Verification* listings on the Certificate of Compliance. The compliance software shall require the user to enter a target value for measured $CFM50_H$ or the SLA corresponding to the target $CFM50_H$,

The SLA of the proposed design shall not be modeled at a value lower than 1.5, regardless of diagnostic testing results.

*Standard Design*

The standard design assumes the default infiltration corresponding to a SLA of 3.8 for ducted HVAC systems and a SLA of 3.2 for non-ducted HVAC systems

*Infiltration Calculations*

The reference method uses the effective leakage area method for calculating infiltration in conditioned zones.

Default Specific Leakage Area

The specific leakage area (SLA) is the ratio of the effective leakage area to floor area in consistent units. The value is then increased by 10,000 to make the number more manageable. If the effective leakage area (ELA) is known in inches, then the SLA may be calculated with Equation R3-7.

Equation R3-7

$$SLA = \left(\frac{ELA}{CFA}\right)\left(\frac{ft^2}{144in^2}\right)(10000) = \left(\frac{ELA}{CFA}\right)69.444$$

Where:

ELA = Effective leakage area in square inches

CFA = Conditioned floor area (ft²)

SLA = Specific leakage area (unitless)

*Effective Leakage Area (ELA) Method*

The Effective Leakage Area (ELA) method of calculating infiltration for conditioned zones documented below shall be used. The ELA for the standard design and for the default values for the proposed design (if diagnostic tests are not used), is calculated from Equation R3-7. The airflow from infiltration is calculated as follows.

Equation R3-8

$$CFM_{infil} = ELA \times \sqrt{A \times |\Delta T_2| + B \times V^2}$$

Where:

$CFM_{infil}$ = Infiltration in cubic feet per minute (cfm)

$\Delta T_2$ = difference between indoor and outdoor temperature for previous hour (°F) (absolute value)

A = stack coefficient, ($cfm^2/in^4/F$)

B = wind coefficient, ($cfm^2/in^4/mph^2$)

V = average wind speed for current hour (mph)

ELA = effective leakage area ($in^2$), measured or calculated using Equation R3-14.

The stack (A) and wind (B) coefficients to be used are shown in Table R3-5.

*Table R3-5 – Infiltration Coefficients*

| *Coefficient* | *One Floor* | *Two Floors* | *Three Floors* |
|---|---|---|---|
| A (stack) | 0.0156 | 0.0313 | 0.0471 |
| B (wind) (Shielding Class 4) | 0.0039 | 0.0051 | 0.0060 |

*Combined Infiltration and Ventilation*
The combined airflow from infiltration and unbalanced mechanical ventilation is calculated as follows.

Equation R3-9

$$CFM_{infil+unbalfan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2}$$

Where:

$CFM_{infil}$ = Infiltration in cubic feet per minute (cfm)

$CFM_{infil+unbalfan}$ = combined infiltration and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$MECH_{unbal}$ = the unbalanced mechanical ventilation in cfm. This value is derived from the absolute value of the difference between the total supply cfm and the total exhaust cfm.

The total airflow from infiltration and mechanical ventilation is calculated as follows.

Equation R3-10

$$CFM_{infil+totfan} = CFM_{infil+unbalfan} + MECH_{bal}$$

Where:

$CFM_{infil+unbalfan}$ = combined infiltration and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$CFM_{infil+totfan}$ = infiltration plus the balanced and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$MECH_{bal}$ = the balanced mechanical ventilation in cfm. This value is the smaller of the total supply fan cfm and the total exhaust fan cfm.

The airflow from natural ventilation is equal to the natural ventilation cooling airflow:

Equation R3-11

$$CFM_{natv} = CFM_{t}$$

Where:

$CFM_{natv}$ = The airflow from natural ventilation cooling.

$CFM_t$ = The total natural ventilation cooling airflow calculated by Equation R3-19.

The total ventilation and infiltration (in cfm) is:

Equation R3-12

$$CFM_{total} = CFM_{natv} + CFM_{infil+totfan}$$

Where:

$Q_{total}$ = Energy from ventilation and infiltration for current hour (Btu)

$CFM_{natv}$ = The airflow from natural ventilation cooling.

$CFM_{infil+totfan}$ = infiltration plus the balanced and unbalanced mechanical ventilation in cubic feet per minute (cfm)

The energy load on the conditioned space from all infiltration and ventilation heat gains or losses is calculated as follows:

Equation R3-13

$$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1$$

Where:

$Q_{total}$ = Energy from ventilation and infiltration for current hour (Btu).

$CFM_{total}$ = The total ventilation and infiltration airflow (cfm).

1.08 = conversion factor in (Btu-min)/(hr-$ft^3$-°F)

$\Delta T_1$ = difference between indoor and outdoor temperature for current hour (°F)

.

The ELA is calculated from the SLA as follows:

Equation R3-14

$$ELA = CFA \times SLA \times \left(\frac{144\,in^2}{1ft^2}\right) \times \left(\frac{1}{10{,}000}\right)$$

Where:

CFA = conditioned floor area ($ft^2$)

SLA = specific leakage area ($ft^2/ft^2$)

ELA = effective leakage area ($in^2$)

Alternatively, ELA and SLA may be determined from blower door measurements:

Equation R3-15

$$ELA = 0.055 \times CFM50_H$$

Where:

$CFM50_H$ = the measured airflow in cubic feet per minute at 50 pascals for the dwelling with air distribution registers unsealed.

Substituting Equation R3-15 into Equation R3-7 gives the relationship of the measured airflow rate to SLA:

Equation R3-16

$$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$

*Controlled Ventilation Crawl Spaces and Sunspaces*

Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Chapter 5. All optional capabilities that are used in the proposed design shall be reported in the *Special Features Inspection Checklist* on the Certificate of Compliance.

*Infiltration Interaction with attic*

The UZM attic model accounts for the infiltration that flows between the conditioned space and the attic through the ceiling. Ceiling infiltration is assumed to be a fixed 40 percent of the conditioned zone natural infiltration rate calculated using the procedure above. The direction of the ceiling infiltration flow is determined by the relative temperatures of the conditioned zone and outdoors. If it is hotter in the conditioned zone than outdoors the ceiling infiltration flows to the attic. The flow reverses if it is cooler in the conditioned zone than outdoors.

When the infiltration flows from the attic into the conditioned zone it may change the conditioned zone load since infiltration from the attic will likely be at a different temperature than ambient. Instead of correcting the load through iteration, the correction to this load is made in the UZM. The form of the correction is based on the requirement that the conditioned zone model has calculated its natural infiltration load to be all coming from air at the ambient temperature. The correction is made by adjusting Qneed, by adding the part of the conditioned zone load from the attic, and subtracting the overcounted part of the load from the ambient temperature.

### Natural Ventilation

*Natural Ventilation Algorithms*

The natural ventilation model is derived from the 2001 ASHRAE Handbook of Fundamentals. The model considers both wind effects and stack effects.

- Wind driven ventilation includes consideration of wind speed, prevailing direction and local obstructions, such as nearby buildings or hills.
- Stack driven ventilation includes consideration of the temperature difference between indoor air and outdoor air and the difference in elevation between the air inlet and the outlet.

For compliance purposes, the air outlet is always assumed to be 180 degrees or on the opposite side of the building from the air inlet and the inlet and outlet areas are assumed to be equal. The default inlet area ( outlet area) is five percent of the total window area.

*Effective Ventilation Area (EVA)*
Both wind and stack driven ventilation depends linearly on the effective ventilation area (EVA). The EVA is a function of the area of the air inlet and the area of the air outlet. For compliance purposes, the default area of air inlet and outlet are both equal to 5 percent of the total window area, i.e., total ventilation area is 10 percent of the window area. For compliance purposes a different window opening area may be determined from the areas of different window opening types - fixed, sliders, and hinged windows. For compliance purposes, the air inlet and the air outlet are each equal to one-half of the *Free Ventilation Area*.

When the inlet area and outlet area are equal, the EVA is the same, i.e. equal to the inlet area or the outlet area. Hence for compliance purposes the EVA is equal to one-half of the *Free Ventilation Area.*

*Stack Driven Ventilation*
Stack driven ventilation results when there is an elevation difference between the inlet and the outlet, and when there is a temperature difference between indoor and outdoor conditions. See Equation R3-17.

Equation R3-17

$$CFM_S = 9.4 \times EVA \times EFF_S \times \sqrt{H \times \Delta T}$$

Where:
$CFM_S$ = Airflow due to stack effects, cfm.

9.4 = Constant.

EVA = Effective ventilation area as discussed above, ft².

EFFs = Stack effectiveness.

H = Center-to-center height difference between the air inlet and outlet.

ΔT = Indoor to outdoor temperature difference, °F.

For compliance purposes the stack effectiveness shall be set at 1.0. The compliance softwareuser shall not be permitted to alter this value.

*Wind Driven Ventilation*
The general equation for wind driven ventilation is shown below. This equation works in either a direction dependent implementation or a direction independent implementation, as explained later in the text.

Equation R3-18

$$CFM_w = EVA \times 88 \times MPH \times WF \times EFF_o \times EFF_d$$

Where:

*$CFM_W$ =* Ventilation due to wind, cfm.

*EVA =* Effective vent area as discussed above, $ft^2$.

*88 =* A constant that converts wind speed in mph to wind speed in feet per minute.

*MPH =* Wind speed from the weather tape, mph.

*WF =* A multiplier that reduces local wind speed due to obstructions such as adjacent buildings. This input is fixed at 0.25 for compliance calculations.

$EFF_O$ = Effectiveness of opening used to adjust for the location of the opening in the building, e.g. crawl space vents. This accounts for insect screens and/or other devices that may reduce the effectiveness of the ventilation opening. This input is also used to account for the location of ventilation area, e.g. the exceptional method for two-zone crawl space modeling provides for an alternative input for $EFF_O$. This input is fixed at 1.0 for compliance calculations other than crawlspace modeling.

$EFF_d$ = Effectiveness that is related to the direction of the wind relative to the inlet surface for each hour. ASHRAE recommends that the effectiveness of the opening, $EFF_d$, be set to between 0.50 and 0.60 when the wind direction is perpendicular or normal to the inlet and outlet. A value of 0.25 to 0.35 is recommended for diagonal winds. When the wind direction is parallel to the surface of the inlet and outlet, $EFF_d$ should be zero.

For compliance calculations, the orientation of the inlet and outlet is not considered. Compliance software shall assume that the wind angle of incidence at 45 degrees on all windows and only the wind speed dependence is maintained. In this case, the product of $EFF_O$ and $EFF_d$ is equal to 0.28 regardless of the direction of the wind.

*Combined Wind and Stack Effects*

Stack effects and wind effects are calculated separately and added by quadrature, as shown below. This algorithm always adds the absolute value of the forces; that is, wind ventilation never cancels stack ventilation even though in reality this can happen.

Equation R3-19

$$CFM_t = \sqrt{CFM_w^2 + CFM_s^2}$$

Where:

$CFM_t$ = Total ventilation rate from both stack and wind effects, cfm.

$CFM_W$ = Ventilation rate from wind effects, cfm.

$CFM_S$ = Ventilation rate from stack effects, cfm.

*Determination of Natural Ventilation for Cooling*

The value of $CFM_t$ described in Equation R3-19 above gives the maximum potential ventilation when the windows are open. Natural ventilation is available during cooling mode when there is venting shown in Table R3-1. The amount of natural ventilation used by computer software for natural cooling is the lesser of this maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint temperature when natural cooling is needed and available. When natural cooling is not needed or is unavailable no natural ventilation is used. Computer software shall assume that natural cooling is needed when the building is in “cooling mode” and when the outside temperature is below the estimated zone temperature and the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature down to the natural ventilation setpoint temperature is used and the natural ventilation setpoint temperature shall be constrained by the compliance software to be greater than the heating setpoint temperature.

*Wind Speed and Direction*

Wind speed affects the infiltration rate and the natural ventilation rate. The infiltration and ventilation rate in the reference method accounts for local site obstructions. For infiltration in the reference method this is done by using Shielding Class 4 coefficients (see 2001 ASHRAE Fundamentals, Chapter 26) to determine the stack and wind driven infiltration and ventilation. This Shielding Class determination was made on the basis of the description of the Shielding Classes given in the 2001 ASHRAE Fundamentals which reads as follows:

> Heavy shielding; obstructions around most of the perimeter, buildings or trees within 30 feet in most directions; typical suburban shielding.

The reference method adjusts the wind speed used in calculations through a WF of 0.25. See Equation R3-18.

***Reporting Requirements on CF-1R***

The natural ventilation inlet area, outlet area and elevation difference are reported in the CF-1R. An additional report is provided for diagnostically tested infiltration. This listing is only produced when the applicant has used reduced infiltration measures to improve the overall energy efficiency of the proposed design. Reduced infiltration credit may be taken for duct sealing and installation of an air retarder without a blower door test. Otherwise, the use of reduced infiltration requires diagnostic blower door testing by an installer and a certified HERS rater to verify the modeled reduced leakage area. Relevant information regarding infiltration and ventilation shall be reported in the *HERS Required Verification* listings on the CF-1R. The listings shall indicate that diagnostic blower door testing shall be performed as specified in ASTM E 779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. This listings shall also report the target $CFM50_H$ required for the blower door test to achieve the modeled SLA and the minimum $CFM50_H$ (corresponding to an SLA of 1.5) allowed to avoid backdraft problems. This minimum allowed value is considered by the Commission to be “unusually tight” in the requirements of the California Mechanical Code.

Also, the *HERS Required Verification* listings shall state that when the measured $CFM50_H$ is less than the minimum allowed value, corrective action shall be taken to either intentionally increase the infiltration or provide for mechanical supply ventilation adequate to maintain the dwelling unit at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating.

When mechanical ventilation is part of the proposed design the exhaust and supply fan wattages shall be reported in this listing and the *HERS Required Verification* listings.

When reduced infiltration or mechanical ventilation is modeled, the *Special Features Inspection Checklist* shall include a statement that the homeowner’s manual provided by the builder to the homeowner shall include instructions that describe how to use the mechanical ventilation to provide for proper ventilation.

Details provided in the CF-1R shall include:

- *Blower Door Leakage Target ($CFM50_H$/SLA):* The measured blower door leakage in cfm at 50 pascals of pressurization and its equivalent Specific Leakage Area (SLA) value.
- *Blower Door Leakage Minimum ($CFM50_H$/SLA):* The limit for the blower door leakage test to avoid backdrafting, which corresponds to a Specific Leakage Area (SLA) of 1.5, considered to be “unusually tight” for California Mechanical Code compliance. The compliance software shall report in the *HERS Required Verification* listings that the Commission considers this minimum CFM and the corresponding SLA of 1.5 or less to be “unusually tight” per the Uniform Mechanical Code. In the sample listing given above a 1600 square foot house and the SLA lower limit of 1.5 is used to determine the *Blower Door Leakage Minimum* shown.
- *Vent. (Ventilation) Fans (CFM):[Supply/Exhaust]:* The total volumetric capacity of supply fans and exhaust fans listed separately, separated by a slash (or reported in separate columns). The balanced portion of mechanical ventilation is the smaller of these two numbers while the unbalanced portion is the difference between these two numbers. These values are reported in cubic feet per minute.
- *Mechanical Vent. (Ventilation) Fans (Watts) [Supply/Exhaust]:* The total power consumption of the supply ventilation fans and the total power consumption of the exhaust ventilation fans in watts.

Use of an air retarding wrap shall be reported in the Special Features and Diagnostic Testing listings.

## 3.5 Attics

The procedures and rules in this section apply to attic roof constructions selected from the following tables of Reference Joint Appendix JA4.

Table 4.2.1 – U-factors of Wood Framed Attic Roofs

Table 4.2.4 – U-factors of Metal Framed Attic Roofs

The reference method models attics as a separate thermal zone and considers the interaction with the air distribution ducts, infiltration exchange between the attic and the house, the solar gains on the roof deck and other factors. These interactions are illustrated in Figure R3-2.

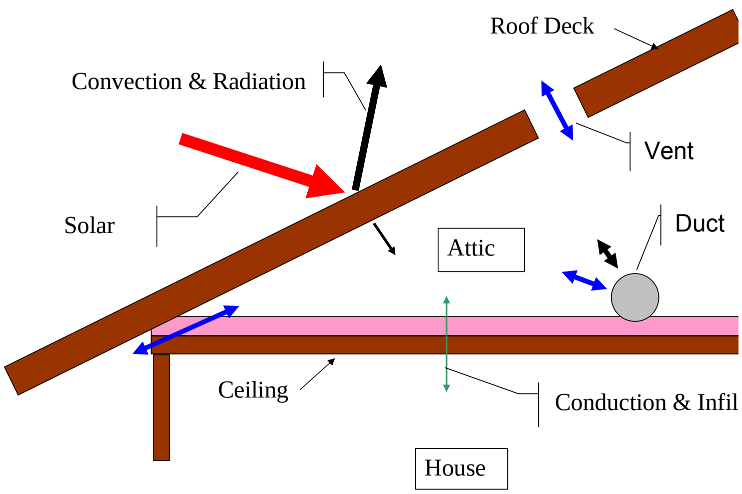



*Figure R3-2 – Components of the Unconditioned Attic Model*

### 3.5.1 Roof Pitch and Attic Geometry

**Proposed Design**. The user shall enter the roof pitch for the roof deck. If the proposed design has more than one roof pitch, the pitch of the largest area shall be used. The roof pitch shall be entered as the ratio of rise to run, e.g. 4:12 or 5:12. The compliance software shall calculate the roof area as the ceiling area divided by the cosine of the roof slope where the roof slope is angle in degrees from the horizontal. The roof deck area is then divided into four equal sections with each section sloping in one of the cardinal directions (north, east, south and west). Gable walls, dormers or other exterior vertical surfaces that enclose the attic are ignored.

**Standard Design**. The standard design shall have the same surface area and orientations as the proposed design.

### 3.5.2 Ceiling/Framing Assembly

**Proposed Design**. The user shall enter a surface area and select a ceiling/framing construction from either Reference Joint Appendix JA4 Tables 4.2.1 (wood framed attics) or 4.2.4 (metal framed attics). The compliance software shall allow a user to enter multiple ceiling constructions and areas which may be assigned to two conditioned zones if zonal control is part of the proposed design. The roof and ceiling areas and construction assemblies shall be consistent with the corresponding areas and construction assemblies in the actual building design and shall equal the overall ceiling area with conditioned space on the inside and unconditioned attic space on the other side. Surfaces that tilt 60 degrees or more are treated as knee walls and are not included as ceilings, but rather are entered separately. The compliance software shall generate a roof, attic and ceiling model based on the user inputs as defined in this and other sections.

**Standard Design**. The standard design shall have the same ceiling area as the proposed design and the ceiling/framing construction shall be based on the Package D prescriptive requirement and Table R3-6. The standard design is modeled with *Standard* insulation installation quality.

*Table R3-6 – Attic Constructions for the Standard Design*

| Building Component | Package D R-value Criteria | Description | Reference Joint Appendix JA4 |
|---|---|---|---|
| Ceiling | R-30 | 2x4's at 24 in. o.c. | Table 4.2.1-A20 |
| | R-38 | 2x4's at 24 in. o.c. | Table 4.2.4-A21 |

### 3.5.3 Attic Ventilation

**Proposed Design**. The compliance software shall allow a user to enter the free ventilation area and the fraction of the area that is located high in the attic. The free ventilation area shall include consideration of bird screens or louvers. There are only two choices for ventilation area one ft² of free ventilation area for each 300 ft² of ceiling area (1/300) or one ft² for each 150 ft² of ceiling area (1/150). To determine the fraction of the ventilation area located high, the user shall determine the total ventilation area (ft²) and the portion of this area that is located within 2 ft of the highest point in the attic. The fraction high is the ratio of the ventilation area located within two feet of the highest point in the attic to the total ventilation area and is a continuous variable for the attic model.

**Standard Design**. When the package D prescriptive requirements require a radiant barrier, the standard design shall have a 1/150 ventilation area and 30 percent of the ventilation area shall be located within 2 ft of the highest point in the attic. When the package prescriptive requirements do not require a radiant barrier, the ventilation area shall be 1/300 and the high ventilation fraction shall be zero.

### 3.5.4 Roof Deck

The roof deck is the construction at the top of the attic and includes the solar optic properties of the exterior surface, the roofing type, the framing, insulation, air gaps and other features. These are illustrated in Figure R3-3.

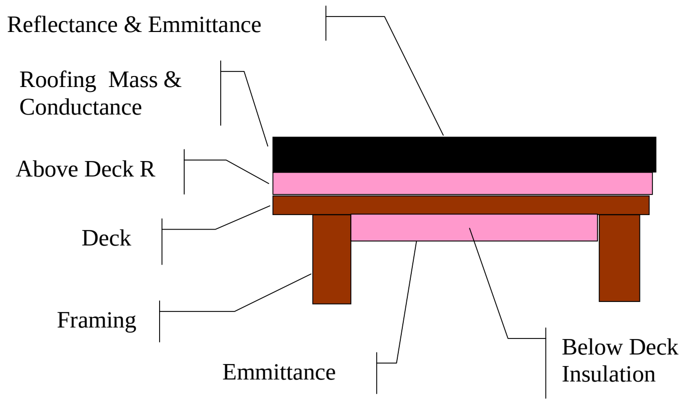



*Figure R3-3 – Components of the Attic through Roof Deck*

***Proposed Design***

A number of inputs are needed to define the roof deck in the proposed design. These are described below along with the defaults and constraints for the proposed design:

- **Solar reflectance and emittance** of the roof surface (unitless). The aged solar reflectance shall be defaulted to 0.10 unless the roofing material is rated by the Cool Roof Rating Council (CRRC) or is an asphalt or composition shingle. For asphalt shingles or composition shingles, the default aged solar reflectance is 0.08. The default emittance for all materials is 0.85. For products rated by the CRRC, the aged reflectance and emittance shall be used. If the aged reflectance is not available from the CRRC, it shall be estimated by multiplying the initial reflectance by 0.70 and adding 0.06 and the aged emittance shall be equal to the initial emittance. Roofing Products shall be reported on the *Special Features Inspection Checklist* on the CF-1R.
- **Roofing Type**. The choice of roofing type determines the air gap characteristics between the roofing material and the deck, the thermal mass characteristics, and establishes whether other inputs are needed, as described below. The choices for roof type are shown below.
    - **Concrete or clay tile.** These are characterized by the combination of an air gap between the deck and the tiles and the tiles themselves having some weight or mass.
    - **Metal tile or wood shakes.** (Note that tapered cedar shingles do not qualify and are treated as a conventional roof surface). These are lightweight (no significant mass), but have an air gap between the tiles or shakes and the deck.
    - **Other high slope roofing types.** Including asphalt and composite shingles and tapered cedar shingles. These products are characterized by a low thermal mass and no air gap between the shingles and the structural roof deck.
    - **Low slope membranes.** These are basically flat roofs with a slope of 2:12 or less.
- **Above deck insulation**. This input defaults to 0.85 for “concrete or clay tile” or for “metal tile or wood shakes” to represent the benefit of the air gap. The default is no insulation for other roof types. The user can enter the R-value of insulation installed above the deck and below the roofing material accounting for the effects of any framing or battens.
- **Above deck mass**. The above deck mass depends on the roofing type. The mass is 10 lb/ft² for concrete and clay tile and 5 lb/ft² for metal tile, wood shakes or other high slope roofing types. For low slope roofs the additional thermal mass is assumed to be gravel or stone and the user chooses one of the following inputs that is less than or equal to the weight of the material being installed above the roof deck:
    - No mass
    - 5 lb/ft²
    - 10 lb/ft²

  - 15 lb/ft²
  - 25 lb/ft²

- **Framing members and below deck insulation.** These inputs represent the support system below the deck and any insulation that would be installed below the deck. Inputs for this part of the roof deck include the R-value of the thermal insulation and thickness and spacing of the framing members. The top chord of trusses is typically a 2x4 spaced at 24 in. o.c., but other situations can occur. Choices for insulation include R-11, R-13, R-15, R-19, etc.
- **Radiant barrier.** The user shall specify whether or not the proposed design has a radiant barrier. A 0.05 emittance shall be assumed if radiant barriers are used. Radiant barriers shall be reported on the *Special Features Inspection Checklist* on the CF-1R. If no radiant barrier is used the value assumed is 0.9. The radiant barrier over discontinuous sheathing option shall be used when a radiant barrier is installed over existing skip sheathing in a reroofing application. There are three choices as described below:

  Continuous Radiant Barrier

  Radiant Barrier over Discontinuous Sheathing

  No Radiant Barrier.

***Standard Design***

The following characteristics shall be used to model the roof deck of the standard design.

- Solar reflectance and emittance of the roof surface (unitless). The standard design for steep slope roofs with a weight of 5 pounds or more per square foot (typically concrete or clay tile roofs), shall have an aged reflectance of 0.15 for all climate zones. For all other steep slope roofs (including asphalt and metal shingles and wood shakes) the aged solar reflectance for the standard design shall be 0.20 in climate zones 10 through 15 and 0.08 in other climate zones. For low slope roofs the aged reflectance shall be 0.55 in Climate zones 13 and 15 and 0.08 in all other zones. The standard design emittance shall be 0.85 for all roofs in all climate zones.
- Roofing Type. For steep slope roofs the roofing type shall be assumed to be “other high slope roofing type” except for roofs with weights of 5 pounds per square foot or more where the standard design roofing type shall be “concrete or clay tile.” For low slope roofs the standard design roofing type shall be a membrane with no added thermal mass.
- Above deck insulation. The standard design shall have no above deck insulation or air gap other than the default for the standard design roofing type
- Above deck mass. The standard design shall have no additional above deck mass, other that the default mass associated with the standard design roofing type.
- Framing members and below deck insulation. The standard design shall assume no insulation and 2x4’s at 24 in. o.c.
- Radiant barrier. The standard design shall have a continuous radiant barrier for the climates where it is required by the Package D prescriptive requirements.

### 3.5.5 Reporting Requirements on CF-1R

The certificate of compliance (CF-1R) shall report the user inputs for attics described in the above sections. Note that information on ceilings and knee walls shall be reported separately pursuant to Section 3.4.6

- *Roof Pitch.* The ratio of rise to run, typically specified as say “4 inches in 12 inches”.
- *Attic Vent Area*. There are two choices: 1/150 or 1/300.

- *Attic Vent High.* The fraction of the vent area that is high due to the presence of ridge, roof or gable end mounted vents. Soffit vents are considered low ventilation. Default value is 0 for attics with standard ventilation. Attics with radiant barriers are required to have a vent high fraction of at least 0.3.
- *Reflectance.* A fraction that specifies the certified aged reflectance of the roofing material. The installed value must be equal to or less than the value specified here. Roof construction with a roof membrane mass of at least 25 lb/ft$^3$ or roof area incorporated integrated solar collectors are assumed to met the minimal solar relectance.
- *Emittance.* A fraction that specifies the certified aged emissivity of the roofing material. The installed value must be equal to or greater than the value specified here. Default value is 0.9 if certified aged reflectance value is not available. Roof construction with a roof membrane mass of at least 25 lb/ft$^3$ or roof area incorporated integrated solar collectors are assumed to met the minimal emittance.
- *Roofing Type*. The user chooses from: concrete or clay tile; metal tile or wood shakes; other high slope roofing types; or low slope membranes.
- *Roofing Mass*. The user chooses from: none, 5, 10, 15, or 25 lb/ft$^2$. Default is none. This is mass in addition to the weight of the roofing tiles themselves. This input is specified only when the roofing type is low-slope membrane.
- *Above Deck R-value.* The R-value of insulation above the roof deck. Default value is 0.
- *Framing Depth and Spacing.* The framing depth for the roof framing members. Default value is 2x4's at 24 in. o.c.
- *Below Deck R-value.* The R-value of insulation below the roof deck. Default value is 0.
- *Radiant Barrier.* The user chooses from: continuous radiant barrier, radiant barrier over discontinuous sheathing, or no radiant barrier.

Refer to drawings in Figure R3-2 and Figure R3-3 for more details on these inputs.

### 3.5.6 Calculations

The algorithms used for the attic model are documented in the following:

- Niles, P.; Palmiter, L.; Wilcox, B.; Nittler, K, *Documentation of UZM, the Unconditioned Zone Model Used in the Residential Standards, October 23, 2007,* CEC-400-2007-021-45DAY..

Inputs to the reference method attic model are documented in the following tables.

*Table R3-7 – Attic Model Inputs – Attic Ventilation*

| Name | Description | Units | Default | Std Design | Input |
|---|---|---|---|---|---|
| Roof Rise | Rise to run as in 4 inches to 12 inches | inches | None | Same as Proposed | rise |
| Vent Area | 1/(Free vent area/attic floor area)as in 300 | none | 1/300 | Depends on Pkg D | ventarea |
| Vent high | Fraction of attic vent high | none | 0 | Depends on Pkg D | frachigh |

*Table R3-8 – Attic Model Inputs – Roofing Type*

| Roofing Type Choice | Description | Standard Design | Input |
|---|---|---|---|
| | | | R23 |
| Steep Slope Roof tile, metal tile, or wood shakes | Roofing with air space | | 0.85 |
| All others | Roofing with no air space | X | 0 |

*Table R3-9 – Attic Model Inputs – Roofing Deck*

| Name | Description | units | Default | Std Design | Input |
|---|---|---|---|---|---|
| Reflectance | Aged Reflectance of Roofing | frac | 0.08 | Depends on Pkg D | refl |
| Emissivity | Aged Emissivity of Roofing | frac | 0.85 | 0.85 | epso |
| Frame Depth | Depth of Framing attached to roof deck | inches | 3.5 | 3.5 | dj |
| Above Deck R | Insulation R above roof Deck | R | 0 | 0 | R23 |

*Table R3-10 – Attic Model Inputs – Roofing Mass*

| | | Library values | | |
|---|---|---|---|---|
| Roofing Mass Choices | Description | d3 | k3 | vc3 |
| 5 PSF mass | Normal gravel | 0.5 | 1 | 24 |
| 10 PSF mass | Concrete Tile | 1.0 | 1 | 24 |
| 15 PSF mass | Heavy Ballast or Pavers | 1.5 | 1 | 24 |
| 25 PSF mass | Very Heavy Ballast or Pavers | 2.5 | 1 | 24 |
| Light Roof | All other roofing | 0.2 | 1 | 24 |

*Table R3-11 – Attic Model Inputs – Radiant Barrier*

| Radiant Barrier Choices | | | | Library values |
|---|---|---|---|---|
| Name | Description | Default | Std Des | epsbf |
| Radiant Barrier | Radiant Barrier on bottom of Deck | None | Depends on Pkg D | 0.05 |
| Skip Radiant Barrier | Radiant Barrier over skip Sheathing | None | | 0.48 |
| No Radiant Barrier | No Radiant Barrier | None | | 0.90 |

*Table R3-12 – Attic Model Inputs – Below Roof Deck Insulation*

| | | Library values | | | | | |
|---|---|---|---|---|---|---|---|
| Name | Description | units | Default | Std Design | Input | d1 | k1 |
| Below Deck R | R-value of insulation at the bottom of the roof deck between the roof framing | R | 0 | 0 | belowdeckR | =R* k1 *12 | 0.025 |

*Table R3-13 – Attic Model Inputs – Roof Deck Framing*

| Framing Spacing Choices | | | | Library values |
|---|---|---|---|---|
| Name | Description | Default | Std Des | floor-to-floor |
| 24 | Roof framing @ 24" O.C. | X | X | 0.07 |
| 16 | Roof framing @ 16" O.C. | | | 0.1 |

*Table R3-14 – Attic Model Inputs – Ceiling Construction*

| name | Floor-to-floor | epsbf | dj | d1 | k1 | d2 | k2 | vc2 | R23 | d3 | k3 | vc3 | epso | alfao |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ceil1 | FF | 0.9 | 3.5 | D1 | 0.025 | 0.5 | 0.0926 | 13 | 0 | 0 | 0 | 0 | 0.9 | 0 |

Table R3-14 shows the inputs for the construction of the ceiling between the attic and one conditioned space below. All of the inputs are fixed except:

- FF the framing factor from Table R3-16.
- D1, the effective depth of the ceiling insulation calculated from Equation R3-20.

Equation R3-20

$$D1 = \left(\frac{1}{U_{table}} + 1.18\right) \times coef1 + coef2$$

Where:

*D1* = Effective depth of insulation, inches

$U_{table}$ = U factor from Reference Joint Appendix JA4 Table 4.2.1 – U-factors of Wood Framed Attic Roofs

Or Reference Joint Appendix JA4 Table 4.2.4 – U-factors of Metal Framed Attic Roofs

coef1 and coef2 are from the table below depending on the Insulation Construction Quality

*Table R3-15 – Attic Model Inputs – Ceiling Insulation Depth Coefficients*

| Insulation Quality | Default | Std Des | Coef1 | Coef2 |
|---|---|---|---|---|
| Standard | X | X | 0.2214 | 0.677 |
| Improved | | | 0.2617 | 0.216 |

*Table R3-16 – Attic Model Inputs – Ceiling Framing*

| Framing Spacing Choices | | | | Library values |
|---|---|---|---|---|
| Name | Description | Default | Std Des | FF |
| 24 | Ceiling framing @ 24" O.C. | X | X | 0.07 |
| 16 | Ceiling framing @ 16" O.C. | | | 0.1 |

*Table R3-17 – Ceiling Construction Quality*

| Ceiling Insulation Heating Factor | | | Library values |
|---|---|---|---|
| Description | Default | Std Des | Ubp |
| Standard Insulation Quality | X | X | .015 x Ceiling Area |
| Improved Insulation Quality | | | .008 x Ceiling Area |

*Table R3-18 – Attic Model Inputs – Knee Walls*

| name | Floor-to-floor | epsbf | dj | d1 | k1 | d2 | k2 | vc2 | R23 | d3 | k3 | vc3 | epso | Alfao |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Knee1 | FLOOR-TO-FLOOR | 0.9 | 3.5 | D1 | 0.025 | 0.5 | 0.0926 | 13 | 0 | 0 | 0 | 0 | 0.9 | 0 |

Table R3-18 shows the input for the construction of the knee walls between the attic and the conditioned space below. All of the inputs are fixed except:

- FF the framing factor from Table R3-20
- D1, the effective depth of the ceiling insulation calculated from Equation R3-21

Equation R3-21

$$D1 = \left(\frac{1}{U_{table}}\right) \times coef1 + coef2$$

where

*D1* = Effective depth of insulation, inches

$U_{table}$ = U factor from Reference Joint Appendix JA4 Table 4.3.1 – U-factors of Wood Framed Walls or Reference Joint Appendix JA4 Table 4.3.4 – U-factors for Metal Framed Walls for Residential Construction

*coef1, coef2* = From Table R3-19 depending on the Insulation Construction Quality

*Table R3-19 – Attic Model Inputs – Knee Wall Insulation Depth Coefficients*

| Insulation Quality | Default | Std Des | Coef1 | Coef2 |
|---|---|---|---|---|
| Standard | X | X | 0.2550 | 0.452 |
| Improved | | | 0.2894 | 0.384 |

*Table R3-20 – Attic Model Inputs – Knee Wall Framing Spacing*

| | | | | Library values |
|---|---|---|---|---|
| Name | Description | Default | Std Des | Framing Fraction |
| 24 | Kneewall framing @ 24" O.C. | | | 0.22 |
| 16 | Kneewall framing @ 16" O.C. | X | X | 0.25 |

## 3.6 Exterior Surfaces Other Than Attics

### 3.6.1 Non-Attic Ceiling and Roof Constructions

The procedures and rules in this section apply to ceiling and roof constructions selected from the following tables of Reference Joint Appendix JA4.

Table 4.2.2 – U-factors of Wood Framed Rafter Roofs

Table 4.2.3 – U-factors of Structurally Insulated Panels (SIPS) Roof/Ceilings

Table 4.2.5 – U-factors of Metal Framed Rafter Roofs

Table 4.2.6 – U-factors for Span Deck and Concrete Roofs

Table 4.2.7 – U-factors for Metal Building Roofs

Table 4.2.8 – U-factors for Insulated Ceiling with Removable Panels

Table 4.2.9 – U-factors for Insulated Metal Panel Roofs and Ceilings

***Proposed Design.*** The compliance software shall allow a user to enter one or more ceiling /roof areas for the proposed design.The roof/ceiling areas, construction assemblies, orientations, and tilts modeled shall be consistent with the corresponding areas, construction assemblies, and tilts in the actual building design and shall equal the overall roof/ceiling area with conditioned space on the inside and unconditioned space on the other side. U-factors shall be selected from Reference Joint Appendix JA4. If new ceiling and wall construction assemblies do not meet the mandatory minimum U-factor required by Title 24, the building shall not pass compliance. If the proposed design has *Improved* insulation installation quality, then all ceiling/roof assemblies in the proposed design are modeled accordingly (see above). The user shall specify the aged reflectance and emittance of the proposed roof surface or accept the default of an aged reflectance of 0.08 and an emittance of 0.85

***Standard Design.*** The non-attic ceiling/roof areas of the standard design building are equal to the non-attic ceiling/roof areas of the proposed design. The standard design roof and ceiling surfaces are assumed to be horizontal (no tilts) and have a U-factor specific to the package D requirements. The U-factors in Table R3-21 shall be used in the standard design for the appropriate R-value criteria in Package D. The standard design generator shall consider all exterior surfaces in the proposed design with a tilt less than 60 degrees as roof elements. Surfaces that tilt 60 degrees or more are treated as walls. The standard design is modeled with *Standard* insulation installation quality U-factors by correcting the U-factors in Table R3-21 with the standard insulation installation quality adjustment factors for ceilings/roofs from above. The aged reflectance and emittance of the standard design shall be determined by the package D requirements.

*Table R3-21 – Non-Attic Roof U-factors for the Standard Design*

| Building Component | Package D R-value Criteria | Standard Design U-factor | Reference Joint Appendix JA4 |
|---|---|---|---|
| Non-Attic Roof | R-30 | 0.033 | Table 4.2.2-A41 |
| | R-38 | 0.027 | Table 4.2.2-A43 |

### 3.6.2 Exterior Walls

***Proposed Design.*** The compliance software shall allow a user to enter one or more exterior wall areas for the proposed design. The wall areas modeled shall be consistent with the corresponding wall areas in the actual building design and the total wall area shall be equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. U-factors for proposed design wall constructions shall be selected from Reference Joint Appendix JA4. If the proposed design has *Improved* insulation installation quality, then walls are modeled accordingly (see above). Walls include all opaque surfaces with a slope greater than 60º but less than 12º from the horizontal.

***Standard Design.*** The gross wall area in the standard design is equal to the gross wall area of the proposed design, including knee walls in the ceiling construction of the proposed design. The gross exterior wall area in the standard design (excluding knee walls) is equally divided between the four main compass points, north, east, south, and west. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. The standard design has *Standard* insulation installation quality. U-factors for the standard design walls shall be those from Table R3-22 for the appropriate Package D R-value criteria multiplied by the standard insulation installation quality factor for walls from Section 3.2.8.

*Table R3-22 – Wall U-factors for the Standard Design*

| Building Component | Package D R-value Criteria | Standard Design U-factor | Reference Joint Appendix JA4 |
|---|---|---|---|
| Wall | R-13 | 0.102 | Table 4.3.1-A3 |
| | R-19 | 0.074 | Table 4.3.1-A5 |
| | R-21 | 0.069 | Table 4.3.1-A6 |

### 3.6.3 Basement Walls and Floors

***Proposed Design.*** Portions of basement walls above grade shall be modeled as conventional above-grade walls. For below-grade basement walls, the user shall enter the area at each of three depths: from zero to 2 feet below grade (shallow), greater than 2 feet to 6 feet below grade (medium), and greater than 6 feet below grade (deep). The compliance software shall allow users to enter as many wall types as necessary to model the proposed design. The U-factor, C-factor, and mass characteristics of below-grade walls shall be selected from Reference Joint Appendix JA4. The thermal performance characteristics for the proposed design below-grade wall constructions shall be the same as the standard design.

***Standard Design.*** The standard design shall have the same basement wall areas as the proposed design and at the same depths. The standard design basement wall shall be assumed to be a wall with a Heat Capacity of 15.7 Btu/($ft^2$-$^oF$), a thickness of 8 inches, and a continuous R-value of 1.5.

**Calculations**. Below grade walls shall be modeled with no solar gains, i.e., absorptivity is zero. Below grade walls are modeled with three exterior conditions depending on whether the depth is shallow, medium, or deep. The temperature of the earth depends on the depth of the wall and is given in Table R3-23. Thermal resistance also shall be increased to account for earth near the construction (see Table R3-23).

*Table R3-23 – Earth Temperatures for Modeling Basement Walls and Floors*

| Class | Depth | Assumed Temperature of the Earth | Thermal Resistance of Earth |
|---|---|---|---|
| Shallow Depth Walls | Up to 2 ft | Average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days 8 through 2). | A thermal resistance with an R-value of 1.57 (hr.ft$^2$.$^o$F/Btu) is added to the outside of the below grade wall. |
| Medium Depth Walls | 2+ to 6 ft | Exterior earth temperature is assumed to be the monthly average temperature from Table R3-26. | A thermal resistance with an R-value of 7.28 (hr.ft2.$^o$F/Btu) is added to the outside of the below grade wall. |
| Deep Walls | More than 6 ft | Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R3-26. | A thermal resistance with an R-value of 13.7 (hr.ft2.$^o$F/Btu) is added to the outside of the below grade wall. |
| Basement Floors | Any | Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R3-26. | A thermal resistance with an R-value of 17.6 (hr.ft2.$^o$F/Btu) is added to the bottom of the basement floor. |

### 3.6.4 Raised Floors

***Proposed Design.*** Compliance software users shall enter floor areas for the standard raised floor construction types listed in Table R3-24. The compliance software shall require user input to distinguish floor areas and constructions that are over crawl spaces. The U-factor for floor constructions and areas shall be consistent with the actual building design. U-factors shall be those from Reference Joint Appendix JA4. For concrete raised floors the assembly types used in Reference Joint Appendix JA4, Table 4.4.6 shall be used.

***Standard Design.*** The floor areas of the standard design are equal to the areas of the proposed design. The raised floor U-factor for the standard design is taken from Table R3-24 and depends on whether or not the floor assembly in the proposed design is located over a crawl space except for raised concrete floors. For this reason, the compliance software shall keep track of which raised floor surfaces are over crawl spaces and which are not.

**Notes**. The effect of a conventional crawl space is modeled with a thermal resistance of R-6; however, for controlled ventilation crawl spaces (an optional capability) and raised concrete floors, the crawl space is modeled as a separate thermal zone and R-6 is not assumed. The R-6 value for a conventional crawlspace shall be automatically calculated by the compliance software and shall not be allowed as a user input. The U-factors in Table R3-24 account for the additional R-6.

*Table R3-24 – Floor U-factors for the Standard Design*

| Floor Type | Package D Criteria | U-factor | Reference Joint Appendix JA4 |
|---|---|---|---|
| Raised Light Floor (crawl space) | R-19 | 0.037 | 4.4.1-A4 |
| Raised Light Floor (no crawl space) | R-19 | 0.048 | 4.4.2-A4 |
| Raised Concrete Floor | R-0 | 0.269 | 4.4.6A1 |
| | R-4 | 0.138 | 4.4.6.A3 |
| | R-8 | 0.092 | 4.4.6.A5 |

### 3.6.5 Reporting Requirements on CF-1R

A row shall be reported for each unique opaque surface in the proposed building. Opaque surfaces include walls, ceilings, and floors. Low-rise residential buildings may have either *Standard* or *Improved* envelope construction quality. This is a feature at the whole building level and not at the surface or construction type level. Envelope construction quality is reported in the *HERS Required Verification* section of the CF-1R.

For buildings that are modeled as multiple thermal zones, the opaque surfaces shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". Alternatively, an additional column may be added to the table to indicate the zone the building element is next to. The zone name used in the header should be the same as the name used in the table titled "Building Zone Information."

Information to be included in the CF-1R includes:

- *Surface Type.* Valid types are Wall, BaseWallA (0-2 ft below grade), BaseWallB (>2.0-6ft below grade), BaseWallC (more than 6 ft below grade), and Floor. If floor is over a crawl space (FlrCrawl), then the U-factors used in the custom budget run are based on having a crawl space. Otherwise, they are not. Floor types and areas are also used to determine the default thermal mass for the proposed design and the thermal mass for the standard design.
- *Area ($ft^2$).* The area of the surface.
- *Assembly U-factor.* The overall U-factor of the construction assembly selected from Reference Joint Appendix JA4. Note that the U-factors reported in this table are the same whether or not construction quality procedures are followed. There is a credit for construction quality, but it is embedded in the software and not reported as adjustment to the U-factor.
- *Cavity Insul R-val.* The rated R-value of the installed insulation in the cavity between framing members. This does not include framing effects or the R-value of drywall, air films, etc. When insulating sheathing is installed over a framed wall, the "Cavity Insul R-val" should report the insulation in the cavity only. This value is not entered by the user, but is determined when the user selects a standard construction from Reference Joint Appendix JA4.
- *Sheath Insul R-val.* The sum total rated R-value of all installed layers of insulating sheathing shall be reported. The sum of the R-values is reported for multiple sheathing layers. This value is not entered by the user, but is determined when the user selects a standard construction from Reference Joint Appendix JA4.
- *True Azimuth.* The actual azimuth of the surface after adjustments for magnetic north. There are various ways of describing the azimuth of surfaces. For compliance software approved by the CEC, a standard convention shall be used. The azimuth is zero degrees for surfaces that face exactly north. From this reference the azimuth is measured in a clockwise direction. East is 90 degrees, south 180 degrees and west 270 degrees. For example, a wall facing south south west (SSW) should be documented at an azmuth of 157.5 degrees from true north.
- *Tilt.* The tilt of the surface. Vertical walls are 90°; flat roofs are 0°; floors are 180°.
- *Solar Gains.* A yes/no response is given to indicate if a surface receives solar gains. Surfaces that do not receive solar gains may include floors over crawl spaces and walls adjacent to garages. Only a yes/no response is required since the surface absorptance is a fixed input.
- *Reference Joint Appendix JA4 .* A reference to the construction assembly selected from Reference Joint Appendix JA4. This name may also be referenced from the thermal mass table to indicate an exterior mass wall.
- *Location/Comments.* User provided text describing where the surface is located or other relevant information.

## 3.7 Slabs-on-Grade

### 3.7.1 Inputs for Proposed Design and Standard Design

The reference method model for slabs-on-grade requires that the area of each concrete slab be divided into four separate classifications: perimeter carpeted, perimeter exposed, interior carpeted and interior exposed. The perimeter area is the area of the slab within 2 ft of the exterior wall. The interior slab area is the total slab area less the perimeter area. The default assumption is that 80 percent of the perimeter and interior slab areas are carpeted or covered by casework and 20 percent of the area is exposed.

***Proposed Design.*** The compliance software shall allow users to enter at least two different insulation and exposed surface perimeter conditions. Typically, compliance software has no practical limit on the number of perimeter conditions that may be entered. The surface area of the perimeter slab shall be calculated assuming a 2 ft perimeter width so the area is equal to 2 ft times the perimeter length. The interior slab area shall be the total slab area less the sum of the perimeter areas. The default condition for the proposed design is that 80 percent of each slab area is carpeted and 20 percent is exposed. Inputs other than the default require that carpet and exposed slab conditions be documented on the design drawings. In climate zone 16, slab edges adjacent to garages and unconditioned spaces may be considered to be insulated with R-7 insulation to a depth of 16 inches (the prescriptive requirement).

***Standard Design.*** The total perimeter area and interior area for the standard design is the same as in the proposed design. The standard design shall assume that 80 percent of each slab area is carpeted and 20 percent is exposed. For the standard design, the slab edge shall assume no insulation with the exception of climate zone 16, which assumes R7 to a depth of 16 inches.

### 3.7.2 Reporting Requirements on CF-1R

The perimeter of heated slabs shall be modeled in minimum compliance with the prescriptive requirements. Note, insulation conditions for heated slabs shall be reported in this table, even though slab losses for heated or radiant floors are not modeled since losses are taken into account when the system efficiency is determined. The CF-1R shall include the following information on slab areas and insulation conditions:

- *Slab Type.* The perimeter type. Possible types are slab edge, crawl space perimeter, etc. Names may be abbreviated.
- *Area (ft²).* The slab area in feet.
- *Surface Condition*. Indicate if the slab area is Exposed or Carpeted. If the default is accepted, then Default may be reported and it is not necessary to separate the slab area between Exposed and Carpeted.
- *Insulation R-Value.* The R-value of the installed insulation. "R-0" or "None" should be reported when no insulation is installed.
- *Insulation Depth (in).* The depth that the insulation extends below the top surface of the slab in inches.
- *Location/Comments.* User provided information on the location of the slab element or other relevant information.

### 3.7.3 Slab Calculations

Slab losses and gains shall be calculated separately for interior areas and perimeter areas as follows:

Equation R3-22
$$Q_{slab} = Q_{per} + Q_{core}$$

Equation R3-23
$$Q_{per} = \sum A_{per}\left[\alpha_1\left(T_{in} - T_{bi-weekly}\right) + \alpha_2\left(T_{in} - T_{monthly}\right) + \alpha_3\left(T_{in} - T_{annual}\right)\right]$$

Equation R3-24
$$Q_{core} = \sum A_{core}\left[\alpha_4\left(T_{in} - T_{monthly}\right) + \alpha_5\left(T_{in} - T_{annual}\right)\right]$$

Where:

$Q_{slab}$ = Hourly heat gain or loss from the total slab area (Btu/h)

$Q_{per}$ = Hourly heat gain or loss from the perimeter slab area (Btu/h)

$Q_{core}$ = Hourly heat gain or loss from the interior slab area (Btu/h)

$A_{per}$ = Perimeter slab area (ft²)

$A_{core}$ = Interior slab area (ft²)

$T_{in}$ = Interior space temperature (F)

$T_{bi\text{-}weekly}$ = Average outdoor temperature for the last two weeks (F)

$T_{monthly}$ = Average monthly temperature (F)

$T_{annual}$ = Average annual temperature (F)

$\alpha_{1\text{-}5}$ = Coefficients from (Btu/h-F-ft²)

*Table R3-25 – Slab Model Coefficients*

*Note that interpolation is allowed between the values published in the following table. Extrapolation is not allowed. Insulation depth is measured from the top surface of the slab.*

| | | | Perimeter | | | Interior | Core |
|---|---|---|---|---|---|---|---|
| | | | Bi-Weekly | Monthly | Annual | Monthly | Annual |
| Surface Condition | Insulation Depth | Insulation R-value | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | $\alpha_4$ | $\alpha_5$ |
| Carpeted | n.a. | R-0 | 0.1157 | 0.0664 | 0.0028 | 0.0517 | 0.0257 |
| | 8 in. | R-5 | 0.0529 | 0.0818 | 0.0084 | 0.0422 | 0.0297 |
| | | R-10 | 0.0443 | 0.0822 | 0.0105 | 0.0401 | 0.0306 |
| | 24 in. | R-5 | 0.0320 | 0.0869 | 0.0103 | 0.0390 | 0.0310 |
| | | R-10 | 0.0205 | 0.0874 | 0.0131 | 0.0363 | 0.0322 |
| | 48 in. | R-5 | 0.0241 | 0.0781 | 0.0147 | 0.0338 | 0.0329 |
| | | R-10 | 0.0205 | 0.0874 | 0.0131 | 0.0291 | 0.0350 |
| Exposed | n.a. | R-0 | 0.2042 | 0.0797 | 0.0014 | 0.0550 | 0.0258 |
| | 8 in. | R-5 | 0.0990 | 0.0950 | 0.0069 | 0.0453 | 0.0292 |
| | | R-10 | 0.0841 | 0.0953 | 0.0091 | 0.0434 | 0.0300 |
| | 24 in. | R-5 | 0.0639 | 0.1001 | 0.0087 | 0.0421 | 0.0304 |
| | | R-10 | 0.0441 | 0.1005 | 0.0116 | 0.0395 | 0.0314 |
| | 48 in. | R-5 | 0.0503 | 0.0891 | 0.0141 | 0.0364 | 0.0324 |
| | | R-10 | 0.0265 | 0.0840 | 0.0198 | 0.0318 | 0.0341 |

*Table R3-26 – Monthly and Annual Average Ground Temperatures*

| Climate Zone | Monthly Temperature ($T_{monthly}$) | | | | | | | | | | | | Annual Average ($T_{annual}$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D | |
| 1 | 52.2 | 51.5 | 51.4 | 51.8 | 53.1 | 54.5 | 55.6 | 56.4 | 56.4 | 55.8 | 54.7 | 53.4 | 53.9 |
| 2 | 53.3 | 51.5 | 51.4 | 52.2 | 55.6 | 58.9 | 61.8 | 63.6 | 63.8 | 62.3 | 59.5 | 56.3 | 57.5 |
| 3 | 55.1 | 54.1 | 54.0 | 54.5 | 56.5 | 58.5 | 60.3 | 61.4 | 61.5 | 60.6 | 58.9 | 56.9 | 57.7 |
| 4 | 55.5 | 54.0 | 53.9 | 54.6 | 57.5 | 60.3 | 62.8 | 64.3 | 64.5 | 63.2 | 60.8 | 58.0 | 59.1 |
| 5 | 55.7 | 54.8 | 54.7 | 55.2 | 56.9 | 58.7 | 60.2 | 61.1 | 61.2 | 60.4 | 59.0 | 57.3 | 57.9 |
| 6 | 59.1 | 58.1 | 58.0 | 58.5 | 60.4 | 62.4 | 64.0 | 65.1 | 65.2 | 64.3 | 62.7 | 60.8 | 61.6 |
| 7 | 60.1 | 59.1 | 59.0 | 59.5 | 61.5 | 63.4 | 65.2 | 66.2 | 66.3 | 65.5 | 63.8 | 61.9 | 62.6 |
| 8 | 60.0 | 58.8 | 58.7 | 59.2 | 61.6 | 63.9 | 66.0 | 67.3 | 67.4 | 66.3 | 64.3 | 62.1 | 63.0 |
| 9 | 60.5 | 59.1 | 59.0 | 59.7 | 62.2 | 64.8 | 67.1 | 68.5 | 68.6 | 67.5 | 65.3 | 62.8 | 63.8 |
| 10 | 59.4 | 57.6 | 57.4 | 58.3 | 61.8 | 65.2 | 68.2 | 70.1 | 70.2 | 68.7 | 65.8 | 62.4 | 63.8 |
| 11 | 54.9 | 52.4 | 52.2 | 53.4 | 58.2 | 63.0 | 67.2 | 69.8 | 70.0 | 67.9 | 63.8 | 59.2 | 61.0 |
| 12 | 54.6 | 52.5 | 52.3 | 53.3 | 57.3 | 61.3 | 64.8 | 67.0 | 67.2 | 65.4 | 62.0 | 58.1 | 59.7 |
| 13 | 57.5 | 54.7 | 54.5 | 55.8 | 61.0 | 66.2 | 70.6 | 73.5 | 73.7 | 71.4 | 67.0 | 62.0 | 64.0 |
| 14 | 54.2 | 51.2 | 51.0 | 52.4 | 58.2 | 63.9 | 68.8 | 72.0 | 72.2 | 69.7 | 64.8 | 59.3 | 61.5 |
| 15 | 66.8 | 64.0 | 63.8 | 65.1 | 70.4 | 75.8 | 80.4 | 83.3 | 83.6 | 81.2 | 76.7 | 71.5 | 73.6 |
| 16 | 44.4 | 41.8 | 41.6 | 42.8 | 47.7 | 52.6 | 56.8 | 59.5 | 59.7 | 57.5 | 53.4 | 48.7 | 50.5 |

## 3.8 Fenestration and Doors

### 3.8.1 Doors

***Proposed Design.*** Compliance software shall allow users to enter doors specifying the U-factor, area, and orientation. For doors with less than 50 percent glass area, the U-factor shall be based on either the NFRC values for the entire door including glass area, or a default value of 0.50 for the opaque portion. The glass area of the door, calculated as the sum of all glass surfaces plus two inches on all sides of the glass (to account for a frame), shall be modeled under the rules for fenestrations; the opaque area of the door shall be considered the total door area minus this calculated glass area. Doors with 50 percent or more glass area shall be modeled under the rules for fenestrations using the total area of the door.

***Standard Design.*** The standard design has 40 square feet of door area for each dwelling unit. All doors are assumed to face north and have a U-factor of 0.50. The net opaque wall area facing front is reduced by 40 $ft^2$ for each dwelling unit for the standard design run.

### 3.8.2 Fenestration Types and Areas

***Proposed Design.*** Compliance software shall allow users to enter individual fenestration or window types, the U-factor, SHGC, area, orientation, and tilt. Performance data (U-factors and SHGC) shall be NFRC values or taken from the CEC default tables. The default table for fenestration U-factors and SHGC, is included in §116 of the Standards.

***Standard Design.*** If the proposed design fenestration area is less than 20 percent of the conditioned floor area, the standard design fenestration area is set equal to the proposed design fenestration area. Otherwise, the standard design fenestration area is set equal to 20 percent of the conditioned floor area. The standard design fenestration area is distributed equally between the four main compass points—north, east, south and west. The standard design has no skylights. The net wall area on each orientation is reduced by the fenestration area (and door area) on each facade. The U-factor and SHGC performance factors for the standard design are taken from the Package D specification.

### 3.8.3 Overhangs and Sidefins

***Proposed Design.*** Compliance software shall allow users to enter a set of basic generic parameters for a description of an overhang and sidefin for each individual fenestration or window area entry. The basic parameters shall include *Fenestration Height, Overhang/Sidefin Length, and Overhang/Sidefin Height.* Compliance software user entries for overhangs may also include *Fenestration Width, Overhang Left Extension* and *Overhang Right Extension.* Compliance software user entries for sidefins may also include *Fin Left Extension* and *Fin Right Extension* for both left and right fins. Walls at right angles to windows shall be modeled as sidefins.

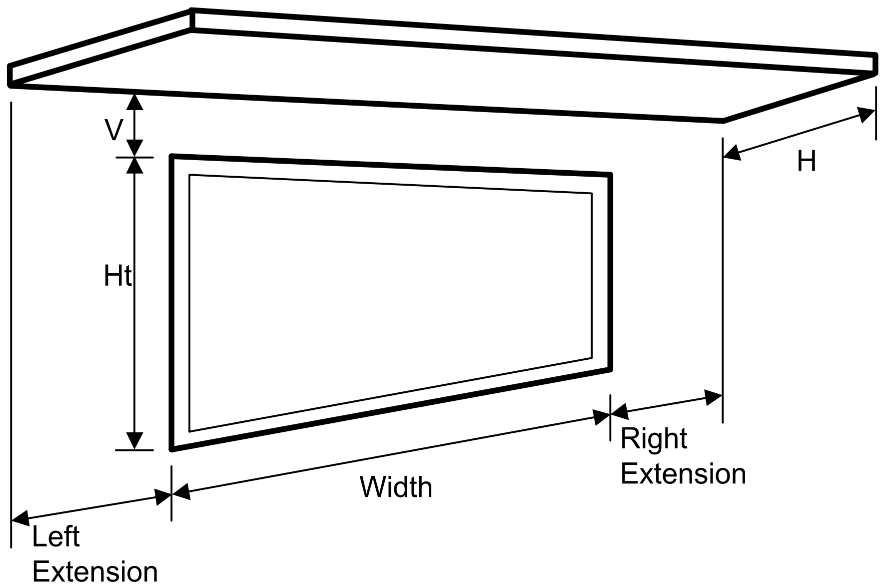



*Figure R3-4 – Overhang Dimensions*

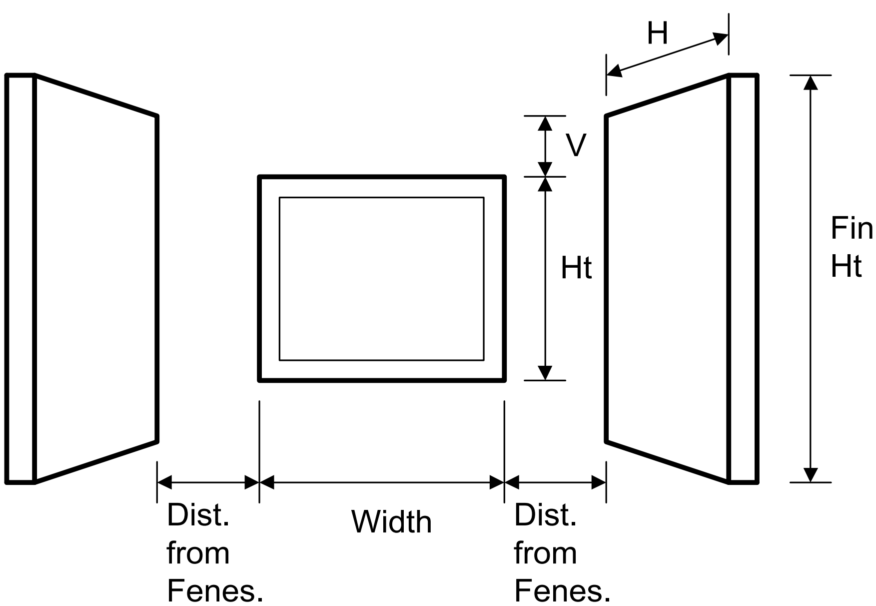


*Figure R3-5 – Side Fin Dimensions*

***Standard Design.*** The standard design does not have overhangs or side fins.

### 3.8.4 Interior Shading Devices

Internally, compliance software shall use two values to calculate solar heat gain through windows: $SHGC_{open}$ and $SHGC_{closed}$. $SHGC_{open}$ is the total solar heat gain coefficient of the fenestration and its exterior shading screen when the operable interior shading device is open. $SHGC_{closed}$ is the total solar heat gain coefficient when the interior shading device is closed. $SHGC_{open}$ is the setting that applies when the air conditioner is not operating, which typically is most of the 24-hour period, while $SHGC_{closed}$ applies only for periods when the air conditioner operates. The standard design and proposed design use the same SHGC values, shown in Table R3-27 below. $SHGC_{open}$ and $SHGC_{closed}$ are not user specified inputs.

The compliance software shall require the user to directly or indirectly specify $SHGC_{fen}$. The compliance software shall assign an interior shading device as listed in Table R3-27. The compliance software shall calculate the overall SHGC for the fenestration with shading devices as described below.

***Proposed and Standard Design***

For both the proposed design and the standard design*,* all windows are assumed to have draperies and skylights are assumed to have no interior shading.

*Table R3-27 – Allowed Interior Shading Devices and Recommended Descriptors*

| Recommended Descriptor | Interior Shading Attachment Reference | Solar Heat Gain Coefficient |
|---|---|---|
| Standard $SHGC_{int}$ (Closed) | Draperies - Default Interior Shade Closed | 0.68 (see Note 1) |
| Standard $SHGC_{int}$ (Open) | Draperies - Default Interior Shade Open | 1.00 |
| None (see Note 2) | No Interior Shading - Only for Skylights (Fenestration tilt <60 degrees) | 1.00 |

Note (general): No other interior shading devices or attachments are allowed credit for compliance with the building efficiency standards.

Note 1: Standard shading shall be assumed for all fenestration with a tilt of 60 degrees or greater from horizontal.

Note 2: *None* is the default interior shading device in the standard and proposed design for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights), i.e. *None* is not an interior shading option for ordinary vertical windows

### 3.8.5 Exterior Shading Screens

***Proposed Design.*** The compliance software shall require the user to either accept the default exterior shading device or select from a specific Commission-approved list of exterior shading devices for each fenestration element (see Table R3-28). The default choice for exterior shading device is *Standard,* which is assigned an average SHGC of 0.76. The compliance software compliance supplement or help system shall explicitly indicate that credit is allowed only for one exterior shading device.

***Standard Design.*** The standard design shall assume “Standard” which is bug screens.

*Table R3-28 – Allowed Exterior Shading Devices and Recommended Descriptors*

| Recommended Descriptor | Exterior Shading Device Reference | Solar Heat Gain Coefficient |
|---|---|---|
| Standard | Bug Screen or No Window Shading | 0.76 |
| WvnScrn | Woven SunScreen (SC<0.35) | 0.30 |
| LvrScrn | Louvered Sunscreen | 0.27 |
| LSASnScrn | LSA Sunscreen | 0.13 |
| RlDwnAwng | Roll-down Awning | 0.13 |
| RlDwnBlnds | Roll -down Blinds or Slats | 0.13 |
| None (see Note 1) | For skylights only - No exterior shading | 1.00 |

Note 1: None is the default for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights), i.e. None is not an exterior shading option for ordinary vertical windows.

### 3.8.6 Reporting Requirements for CF-1R

The term "fenestration" is used to refer to an assembly of components consisting of frame and glass or glazing materials. According to the standards (§101), fenestration includes "any transparent or translucent material plus frame, mullions, and dividers, in the envelope of a building." Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. Opaque doors are also included in this section since they represent "openings" in the gross wall or roof, just like window or skylights. This listing reports information about each fenestration or door. One row is to be included in the CF-1R listing for each unique condition. When compliance is for all orientations, the building facade orientation shall be reported as "*Any*".

This listing shall include information about each fenestration in the proposed building. Fenestrations include windows, skylights, and glazing in doors or other transparent or translucent surfaces. One row is included in the listing for each unique fenestration. Compliance software shall restrict users to select from a limited list of exterior shading devices and their associated solar heat gain coefficients (SHGCs), namely, those devices and SHGCs listed in the Table R3-28. Compliance software shall not allow users to enter custom shading devices nor account for differences in alternative color, density, or light transmission characteristics. Compliance software shall not allow for shading by other structures, objects or self shading other than those allowed by modeling fins and/or overhangs. Compliance software is required to calculate, but not report, $SHGC_{open}$ and $SHGC_{closed}$ using 2008 Standards calculation procedures and assumptions.

For buildings that are modeled as multiple thermal zones, the fenestrations shall be assigned to the zone and indicated with a header "Zone = <Zone Name>". Alternatively, an additional column may be added to the table to indicate the zone the building element is next to. The zone name used in the header should be the same as the name used in the table titled "Building Zone Information".

The CF-1R shall include the following information:

- *Fenestration #/Type/Orien.* The # is a unique number for each different fenestration surface entry. The type is Wdw (window) Dr (door) or Sky (skylight). The *Orien* (orientation) is the side of the building (front, left, right or back) followed by the nearest 45° compass point in parenthesis (N, NE, etc.). When compliance is for all orientations, only the side of the building may be reported (front, right, etc.)
- *Area ($ft^2$).* The area of the surface in square feet. This should be the rough frame opening.
- *U-factor*. The rated U-factor of the fenestration product, in Btu/h-$ft^2$-°F.

- *True Azimuth.* The true (or actual) azimuth of the glazed surface after adjustment for building rotation. The convention for describing the azimuth is standardized as discussed above under opaque surfaces.
- *Tilt.* The tilt of the glazed surface. Most windows will have a 90° tilt. Skylights typically have a tilt equal to the corresponding roof surface.
- *Fenestration SHGC:* The solar heat gain coefficient of the fenestration.
- *Exterior Shade Type/SHGC*. The type of exterior shading device and its solar heat gain coefficient from Table R3-7. "*Standard/0.76*" or " " shall appear when no special exterior shading device is included in the building plans. *Standard (partial bugscreen)* shading shall automatically be given for all window area without other forms of exterior shading devices. This shading assumes that a portion of the window area is covered by bugscreens. Other valid exterior shades include louvered screens (*LvrScrn*), woven sunscreen (*WvnScrn*), and Low Sun Angle Sunscreen (*LSASnScrn*). When used for compliance purposes, compliance software shall not allow or accept input for user-defined exterior shades.

***Overhangs***

Overhangs are a minimum compliance software capability and information shall be reported in the CF-1R as follows:

- *Fenestration #/Type/Orien.* This corresponds to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out frame opening for the fenestration (in feet) measured from the edge of the opening on one side to the edge of the opening on the other side.
- *Fenestration Ht.* The height of the rough-out frame opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Overhang Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the overhang.
- *Overhang Ht "V".* The vertical distance (in feet) from the top of the glazing frame to the bottom edge of the overhang at the distance "H" from the glazing surface. See Figure R3-4.
- *Overhang Left Extension.* The distance in feet from the left edge of the glazing frame to the left edge of the overhang. "Left" and "right" are established from an exterior view of the window.
- *Overhang Right Extension.* The distance in feet from the right edge of the glazing frame to the right edge of the overhang.

***Side Fins***

The CF-1R shall contain the following information on side fins:

- *Fenestration #/Type/Orien.* This shall correspond to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out opening for the fenestration (in feet) measured from the edge of the opening or frame on one side to the edge of the opening or frame on the other side.
- *Fenestration Ht.* The height of the rough-out opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Left Fin Dist from fenes*. The distance in feet from the nearest glazing frame edge to the fin. "Left" and "right" are established from an exterior view of the window.
- *Left Fin Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the fin.
- *Left Fin Ht "V"*. The vertical distance (in feet) from the top of the glazing frame to the top edge of the fin.
- *Left Fin, Fin Ht.* The height of the fin, in feet.

- *Right Fin.* Similar to Left Fin items.

***Solar Gain Targeting***
This information is only used for special cases, such as sunspaces (an optional modeling capability, and hence a Special Feature). Solar gains that enter conditioned spaces shall be targeted to the air, but when glazing surfaces enclose unconditioned spaces, such as sunspaces, the computer software shall target all but 25 percent of the solar gains from these surfaces to mass elements located within the unconditioned space. More than one row of targeting data may be included for each glazed surface. Unassigned solar gain is targeted to the air in the unconditioned space. The compliance software shall target 25 percent of the solar gain from any sunspace fenestration surface to high surface area lightweight mass or the air. The compliance software shall assign 50 percent of the solar gain to the slab floor of a sunspace. For sunspaces with limited floor area the ratio of targeting may be switched between the floor and lightweight mass surfaces.

Note that the use of any optional capability such as sunspace modeling shall be reported in the *Special Features Inspection Checklist*. In addition, solar gain targeting shall be separately reported in the *Special Features Inspection Checklist* so that the local enforcement agency can verify that these inputs are reasonable.

Information reported on the CF-1R shall include:

*Fenestration #/Type/Orien.* The fenestration surface which transmits solar gain to an interior unconditioned space thermal mass. This corresponds to an item in the fenestration surfaces table.

*Mass Name.* The name of the mass element to which solar gains are directed. The mass name corresponds to an item in the thermal mass table.

*Winter Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a heating mode.

*Summer Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a cooling mode.

### 3.8.7 Fenestration Calculations

***Solar Gain***
Solar gain through glazing shall be calculated using the methods documented in the *Algorithms and Assumptions Report, 1988*. However, solar gain through windows is reduced to 72 percent of the full solar gain and an algorithm is used to calculate the transmitted solar gain as a function of the angle of incidence on the glazing. The 0.72 multiplier is intended to compensate for exterior shading from landscaping, terrain, and adjacent buildings, as well as dirt and other window obstructions.

The equations used to calculate the solar heat gain through windows as a function of the angle of incidence are given below in the form of two multipliers: - $G_{dir}$ - the ratio of the solar heat gain to the space relative to direct beam insolation at normal incidence, and $G_{dif}$ - the ratio of solar heat gain to the space relative to the diffuse insolation on a horizontal surface. These ratios are unitless.

Equation R3-25
$$G_{dir} = SHGC_{fen} * Area * [fsunlit * CosI * P(CosI) + GrndFac]$$

and

Equation R3-26
$$G_{dif} = SHGC_{fen} * Area * DMSHGC * (vfSky + vfGrnd * GrndRf)$$

Where:

Equation R3-27 $$P(\text{CosI}) = C1 * \text{CosI} + C2 * \text{Cos}^2\text{I} + C3 * \text{Cos}^3\text{I} + C4 * \text{Cos}^4\text{I}$$

Equation R3-28 $$\text{GrndFac} = \text{vfGrnd} \times \text{CosG} \times \text{GrndRf} \times \text{DMSHGC}$$

*$SHGC_{fen}$* = Fenestration Solar Heat Gain Coefficient at normal beam incidence - primary user input [unitless]

*CosI* = The cosine of the angle of incidence of the direct beam insolation on the window. [unitless]

*CosG* = The cosine of the angle of incidence of the direct beam insolation on the ground. [unitless]

DMSHGC = Diffuse Multiplier for Solar Heat Gain Coefficient [unitless]

fsunlit = Fraction of the window sunlit by direct beam at this hour [unitless]

C1, ...,C4 = Polynomial coefficients for angular dependence (cosine of the angle of incidence) of solar heat gain - see Table R3-29.

vfSky = View factor of window to sky [unitless]

vfGrnd = View factor from window to ground [unitless]

GrndRf = Ground Reflectance [unitless] = 0.20

*Table R3-29 – Polynomial Coefficients for Angular Dependence*

| Glazing Type: | Single Pane | More Than One Pane |
|---|---|---|
| $SHGC_{fen}$ | 0.860 | 0.695 |
| C1 | 3.549794 | 1.881643 |
| C2 | -4.597536 | 1.014431 |
| C3 | 2.432124 | -4.009235- |
| C4 | -0.384382 | 2.113160 |
| DMSHGC | 0.905814 | 0.828777 |

***Interior and Exterior Shading***

Draperies are assumed to be closed only for hours when the air conditioner operates. To approximate this affect during transitions between periods of operation and non-operation, compliance software may assume that the internal device remains closed for the hour following an hour of air conditioner operation. As soon as that hour passes, the internal shading device shall be opened unless the air conditioner continues to run. The internal device shall be either totally open or totally closed for any given hour.

External sunscreens are assumed to be in place all year, whether the building is in a heating or cooling mode.

The shading effects of overhangs, side fins and other fixed shading devices are determined hourly, based on the altitude and azimuth of the sun for that hour, the orientation of the fenestration, and the relative geometry of the fenestration and the fixed shading devices.

***Solar Heat Gain Coefficients***

Compliance software use two solar heat gain coefficient values: “$SHGC_{open}$ “ and “$SHGC_{closed}$.” “$SHGC_{open}$ “ applies when the air conditioner is not in operation (off) and “$SHGC_{closed}$ “ applies when the air conditioner is in operation. The compliance software user shall not be allowed to enter values for $SHGC_{open}$ and $SHGC_{closed}$. The compliance software shall automatically determine these values from the user’s choices of exterior shading devices and from the assumption that vertical glazing has a drapery and non-vertical (skylight) glazing has no interior shading device.

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed solar heat gain coefficients are listed in Table R3-27 and Table R3-28.

The formula for combining solar heat gain coefficients is:

Equation R3-29

$$SHGC_{comb} = [(0.2875 \times SHGC_{max}) + 0.75] \times SHGC_{min}$$

Where:

$SHGC_{comb}$ = the combined solar heat gain coefficient for a fenestration component and an attachment in series.

$SHGC_{max}$ = the larger of $SHGC_{fen}$ and $SHGC_{dev}$

$SHGC_{min}$ = the smaller of $SHGC_{fen}$ and $SHGC_{dev}$

Where:

$SHGC_{fen}$ = the solar heat gain coefficient of the fenestration which includes the window glazing, transparent films and coatings, and the window framing, dividers and muntins,

$SHGC_{dev}$ = the solar heat gain coefficient of the interior or exterior shading device when used with a metal-framed, single pane window.

For $SHGC_{closed}$, the combination SHGC, $SHGC_{fen+int}$ , (the combined SHGC for the fenestration and the interior device) is calculated first and then the combination $SHGC_{fen+int+ext}$ is calculated to determine the overall $SHGC_{closed}$. $SHGC_{open}$ is determined from the combination of $SHGC_{fen}$ and $SHGC_{ext}$.

## 3.9 Inter-Zone Transfer

These reports are used only for proposed designs modeled as multiple thermal zones which is considered an exceptional condition and shall also be listed in the *Special Features Inspection Checklist* for the CF-1R. The *Special Features Inspection Checklist* shall direct plan and field checkers to the listings for *Interzone Surfaces* and *Interzone Ventilation*. The *Interzone Surfaces* listing describes the characteristics of the surfaces that separate the zones.

### 3.9.1 Inter-Zone Surfaces Reporting Requirements for CF-1R

For buildings that are modeled with more than two thermal zones, the inter-zone surfaces shall be grouped so that it is clear which zones are separated by the surfaces. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention. This information may also be provided through additional columns in a table.

The information for inter-zone surfaces included in the CF-1R shall include:

- *Surface Type.* The type of surface separating the zones. Possible types are window, wall, etc.
- *Area ($ft^2$).* The area of the surface in square feet that separates the zones.
- *U-val.* The U-factor of the surface.
- *Cavity Insul R-val.* The R-value of insulation installed in cavity of the framed construction assembly. This does not account for framing effects, drywall, air films, etc.
- *Sheath Insul R-val.* The total R-value of all insulation layers (layers R-2 or greater) not penetrated by framing. Excludes low R-value layers such as sheetrock, building paper, and air films.
- *Reference Joint Appendix JA4*. A reference to a selection from Reference Joint Appendix JA4.
- *Location/Comments.* User provided information on the location of the inter-zone surface or other relevant information.

### 3.9.2 Inter-Zone Ventilation Reporting Requirements for CF-1R

For buildings that are modeled with more than two thermal zones, the inter-zone ventilation items shall be grouped so that it is clear which zones are linked by the items. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention. This information may also be provided through additional columns in a table.

The information for inter-zone ventilation included in the CF-1R shall include:

- *Vent Type.* Possible types are natural and fan.
- *Inlet Area.* The area of the air inlet in square feet. This is used only when vent type is "natural".
- *Outlet Area.* The area of the air outlet in square feet. This is used only when vent type is "natural". The maximum area that may be modeled is 40 $ft^2$ of opening.
- *Height Diff.* The elevation difference between the inlet and the outlet in feet. This is used only when vent type is "natural". Default is two feet.
- *Fan Watts.* The fan power rating in watts. This is used only for sunspaces and only then when vent type is "fan". Fan energy may be reported as a separate line item or added to the TDV energy for heating.
- *Fan Flow (cfm).* The cubic feet per minute of air flow provided when the fan is operating. This is used only for sunspaces and then only when vent type is "fan".
- *Location/Comments*. User provided text describing where the item is located or other relevant information.

## 3.10 HVAC System Overview

This section describes the general procedures for heating and cooling systems in low-rise residential buildings. The HVAC system includes the cooling system, the heating system and in many cases an air distribution system. More detail on these sub-systems is provided in subsequent sections.

### 3.10.1 System Type

***Proposed Design***

Compliance software shall require the user to enter data to characterize the HVAC systems used to heat and/or cool the proposed design. See subsequent sections for more detail of the required information. Compliance software shall be able to distinguish what fuel is being used to heat the building and what fuel is used to cool the dwelling. This may be based on direct user input or indirectly determined from the user's selection of HVAC equipment types. Compliance software shall require the user to enter the type of distribution system that is used in the proposed design.

***Standard Design***

The standard heating and cooling system is defined in Table R3-30 and Table R3-31. For most proposed designs, the standard design system is a split system air conditioner and gas furnace or a split system heat pump depending on the type of fuel that is used for heating in the proposed design. The standard design system shall have the efficiency and features required by prescriptive Package D.

The standard design shall have air distribution ducts. If the proposed design has an attic, then the standard design shall assume that the ducts are located in the attic. If the proposed design does not have an attic, but has a crawlspace or basement, the standard design shall assume that the ducts are located in the crawlspace or basement. If the proposed design has neither an attic nor a crawlspace/basement, the air distribution ducts shall be assumed to be located indoors.

*Table R3-30 – Summary of Standard Design HVAC System*

| Proposed Design | | Standard Design | | |
|---|---|---|---|---|
| **Heating System** | **Cooling System** | **Heating System** | **Cooling System** | **Detailed Specifications** |
| Through-the-wall heat pump | | Same equipment as proposed design with no air distribution ducts | | Equipment efficiency determined by CEC Appliance Efficiency Regulations |
| Gas wall furnace with our without ducts and/or circulation fan | Any | Same equipment as proposed design with no air distribution ducts | Split system AC with air distribution ducts | |
| Any other electric heat including electric resistance, water source heat pump, etc. | Any | Split system heat pump with air distribution ducts<br>For multi-family buildings, air distribution duct on configuration are the same as those in the proposed design. | | SEER per Package D<br>Verified refrigerant charge (prescriptive requirement)<br>No credit for sizing<br>No credit for *cooling coil airflow*<br>No credit for reduced fan power |
| All other gas heating | Any | Split system air conditioner with gas furnace and air distribution ducts.<br>For multi-family buildings, air distribution duct configurations are the same as those in the proposed design. | | |
| Note: The standard design cooling system is also used for the proposed design if the proposed design has no air conditioning | | | | |

*Table R3-31 – Summary of Standard Design Air Distribution System*

*This table is applicable only when the standard design system has air distribution ducts as determined in Table R3-30. For multi-family buildings, air distribution duct configurations are the same as those in the proposed design.*

| | Standard Design | |
|---|---|---|
| **Configuration of the Proposed Design** | **Standard Design Duct Location** | **Detailed Specifications** |
| Attic over the dwelling unit | Ducts and air handler located in the attic | Ducts sealed (prescriptive requirement)<br>No credit for reduced duct area<br>No credit for increased duct R-value or buried ducts<br>No credit for low-leakage air handler |
| No attic but crawlspace or basement | Ducts and air handler located in the crawlspace or basement | |
| No attic, crawlspace or basement | Ducts and air handler located indoors | |

### 3.10.2 Multiple System Types

**Proposed Design.** For proposed designs using more than one system type, equipment type or fuel type, and the types do not serve the same floor area, the user shall either zone the building or enter the floor area served by each system type. The compliance software shall weight the load to each type by zone or floor area. Alternatively, the software may specifically calculate the load for each zone.

For floor areas served by more than one heating system, equipment, or fuel type, the user of the program shall specify the equipment that serves each space, unless the Exception to §151(b)3 applies.

For floor areas served by more than one cooling system, equipment, or fuel type, the user of the program shall specify which system, equipment, and fuel type satisfies the cooling loads.

**Standard Design**. The standard design system shall be that specified in Table R3-30 and detailed in later sections of this chapter.

### 3.10.3 Multiple Systems Servings Same Area

If a space or a zone is served by more than one heating system, compliance shall be demonstrated with the most TDV energy consuming system serving the space or the zone. For spaces or zones that are served by electric resistance heat in addition to other heating systems, the electric resistance heat shall be deemed to be the most TDV energy consuming system. See eligibility criteria in Reference Residential Appendix RA-4 for installation requirements for exceptions.

### 3.10.4 No Cooling

***Proposed Design***: When the proposed design has no air conditioning system, the proposed design is required to model the standard design cooling system defined in Table R3-30. Since the proposed design system is identical to the standard design system, there is no penalty or credit.

***Standard Design***: The standard design system is defined in Table R3-30

### 3.10.5 Reporting Requirements on CF-1R

Information is provided on the type of heating and cooling systems proposed for each zone of the building. Data in the table is organized to accommodate any type of heating or cooling system so some of the information is not applicable for all system types. When the information is not applicable, "na" is reported. Data in this table should be organized first by thermal zones and then by heating and cooling systems. Note that the thermostat type is reported under "Building Zone Information" described above.

For buildings that are modeled as multiple thermal zones, the items shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

Information on the CF-1R may include:

- *Equipment Type*. The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R3-32 and Table R3-33. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows. If Gas Absorption equipment is specified, it shall be reported in the *Special Features Inspection Checklist* on the CF-1R forms printed by the compliance software.
- *Minimum Equipment Efficiency.* The minimum equipment efficiency needed for compliance. The applicable efficiency units should also be reported, for instance AFUE for furnaces and boilers, HSPF for electric heating equipment, and SEER for heat pumps (cooling) and central air conditioners. In the case of combined hydronic heating, the name of the water heating system shall be identified. If the equipment type is Electric (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which use a maximum HSPF of 3.55. EER indicates that the energy efficiency ratio at ARI test conditions has been specified and will be verified according to the procedure in Reference Residential Appendix RA3 - Procedures for Verifying the Presence of a Charge Indicator Display or High Energy Efficiency Ratio Equipment according to Reference Residential Appendix RA3.4, and shall also be reported in the *Hers Required Verification* listings.
- *Verified Refrigerant Charge.* The choices are ‘Yes’ or ‘No’ where ‘Yes’ means that either refrigerant charge is verified or a charge indicator display is installed and verified. Refrigerant charge credit is applicable to split system air conditioners and heat pumps only. The two equipment types that can comply by verifying refrigerant charge are SplitAirCond, and SplitHeatPump.
- *Verified Cooling Coil Airflow.* Yes indicates that the air flow will be tested and verified according to the procedure in Reference Residential Appendix RA3 - Forced Air System Fan Flow and Air Handler Fan Watt Draw section RA3.3 and shall also be reported in the *Hers Required Verification* listings. No indicates that the default air flow is used. The *cooling coil airflow* can be verified either at the Prescriptive level as required by Package D in cooling zones or at some higher CFM/ton (nominal) specified by the builder.

- *Verified Fan Energy*. A number such as 0.58 indicates the user specified air handler fan watt draw per cfm that will be tested and verified according to the procedure in Reference Residential Appendix RA3 - Forced Air System Fan Flow and Air Handler Fan Watt Draw section RA3.3 and shall also be reported in the *Hers Required Verification* listings No indicates that the default fan watt draw is used.
- *Verified Maximum Cooling Capacity*. Yes indicates that the proposed design will have an air conditioner sized according to the compliance software calculations in Reference Residential Appendix RA1 – HVAC Sizing section RA1-3 and this shall also be reported in the *Hers Required Verification* listings. Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, and sealed and tested new duct systems. No indicates that no sizing credit is being taken.

*Table R3-32 – HVAC Heating Equipment Descriptors*

| Recommended Descriptor | Heating Equipment Reference |
|---|---|
| CntrlFurnace | Gas- or oil-fired central furnaces, propane furnaces or heating equipment considered equivalent to a gas-fired central furnace, such as wood stoves that qualify for the wood heat exceptional method. Gas fan-type central furnaces have a minimum AFUE=78%. Distribution can be gravity flow or use any of the ducted systems. [Efficiency Metric: AFUE] |
| Heater | Non-central gas- or oil-fired space heaters, such as wall heaters floor heaters or unit heater. Equipment has varying efficiency requirements. Distribution is ductless and may be gravity flow or fan-forced.. Can refer to floor furnaces and wall heaters within the description field for CntrlFurnaces, [Efficiency Metric: AFUE] |
| Boiler | Gas or oil boilers. Distribution systems can be Radiant, Baseboard or any of the ducted systems. Boiler may be specified for dedicated hydronic systems. Systems in which the boiler provides space heating and fires an indirect gas water heater (IndGas) may be listed as Boiler/CombHydro Boiler and shall be listed under “Equipment Type” in the HVAC Systems listing. [Efficiency Metric: AFUE] |
| SplitHeatPump | Heating side of central split system heat pump heating systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: HSPF] |
| PkgHeatPump | Heating side of central packaged heat pump systems. Central packaged heat pumps are heat pumps in which the blower, coils and compressor are contained in a single package, powered by single phase electric current, air cooled, rated below 65,000 Btuh. Distribution system shall be one of the ducted systems. [Efficiency Metric: HSPF] |
| LrgPkgHeatPump | Heating side of large packaged units rated at or above 65,000 Btu/hr (heating mode). Distribution system shall be one of the ducted systems. These include water source and ground source heat pumps. [Efficiency Metric: COP] |
| RoomHeatPump | Heating side of non-central room air conditioning systems. These include small ductless split system heat pump units and packaged terminal (commonly called “through-the-wall”) units. Distribution system shall be Ductnone. [Efficiency Metric: COP] |
| Electric | All electric heating systems other than space conditioning heat pumps. Included are electric resistance heaters, electric boilers and storage water heat pumps (air-water) (StoHP). Distribution system can be Radiant, Baseboard or any of the ducted systems. [Efficiency Metric: HSPF] |
| CombHydro | Water heating system can be storage gas (StoGas, LgStoGas), storage electric (StoElec) or heat pump water heaters (StoHP). Distribution systems can be Radiant, Baseboard, or any of the ducted systems and can be used with any of the terminal units (FanCoil, RadiantFlr, Baseboard, and FanConv). |

*Table R3-33 – HVAC Cooling Equipment Descriptors*

| Recommended Descriptor | Cooling Equipment Reference |
|---|---|
| NoCooling | Entered when the proposed building is not air conditioned or when cooling is optional (to be installed at some future date). Both the standard design equivalent building and the proposed design use the same default system (refer to sections 3.9.4. [Efficiency Metric: SEER] |
| SplitAirCond | Split air conditioning systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER] |
| PkgAirCond | Central packaged air conditioning systems less than 65,000 Btuh cooling capacity. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER] |
| LrgPkgAirCond | Large packaged air conditioning systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER] |
| RoomAirCond | Non-central room air conditioning cooling systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called through-the-wall) air conditioning units. Distribution system shall be Ductnone. [Efficiency Metric: EER] |
| SplitHeatPump | Cooling side of split heat pump systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER<65,000 Btu/hr EER>65,000 Btu/hr] |
| PkgHeatPump | Cooling side of central single-packaged heat pump systems with a cooling capacity less than 65,000 Btuh. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER] |
| LrgPkgHeatPump | Cooling side of large packaged heat pump systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER] |
| GasCooling | Gas absorption cooling. Three descriptors, COP95, the rated COP for the gas portion, CAP95, the rated capacity, and PPC, the parasitic electric energy at rated conditions in Watts. |
| RoomHeatPump | Cooling side of non-central, room heat pump systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called ”through-the-wall”) units. Distribution system shall be Ductnone. [Efficiency Metric: EER] |
| EvapDirect | Direct evaporative cooling systems. Assume minimal efficiency air conditioner. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER] |
| EvapIndirDirect | Indirect-direct evaporative cooling systems. Assume energy efficiency ratio of 13 EER. |
| EvapIndirect | Indirect evaporative cooling systems. Assume energy efficiency ratio (EER) or 13. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: EER] |
| Evap/CC | Evapratively Cooled Condensers A split mechanical system, with a water-cooled condenser coil. (Efficiency metric: EER) |
| IceSAC | Ice Storage Air Conditioning. Split air conditioner condensing coil in combination with ice storage. (Efficiency metric ia system performance tables) |

*Table R3-34 – HVAC Distribution Type and Location Descriptors*

| Recommended Descriptors | HVAC Distribution Type and Location Reference |
|---|---|
| Air Distribution Systems | Fan-powered, ducted distribution systems that can be used with most heating or cooling systems. When ducted systems are used with furnaces, boilers, or combined hydronic/water heating systems the electricity used by the fan shall be calculated using the methods described later in this manual. R-value shall be specified in "Duct R-value" column when a ducted system is specified |
| DuctsAttic | Ducts located overhead in the unconditioned attic space |
| DuctsCrawl | Ducts located underfloor in the unconditioned crawl space |
| DuctsCVC | Ducts located underfloor in a controlled ventilation crawl space |
| DuctsGarage | Ducts located in an unconditioned garage space. |
| DuctsBasemt | Ducts located in an unconditioned basement space |
| DuctsInEx12 | Ducts located within the conditioned floor space except for less than 12 lineal feet of duct, typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space. |
| DuctsInAll | HVAC unit or systems with all HVAC ducts located within the conditioned floor space. Location of ducts in conditioned space eliminates conduction losses but does not change losses due to leakage. Leakage from either ducts that are not tested for leakage or from sealed ducts are modeled as leakage to outside the conditioned space. |
| DuctsNone | Air distribution systems without ducts such as ductless split system air conditioners and heat pumps, window air conditioners, through-the-wall heat pumps, etc. |
| DuctsOutdoor | Ducts located in exposed locations outdoors. |
| Ductless Systems | Ductless radiant or warm/cold air systems using fan-forced or natural air convection and hydronic systems relying upon circulation pumps and fan-forced or natural air convection, and |
| Furnaces | Heating equipment such as wall and floor furnaces |
| Radiant | Radiant electric panels or fanless systems used with a boiler, electric or heat pump water heater, or combined hydronic heating equipment. |
| LowLICod | Verified Low Leakage Ducts in Conditioned Space - defined as duct systems for which air leakage to outside conditions is equal to or less than 25 cfm when measured in accordance with Reference Residential Appendix RA3.1.4.3.9, |
| LowLkAH | Low Leakage Air Handlers – for factory sealed air handler unit tested by the manufacturer and certified to the Commission to have achieved a 2 percent or less leakage rate at 1-inch water gage – as prescribed in Reference Residential Appendix RA3.1.4.3.10. |
| Baseboard | Electric baseboards or hydronic baseboard finned-tube natural convection systems |

## 3.11 *Heating Systems*

### 3.11.1 Proposed Design

Compliance software shall be able to model the basic types of heating equipment and the efficiency metrics listed in the Appliance Efficiency Regulations, except for combined hydronic space and water heating systems, which is an optional modeling capability. Compliance software shall require the user to enter the basic information to model the energy use of these pieces of equipment. At a minimum this includes some type of seasonal efficiency for heating and information on whether or not the HVAC system has ducts and the performance characteristics of those ducts. With gas heating systems, the compliance software shall require the user to identify if the gas heating system is ducted or non-ducted. The gas heating system type shall also be identified: central gas furnace or non-central gas furnace system. If the system is a non-ducted non-central gas furnace system, the compliance software shall require the user to select the type and size of the equipment from the Appliance Efficiency Regulations for Gas Fired Wall Furnaces, Floor Furnaces and Room Heaters, where the system size, as a default, may be determined as 34 Btu/hour per square foot of conditioned floor area.

### 3.11.2 Standard Design

When electricity is used for heating, the heating equipment for the standard design shall be an electric split system heat pump with a Heating Seasonal Performance Factor (HSPF) meeting the Appliance Efficiency Regulations requirements for split systems. When electricity is not used for heating, the equipment used in the standard design building shall be a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) meeting the Appliance Efficiency Regulations minimum efficiency for central systems. When a proposed design uses both electric and non-electric heat, the standard design shall be a gas furnace

### 3.11.3 Heating System Calculations

Compliance Software programs shall use the following inputs and algorithms to calculate heating energy use.

Equation R3-30

$$NetHLoad_{hr} = \frac{HLoad_{hr}}{\eta_{seasonal,dist}} + Qneed$$

Where:

$NetHLoad_{hr}$ = The net heating load that the heating equipment sees. This accounts for air distribution duct losses. If there are no air distribution ducts then NetHLoad = $HLoad_{hr}$.

$HLoad_{hr}$ = Space heating load for the hour from the compliance software simulation for portions of the system with ducts in unconditioned zones not modeled with UZM, Btu.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the heating season from Equation R3-54 for portions of the system with ducts in unconditioned zones not modeled with UZM.

Qneed = The required heating system output (including duct losses and adjustments) calculated by UZM

***Furnaces and Boilers***

Once the net heating load is known, heating energy for gas fired equipment is calculated each hour by dividing the net heating load for that hour by the AFUE. There are no hourly adjustments for part load conditions or temperature dependencies.

Equation R3-31

$$FurnFuel_{hr} = \frac{NetHLoad_{hr}}{AFUE_{eff}}$$

where

$AFUE_{Eff}$ = Annual fuel utilization efficiency. This is a constant for the year.

$NetLoad_{hr}$ = The hourly load calculated from Equation R3-30 and using algorithms similar to those described in this chapter.

***Heat Pump and Electric Furnace***

The compliance software has a heat pump model which takes account of outdoor temperature. The model uses the following inputs.

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = Defaults to 1/(0.4*HSPF)

Cap47 = Rated compressor heating capacity at 47 F. Defaults to heating load generated by program using a method similar to those specified in Reference Residential Appendix RA1.

If the heat pump compressor is not large enough to meet the load in the hour, the compliance software assumes there is sufficient backup resistance heat. In the case of an electric furnace, the load shall be met entirely by resistance heat. For heat pumps, the compliance software shall calculate the hourly heating electricity consumption in kWh using the DOE2.1E heat pump algorithm.

For equipment without an HSPF rating, the HSPF may be calculated as:

Equation R3-32

$$\text{HSPF} = (3.2 \text{ x COP}) - 2.4$$

***Air Distribution Fans***

The test method for calculating AFUE ignores electric energy used by air distribution fans and the contribution of the fan motor input to the heating output. With TDV, electric energy shall be calculated separately from gas energy. For forced-air heating systems, compliance software programs shall calculate fan energy (Watts per Btu output) as

Equation R3-33

$$\text{Fan}_{\text{wh,heat}} = \text{W/BtuHeat} \times \text{NetHLoad}_{\text{hr}}$$

Equation R3-34

$$\text{W/BtuHeat} = \frac{\text{CFM Heat} \times \text{W/CFM Heat}}{\text{Cap Heat}}$$

Where:

$\text{Fan}_{\text{wh,heat}}$ = Fan consumption for an hour of the simulation

$\text{NetHLoad}_{\text{hr}}$ = Heating load for an hour of the simulation (see Equation R3-30)

W/CFM Heat = 0.88 * W/CFM Cool

CFM Heat = 0.93 CFM Cool

Cap Heat = 1.08 Btu/CFM-$^{o}$F * CFM Heat * 40$^{o}$F

## 3.12 *Cooling Systems*

### 3.12.1 Proposed Design

Compliance software shall be able to model the basic types of cooling equipment and the efficiency metrics listed in Table R3-33. Compliance software shall require the user to enter the basic information to model the energy use of these pieces of equipment. At a minimum the cooling distribution system shall be described as explained in a subsequent section of this manual including an indication of whether the cooling system is ducted or non-ducted and whether it is central or non-central and the type of equipment as identified in the Appliance Efficiency Regulations. If the cooling system is non-ducted, the compliance software shall require the user to select the type and capacity of the equipment from the Appliance Efficiency Regulations for Room Air Conditioners, Room Air Conditioning Heat Pumps, Package Terminal Air Conditioners and Package Terminal Heat Pumps.

### 3.12.2 Standard Design

The cooling system for the standard design building shall be a split system air conditioner or heat pump meeting the minimum Package D prescriptive requirements. The standard design system shall assume verified refrigerant charge, unverified air flow and no credit for sizing. See Table R3-30.

### 3.12.3 Refrigerant Charge or Charge Indicator Display

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. Field measurements indicate that typical California air conditioning systems are installed without proper charge, and for computer software energy calculations, the $F_{chg}$ factor is set to 0.90 to account for the impact of this condition. If the system has a charge indicator light (CID) that is installed, certified and verified according to the procedures of Reference Residential Appendix RA3 the $F_{chg}$ factor may be set to 0.96 for computer software energy calculations. See Equation R3-40 and Equation R3-41. Credit for refrigerant charge is only available for split system air conditioners and heat pumps.

***Proposed Design.*** The compliance software shall allow the user to indicate if split system air conditioners or heat pumps have diagnostically tested refrigerant charge or a field verified charge indicator display. This applies only to split system air conditioners and heat pumps. It does not apply to package air conditioners and heat pumps. These features require field verification or diagnostic testing and shall be reported in the *Hers Required Verification* listings on the CF-1R. Details on refrigerant charge measurement are discussed in Reference Residential Appendix RA3. Information on the requirements for charge indicator displays is located in Reference Joint Appendix JA6

***Standard Design.*** The standard design building shall be modeled with either diagnostically tested refrigerant charge or a field verified charge indicator display if required by Package D.

### 3.12.4 Maximum Cooling Capacity Credit

Correctly sized systems installed so they operate at full capacity are desirable because oversized cooling systems have been shown to result in larger peak electrical demands. Systems which have the combination of verified adequate airflow, sealed and tested new duct systems and also meet the requirements for Maximum Cooling Capacity for compliance softwareCredit may take credit in computer software calculations by setting the Fsize factor (see Equation R3-40 and Equation R3-41) to 0.95. For all other systems the Fsize factor shall be set to 1.0.

The Design Cooling Capacity shall be calculated using the procedure in Reference Residential Appendix RA1. The Maximum Cooling Capacity for compliance software Credit shall be calculated using the procedure in Reference Residential Appendix RA1. For compliance software energy calculations all loads are assumed to be met in the hour they occur regardless of the compressor size.

***Proposed Design.*** The compliance software shall allow the user to specify that the maximum cooling capacity determined using Reference Residential Appendix RA1 will be met. Compliance credit may be taken if the installed cooling capacity is less than or equal to the maximum cooling capacity, and if the system will have verified cooling coil airflow, and sealed and tested ducts. The compliance software shall not allow compliance credit to be taken for cooling capacity less than the maximum cooling capacity if any of these other features are not also specified for compliance. If this alternative is not used, the proposed design shall make no adjustment to the duct efficiency of the standard design for this feature. If compliance credit is taken for this alternative, it must be reported in the *Hers Required Verification* listings of the CF-1R along with the other measures that are required to take the credit.

***Standard Design.*** The standard design shall not take credit for correct sizing.

***Reporting Requirements on CF-1R***

This listing is always provided, however, the column for maximum cooling capacity is completed only when compliance credit is specified for verified cooling capacity as specified in Section 3.11.4 . Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, sealed and tested new duct systems. The design loads are calculated in accordance with Reference Residential Appendix RA1, section RA1-2.14 using the 1.0 percent Summer Design Dry Bulb and 1.0 percent Summer Design Wet Bulb outdoor design temperature data from Reference Joint Appendix JA2, Table 2.3 and inside design temperatures from §150(h). Heating system sizing is not required, but may be included at the compliance software vendors option.

Information to be provided on the CF-1R may include:

*Equipment Type*. The type of heating or cooling equipment.

*Sizing Location*. Location for sizing calculation from list in the Reference Joint Appendix JA2 Table 2-2.

*Cooling Outside Design Temperature (°F).* As defined for the sizing location in the Reference Joint Appendix JA2 Table 2-3.

*Cooling Outside Daily Range (°F).* As defined for the sizing location in the Reference Joint Appendix JA2 Table 2-3.

*Inside Design Temperature (°F).* As required in §150(h).

*Sensible Design Cooling Load (Btu/hr).* Total sensible cooling load at design conditions including duct losses. Calculated in accordance with Reference Residential Appendix RA1 Section RA1.2.15.

*Design Cooling Capacity* at ARI Conditions (Btu/hr). Rated capacity needed to meet the Sensible Design Cooling Load calculated in accordance with Reference Residential Appendix RA1 Section RA1.2.16.

*Maximum Allowable Cooling Capacity* for compliance software Credit for the building. Maximum total rated system cooling capacity that may be installed if claiming the sizing credit. For buildings with more than one system the sum of the sizes of the equipment installed must be less than the total Allowable Cooling Capacity for compliance software Credit for the building calculated in accordance with Reference Residential Appendix RA1 section RA1.3.1.

### 3.12.5 Central System Cooling Coil Airflow

***Proposed Design.*** The default for the proposed design assumes inadequate airflow. However, compliance credit may be taken if verified cooling coil airflow is specified and diagnostically tested using the procedures of Reference Residential Appendix RA3. Verified cooling coil airflow shall be reported in the *Hers Required Verification* listings of the CF-1R.

***Standard Design.*** The standard design shall assume prescriptive cooling coil airflow when Cooling Airflow and Watt Draw is required by Package D. When cooling airflow and watt draw is not required by Package D, the standard design shall assume 300 cfm per ton.

***Cooling Coil Airflow CFM/tonThe efficiency of an air conditioning system is affected by airflow across the cooling (evaporator) coil. Cooling coil airflow is specified in cubic feet per minute per nominal ton***

***(cfm/ton) as specified by the manufacturer. Cooling airflow is the flow achieved under normal air conditioning operation.***

### 3.12.6 Central System Cooling Coil Airflow Verification

Adequate airflow is required to allow air conditioning systems to operate at their full efficiency and capacity. Computer software calculations account for airflow by setting the $F_{air}$ factor (see Equation R3-40 and Equation R3-41). If values other than the default are used, airflow shall be tested, certified and verified using the procedures of Reference Residential Appendix RA3 section 3.2.2.7.

The installer shall measure and certify the airflow. The certified HERS rater shall diagnostically test and verify the airflow rate.

***Sufficient Flow for Valid Standard Refrigerant Charge Test***
Sufficient airflow is also required to ensure that the refrigerant charge procedure in Reference Residential Appendix RA3.2 will produce valid results. Verifying sufficient airflow is a prerequisite for the refrigerant charge test. Either the flow measurement procedure or the temperature split test of Reference Residential Appendix RA3 may be used to demonstrate Sufficient Airflow.

***Air Handler Fan Flow***
Table R3-35 shows the criteria used for calculations and measurement of airflow for cooling systems.

*Table R3-35 – Airflow Criteria*

*Note: All airflows are for the fan set at the speed used for air conditioning.*

| Test and Condition | Cooling airflow (Wet Coil) | |
|---|---|---|
| Default Cooling Airflow | 300 cfm/ton | |
| Flow needed for a valid refrigerant charge test | 300 cfm/ton (See Note 1) | |
| Prescriptive cooling coil airflow | 350cfm/ton | |
| Verified cooling coil airflow | >350 cfm/ton | Specified by compliance softwareuser |

Note 1. In lieu of airflow measurements, the system can pass the temperature split test documented in Reference Residential Appendix RA3.2.2.7.

### 3.12.7 Fan Energy

***Proposed Design.*** The compliance software shall allow the user to specify whether or not the proposed design will take credit for reduced fan watts. The credit for reduced fan watts shall be reported in the *Special Features Inspection Checklist* on the CF-1R. The proposed design default shall be 0.80 W/cfm. Lower numbers may be used when field verified.

***Standard Design.*** The standard design shall be modeled with 0.58 W/cfm.

For systems with low fan watts and prescriptive cooling coil airflow or greater as verified using the procedures of Reference Residential Appendix RA3, credit may be taken for reduced fan energy in computer software calculations. This credit is applied if the actual installed fan watts/cfm are less than or equal to the standard design value of 0.58 W/cfm. The watt draw and airflow must be certified by the installer and verified by a HERS rater using the procedure in Reference Residential Appendix RA3. Fan watts and adequate airflow must be measured simultaneously. The air handler airflow measured simultaneously must meet or exceed the prescriptive cooling coil airflow or greater criteria.

### 3.12.8 Cooling System Calculations

Air conditioning systems shall be sized, installed, tested and modeled according to the provisions of this section.

***Cooling System Energy***

The compliance softwarecalculates the hourly cooling electricity consumption in kWh using Equation R3-35. In this equation, the energy for the air handler fan and the electric compressor or parasitic power for the outdoor unit of a gas absorption air conditioner are combined. The compliance software\ calculates the hourly cooling gas consumption in therms using Equation 3-36.

Equation R3-35

$$AC_{kWh} = \frac{Fan_{Wh} + Comp_{Wh} + PPC_{Wh}}{1{,}000}$$

Equation 3-36

$$AC_{therms} = \frac{Absorption_{Btu}}{100{,}000}$$

Where:

$AC_{kWh}$= Air conditioner kWh of electricity consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

$Fan_{Wh}$= Fan watt-hours for a particular hour of the simulation. See Equation R3-49.

$Comp_{Wh}$= Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R3-37.

$PPC_{Wh=}$ Parasitic Power watt-hours for gas absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R3-44.

$AC_{therms}$= Air conditioner therms of gas consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

$Absorption_{Btu=}$ Gas consumption in Btu for absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R3-43.

*Electric Compressor Systems*

The reference method calculates the energy for electrically driven compressors using the algorithms described in this section.

Compressor watt-hours for a particular hour of the simulation shall be calculated using Equation R3-37.

Equation R3-37

$$Comp_{wh} = \frac{CLoad_{hr}}{\eta_{seasonal,dist} \times CE_t} + \frac{Fan_{wh} \times 3.413}{CE_t} + Qneed/CE_t$$

Where:

$CLoad_{hr}$ = Space sensible cooling load for the hour from the compliance software simulation for portions of the system with ducts in unconditioned zones not modeled with UZM (Btu).

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R3-54 for portions of the system with ducts in unconditioned zones not modeled with UZM.

$Fan_{wh}$ = Fan watts this hour. This is calculated using Equation R3-49.

$CE_t$ = Sensible energy efficiency at a particular outdoor dry bulb temperature. This is calculated using Equation R3-38 below.

Qneed = The required heating system output (including duct losses and adjustments) calculated by UZM

Equation R3-38
$$CE_t = EER_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

Where:

$DB_t$ = Outdoor dry bulb temperature taken from the CEC weather file in Reference Joint Appendix JA2

$EER_t$ = Energy efficiency ratio at a particular dry bulb temperature. $EER_t$ is calculated using Equation R3-39 below.

Equation R3-39

when

| | |
|---|---|
| $DB_t$ < 82 ºF | $EER_t = SEER_{nf}$ |
| $82 \leq DB_t < 95$ | $EER_t = SEER_{nf} + ((DB_t - 82)*(EER_{nf} - SEER_{nf}) / 13)$ |
| $DB_t \geq 95$ | $EER_t = EER_{nf} - (DB_t - 95) * 0.12$ |

Where:

$SEER_{nf}$ = Seasonal energy efficiency ratio without distribution fan consumption ("nf" = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R3-40.

$EER_{nf}$ = Energy efficiency ratio at ARI conditions without distribution fan consumption ("nf" = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R3-41.

Equation R3-40
$$SEER_{nf} = (1.0452 \times SEER + 0.0115 \times SEER^2 + 0.000251 \times SEER^3) \times F_{chg} \times F_{air} \times F_{size}$$

Equation R3-41
$$EER_{nf} = (1.0452 \times EER + 0.0115 \times EER^2 + 0.000251 \times EER^3) \times F_{chg} \times F_{air} \times F_{size}$$

Where:

SEER = Seasonal energy efficiency ratio for the air conditioner. The EER shall be used in lieu of the SEER for equipment not required to be tested for a SEER rating.

EER = Energy efficiency ratio at ARI test conditions, if not input, then values are taken from Equation R3-42.

$F_{chg}$ = The refrigerant charge factor, default = 0.9. For systems with a verified charge indicator light (Reference Residential Appendix RA3.4) or verified refrigerant charge (Reference Residential Appendix RA3), the factor shall be 0.96.

$F_{air}$ = The system airflow factor, default = 0.925. The system airflow factor depends on the cooling coil airflow (evaporator air flow) described in Reference Residential Appendix RA3.3. If the fan flow rate is below 300 cfm/ton, Fair = 0.925. If the fan flow rate is above 400 cfm/ton, Fair = 1.0. Between 300 and 400 cfm/ton, interpolation is used.

$F_{size}$ = Compressor sizing factor, default = 0.95. For systems sized according to the Maximum Cooling Capacity for compliance software Credit (see Section 3.12.4), the factor shall be 1.0.

Equation R3-42

When

SEER <11.5 EER = 10 - (11.5 - SEER) x 0.83

SEER >= 11.5 EER = 10

*Gas Absorption Systems*

Gas absorption cooling systems are an optional modeling capability. To determine the electric and gas energy use of gas absorption air conditioning systems the algorithms described in this section should be used.

Equation R3-43

$$Absorption_{Btu} = \frac{CLoad_{hr}}{\eta_{seasonal,dist} \times AE_t} + \frac{Fan_{wh} x3.413}{AE_t} + Qneed/AE_t$$

Equation R3-44

$$PPC_{wh} = \frac{CLoad_{hr}}{\eta_{seasonal,dist} \times PE_t} + Qneed/PE_t$$

Where:

$CLoad_{hr}$ = Space sensible cooling load for the hour from the compliance software simulation for portions of the system with ducts in unconditioned zones not modeled with UZM (Btu).

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R3-54 simulation for portions of the system with ducts in unconditioned zones not modeled with UZM.

$Fan_{wh}$ = Fan watts this hour. This is calculated using Equation R3-49.

$AE_t$ = Sensible energy efficiency of the gas absorption system at a particular outdoor dry bulb temperature. This is calculated from Equation R3-45 below.

Qneed = The required cooling system output (including duct losses and adjustments) calculated by UZM

Equation R3-45

$$AE_t = COP_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

Where:

$DB_t$ = Outdoor dry bulb temperature taken from the CEC weather file.in Reference Joint Appendix JA2 $COP_t$ = COP (coefficient of performance for the gas consumption) of the gas absorption system at a particular dry bulb temperature calculated using Equation R3-47.

$PEER_t$ = PEER (parasitic electricity energy efficiency for the gas absorption system) at a particular outdoor dry bulb temperature calculated using Equation R3-48.

$PE_t$ = Sensible energy efficiency of the parasitic power at a particular outdoor dry bulb temperature. This is calculated using Equation R3-46 below.

Equation R3-46 $$PE_t = PEER_t \times \left(0.88 + 0.00156 \times \left(DB_t - 95\right)\right)$$

Equation R3-47

| | |
|---|---|
| $DB_t$ < 83 ºF | $COP_t = COP_{82}$ |
| 83 < $DB_t$ < 95 | $COP_t = COP_{82}$ + (($DB_t$ - 82)*($COP_{95}$ - COP82) / 13) |
| $DB_t$ > 94 | $COP_t = COP_{95}$ - ($DB_t$ - 95) * 0.00586 |

Equation R3-48

| | |
|---|---|
| $DB_t$ < 83 ºF | $PEER_t = PEER_{82}$ |
| 83 < $DB_t$ < 95 | $PEER_t = PEER_{82}$ + (($DB_t$ - 82)*( $PEER_{95}$ - $PEER_{82}$) / 13) |
| $DB_t$ > 94 | $PEER_t = PEER_{95}$ - ($DB_t$ - 95) * 0.00689 |

Where:

$CAP_{95}$= Rated capacity of the gas absorption system, Btuh, input by the compliance user

$COP_{95}$ = Rated COP of the gas absorption system, input by compliance user

PPC = Parasitic electric energy at rated conditions, W, input by compliance user

$COP_{82}$ = $COP_{95}$ * 1.056

$PEER_{95}$= $CAP_{95}$ / PPC, Btu / Wh

PEER82= $PEER_{95}$ * 1.056

*Fan Energy for Cooling*

While in a cooling mode, the fan energy associated with the air conditioner is calculated separately from the compressor energy according to Equation R3-49. Calculations are performed hourly.

Equation R3-49 $$Fan_{wh} = \frac{FanW / Btu}{\left(0.88 - 0.002286 * \left(Tout - 95\right)\right) * F_{chg} * F_{air} * F_{size}} \times \left(\frac{CLoad_{hr}}{\eta_{seasonal,dist}} + Qneed\right)$$

Where:

FanW/Btu = FanCfm/ton * FanW/cfm / 12000 Btu/ton.

:

FanCfm/ton = Cooling coil airflow, cfm per nominal ton of capacity (cfm/ton). See Section 3.11.5 above.

FanW/cfm = Fan Watts per cfm (W/cfm) of cooling coil airflow. See Section [3.11.7] above..

$CLoad_{hr}$ = Space sensible cooling load for the hour from the compliance softwaresimulation for portions of the system with ducts in unconditioned zones not modeled with UZM (Btu).

$\eta_{seasonal, dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R3-54. for portions of the system with ducts in unconditioned zones not modeled with UZM.

Qneed = The required heating system output (including duct losses and adjustments) calculated by UZM.

## *3.13 Air Distribution Systems*

The procedures in this section shall be used to calculate the efficiency of duct systems. The energy impact of attics on air distribution systems is calculated using the UZM model. For the purposes of duct efficiency calculations, the supply duct begins at the exit from the furnace or air handler cabinet.

### 3.13.1 Air Distribution Ducts

***Proposed Design.*** Compliance software shall be able to model the basic types of HVAC distribution systems and locations listed in Table R3-30. As a default, for ducted systems HVAC ducts and the air handler are located in the attic. Proposed HVAC systems with a duct layout and design on the plans may locate the ducts in the crawlspace or a basement if the layout and design specify that all of the supply registers are located in the floor or within two feet of the floor, and show the appropriate locations for the ducts. Otherwise, the default location is the attic as shown in Table R3-12. If all supply registers are at the floor, but the building has both a crawlspace and a basement, the duct location may be taken as a floor area weighted average of the duct efficiencies of a crawlspace and a basement. If the modeled duct location is not in the attic, the compliance software shall specify that all supply registers for the building are located in the floor or within two feet of the floor, and this shall be noted in the *Special Features Inspection Checklist* of the CF-1R.

Proposed HVAC systems with a complete duct design, including the duct layout and design on the plans, may allocate duct surface area in more detail in the compliance software model but the distribution of duct surface areas by location shall appear on the *Hers Required Verification* list of the CF-1R. The HERS rater shall verify the existence of duct design and layout and the general consistency of the actual HVAC distribution system with the design.

The compliance software shall allow users to specify if they will be using diagnostic testing of HVAC distribution efficiency of a fully-ducted system during the construction of the building to confirm the modeling of improved HVAC distribution efficiency measures such as duct leakage. The default shall be that no diagnostic testing will be done. Duct efficiency credits may not be taken and diagnostic testing may not be done on any HVAC system that uses nonducted building cavities such as plenums or platform returns, to convey conditioned air unless they are defined or constructed with sealed sheet metal or duct board Building cavities, including support platforms, may contain ducts. If the user does not select diagnostic testing, the compliance software shall require users to input at least two (2) basic parameters to determine HVAC distribution efficiency: the total conditioned floor area of the building as specified above and the R-value of the duct insulation which may be defaulted to the minimum duct insulation requirements. Additional data may be required to determine seasonal distribution system efficiency. The default input parameters are presented in Chapter 3. If the user specifies diagnostic testing to be performed during construction, the compliance software shall prompt the user to enter the data described Section 3.12.7, *Seasonal Distribution System Efficiency* and shall report all required measurements and the features used to achieve higher HVAC distribution efficiencies in the *Hers Required Verification* listings on the CF-1R. When the user chooses diagnostic testing, the diagnostic testing shall be performed as described in Reference Residential Appendix RA3. The duct leakage factors in Table R3-39 shall be used when Low Leakage Air Handlers or Low Leakage Ducts in Conditioned Space are specified.

***Standard Design.*** The standard heating and cooling system for central systems is modeled with non-designed air distribution ducts located in an attic space, with the duct leakage factor for sealed and tested new duct systems (see Table R3-39) and a radiant barrier in climate zones where required by Package D. The standard design duct insulation is determined by the Package D specifications for the applicable climate zone. The standard design building is assumed to have the same number of stories as the proposed design for purposes of determining the duct efficiency. HVAC distribution system efficiencies shall be calculated using the algorithms and equations in Chapter of this manual for both the proposed design and the standard design. The standard design calculation shall use the default values of that procedure. For non-central HVAC systems, the standard design shall have no ducts.

### 3.13.2 Building Information and Defaults

The compliance software shall use values for the parameters in Table R3-36 to calculate duct efficiencies. Standard design values and proposed design defaults are also shown. Proposed designs may claim credit for other values using the procedures in the following sections.

*Table R3-36 – Duct Efficiency Input Parameters and Defaults*

| Parameter | | Standard Design Value | Proposed Design Default |
|---|---|---|---|
| 1. | Duct Location | Ducts in the attic | Ducts in the attic |
| 2. | Insulation level of ducts | Package D requirement | Mandatory Minimum Requirement |
| 3. | The surface area of ducts | 27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories. | |
| 4. | The leakage level | Sealed and tested. | Untested |
| | | | |
| 5. | Attic radiant barrier. | Yes in climate zones where required by Package D, otherwise No | No radiant barrier |

When two HVAC systems with ducts in the attic serve a building each system shall be modeled separately in UZM. If more than 2 systems with ducts in the attic serve a building, the most similar systems shall be combined into 2 systems and modeled in UZM using the sum of cooling coil airflow and capacities and capacity weighted efficiencies. If more than one HVAC system without ducts in the attic serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

See Section 3.16 for information on existing HVAC systems that are extended to serve an addition.

Diagnostic inputs may be used for the calculation of improved duct efficiency in the proposed design. The diagnostics include observation of various duct characteristics and measurement of duct leakage as described in the following sections. These observations and measurements replace those assumed as default values.

### 3.13.3 Special Credits

Credit is available for supply duct systems entirely in conditioned space, with reduced surface area in unconditioned spaces and varying combinations of higher performance insulation. In order to claim these credits the detailed duct system design shall be documented on the plans, and the installation shall be certified by the installer and verified by a HERS rater. The size, R-value, and location of each duct segment in an unconditioned space and if buried in attic insulation, the information described below shall be shown in the design and entered into the compliance software. The compliance software shall calculate the area and effective R-value of the duct system in each location using the procedures specified below.

***Duct Location***

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses.

***Return Duct Location***

If return ducts are located entirely in the basement, the calculation shall assume basement conditions for the return duct efficiency calculation. If the return duct is located entirely in conditioned space and the system meets the requirements for *Verified Low Leakage Ducts in Conditioned* Space, the return duct shall be assumed to be in conditioned space. Otherwise, the return duct shall be entirely located in the attic for the purposes of conduction and leakage calculations. Return duct surface area is not a compliance variable.

***Supply Duct Location***

Default supply duct locations shall be as shown in Table R3-36. The supply duct surface area for crawl space and basement applies only to buildings or zones with all supply ducts installed in the crawl space or basement. If the supply duct is installed in locations other than crawl space or basement, the default supply duct location shall be "Other." For houses with 2 or more stories 35 percent of the default duct area may be assumed to be in conditioned space as shown in Table R3-37.

The surface area of supply ducts located in conditioned space shall be ignored in calculating conduction losses.

*Table R3-37– Location of Default Supply Duct Area*

| Supply duct location | **Location of Default Supply Duct Surface Area** | |
|---|---|---|
| | One story | Two or more story |
| All in Crawl Space | 100% crawl space | 65% crawl space 35% conditioned space |
| All in Basement | 100% Basement | 65% basement 35% conditioned space |
| Other | 100% attic | 65% attic 35% conditioned space |

***Diagnostic Supply Duct Location***

Supply duct location and areas other than the defaults shown in Table R3-37may be used following the procedures in Reference Residential Appendix RA3.1.4.1.

***Duct Surface Area***

The supply-side and return-side duct surface areas shall be treated separately in distribution efficiency calculations. The duct surface area shall be determined using the following methods.

*Return Duct Surface Area*

Return duct surface area is not a compliance variable and shall be calculated using Equation R3-50.

Equation R3-50

$$A_{r,out} = K_r \times A_{floor}$$

Where $K_r$ (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

*Default Supply Duct Surface Area*

The standard design and default supply duct surface area shall be calculated using Equation R3-51.

Equation R3-51

$$A_{S,out} = 0.27 \times A_{floor} \times K_S$$

Where $K_s$ (supply duct surface area coefficient) shall be 1 for one story building and 0.65 for two or more stories.

*Supply Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space*

For proposed design HVAC systems with air handlers located outside the conditioned space but with less than 12 lineal feet of duct located outside the conditioned space including air handler and plenum, the supply duct surface area outside the conditioned space shall be calculated using Equation R3-52.

Equation R3-52

$$A_{s,out} = 0.027 \times A_{floor}$$

*Diagnostic Duct Surface Area*

Proposed designs may claim credit for reduced surface area using the procedures in Reference Residential Appendix RA3.1.4.1.

***Surface Area and Location***

The surface area of each supply duct system segment shall be calculated based on its inside dimensions and length. The total supply surface area in each unconditioned space location (attic, attic with radiant barrier, crawl space, basement, other) shall be the sum of the area of all duct segments in that location. The compliance software shall assign duct segments located in “other” locations to the attic location for purposes of calculation. The surface area of supply ducts completely inside conditioned space need not be input in a compliance software and is not included in the calculation of duct system efficiency. The area of ducts in floor cavities or vertical chases that are surrounded by conditioned space and separated from unconditioned space with draft stops are also not included.

### 3.13.4 Duct System Insulation

***General***

An air film resistance of 0.7 (h-ft²-°F/Btu) shall be added by the compliance software to the insulation R-value to account for external and internal film resistance. For the purposes of conduction calculations in both the Standard and Proposed designs, 85 percent of the supply and return duct surface shall be assumed to be duct material at its specified R-value and 15 percent shall be assumed to be air handler, plenum, connectors and other components at the mandatory minimum R-value.

***Standard Design Duct Insulation R-value***

Package D required duct insulation R-values shall be used in the Standard design.

***Proposed Design Duct Insulation R-value***

The default duct wall thermal resistance shall be the mandatory requirement. Higher insulation levels may be used in the proposed design if all the ducts outside conditioned space are insulated to this value or greater.

Credit for systems with mixed insulation levels or ducts buried in the attic require the diagnostic procedure in Reference Joint Appendix JA3.1.4.1

***Effective R-value***

The effective R-value of a supply or return duct system constructed entirely of materials of one rated R-value shall be the rated R-value plus the film coefficient. If materials of more than one R-value are used, the area weighted effective R-value shall be calculated by the compliance software using Equation R3-53 and including each segment of the duct system which has a different R-value.

Equation R3-53

$$R_{eff} = \frac{(A_1 + A_2 .... + A_N)}{\left[\frac{A_1}{R_1} + \frac{A_2}{R_2} .... + \frac{A_N}{R_N}\right]}$$

Where:

$R_{eff}$ = Area weighted effective R-value of duct system for use in calculating duct efficiency,(h-ft²-°F/Btu)

$A_N$ = Area of duct segment n, square feet.

$R_n$ = R-value of duct segment n including film resistance, (duct insulation rated R + 0.7), (h-ft²-°F/Btu)

***Buried Attic Ducts***

Ducts partly or completely buried in blown attic insulation in dwelling units meeting the requirements for High Insulation Quality (Reference Residential Appendix RA3.5) and Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems (Reference Residential Appendix RA3.1) may take credit for increased effective duct insulation using the following procedure. The duct design shall identify the segments of the duct that meet the requirements for being buried, and these shall be separately input into the computer software. Ducts to be buried shall have a minimum of R-4.2 duct insulation prior to being buried. The computer software shall calculate the correct R-value based on the specified attic insulation R-value, insulation type, and duct size for ducts installed on the ceiling, and whether the installation meets the requirements for deeply buried ducts for duct segments buried in lowered areas of ceiling. Correct installation of the duct system and attic insulation shall be certified by the installer and verified by a certified HERS rater (including that the requirements of Reference Residential Appendix RA3.5 and Reference Residential Appendix RA3.1 are met).

***Buried Ducts on the Ceiling***

The portions of duct runs directly on or within 3.5 inches of the ceiling gypsum board and surrounded with blown attic insulation of R-30 or greater may take credit for increased effective duct insulation as shown in Table R3-38. Credit shall be allowed for buried ducts on the ceiling only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

***Deeply Buried Ducts***

Duct segments deeply buried in lowered areas of ceiling and covered by at least 3.5” of insulation above the top of the duct insulation jacket may claim effective insulation of R-25 for fiberglass insulation and R-31 for cellulose insulation.

*Table R3-38 – Buried Duct Effective R-values*

| | Nominal Round Duct Diameter | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Attic Insulation | 4" | 5" | 6" | 7" | 8" | 10" | 12" | 14" | 16" |
| | Effective Duct Insulation R-value for Blown Fiberglass Insulation | | | | | | | | |
| R-30 | R-13 | R-13 | R-13 | R-9 | R-9 | R-4.2 | R-4.2 | R-4.2 | R-4.2 |
| R-38 | R-25 | R-25 | R-25 | R-13 | R-13 | R-9 | R-9 | R-4.2 | R-4.2 |
| R-40 | R-25 | R-25 | R-25 | R-25 | R-13 | R-13 | R-9 | R-9 | R-4.2 |
| R-43 | R-25 | R-25 | R-25 | R-25 | R-25 | R-13 | R-9 | R-9 | R-4.2 |
| R-49 | R-25 | R-25 | R-25 | R-25 | R-25 | R-25 | R-13 | R-13 | R-9 |
| R-60 | R-25 | R-25 | R-25 | R-25 | R-25 | R-25 | R-25 | R-25 | R-13 |
| | Effective Duct Insulation R-value for Blown Cellulose Insulation | | | | | | | | |
| R-30 | R-9 | R-4.2 | R-4.2 | R-4.2 | R-4.2 | R-4.2 | R-4.2 | R-4.2 | R-4.2 |
| R-38 | R-15 | R-15 | R-9 | R-9 | R-4.2 | R-4.2 | R-4.2 | R-4.2 | R-4.2 |
| R-40 | R-15 | R-15 | R-15 | R-9 | R-9 | R-4.2 | R-4.2 | R-4.2 | R-4.2 |
| R-43 | R-15 | R-15 | R-15 | R-15 | R-9 | R-4.2 | R-4.2 | R-4.2 | R-4.2 |
| R-49 | R-31 | R-31 | R-15 | R-15 | R-15 | R-9 | R-9 | R-4.2 | R-4.2 |
| R-60 | R-31 | R-31 | R-31 | R-31 | R-31 | R-15 | R-15 | R-9 | R-9 |

### 3.13.5 Duct/Air Handler Leakage

Duct/air handler leakage factors shown in Table R3-39 shall be used in calculations of delivery effectiveness. Table R3-39 shows default duct leakage factors for dwelling units. Sealed and tested duct systems require the diagnostic leakage test by the installer and verification by a HERS rater meeting the criteria described in Reference Residential Appendix RA3. The duct leakage factors for sealed and tested new duct systems correspond to sealed duct requirements in newly constructed dwelling units, to entirely new duct systems in existing dwelling units, and to duct systems in alterations and additions that have been sealed to meet the duct leakage requirements of newly constructed buildings. The duct leakage factors for sealed and tested duct systems in existing dwelling units apply only to sealed duct requirements for alterations to existing dwelling units and to extensions of existing duct systems to serve additions. See Section 3.16 for ducts in existing dwelling units that are sealed and tested in conjunction with alterations or additions.

***Low Leakage Air Handlers***

The credit for low leakage air handlers requires HERS verification that a certified low leakage air handler is installed and must be used in combination with the existing credit for verified duct leakage. To qualify, air handlers must be factory sealed units tested by the manufacturer and certified to the Commission to have achieved a 2 percent or less leakage rate at 1-inch water gauge when all air inlets, air outlets and condensate drain port(s), when present, are sealed. Qualifying duct systems may take credit for 0.97 leakage factor if they pass the Sealed and Tested New Duct Criteria or a higher Factor if they show leakage less than 2 x (1-Factor).

***Verified Low Leakage Ducts in Conditioned Space***

Systems that have all ducts entirely in conditioned space and for which the verified duct leakage to outside conditions is equal to or less than 25 cfm when measured in accordance with Reference Residential Appendix RA3.1.4.3.9 may take credit for a 1.0 leakage factor and no conduction losses.

*Table R3-39 – Duct/Air Handler Leakage Factors*

| Case | $a_s = a_r$ |
|---|---|
| Untested duct systems in homes built prior to June 1, 2001 | 0.86 |
| Untested duct systems in homes built after June 1, 2001 | 0.89 |
| Sealed and tested duct systems in existing dwelling units | 0.915 |
| Sealed and tested new duct systems | 0.96 |
| Verified low leakage ducts in conditioned space | 1.00 |
| Low leakage air handlers in combination with sealed and tested new duct systems | 0.97 or as measured |

### 3.13.6 Reporting Requirements on CF-1R

***General Information***

A listing shall be displayed when ducts are included in the heating and/or cooling system and when sealing and testing is specified. As many rows as necessary may be used to describe each duct system. Information on the CF-1R may include:

- *Equipment Type.* The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R3-32 and Table R3-33. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows.
- *Duct R-value (hr-ft$^2$-°F/Btu)*. The nominal R-value of the duct insulation.
- *Distribution Type and Location*. The default distribution type and location is a ducted, central system with 100% of the ducts in the attic. If a duct design is specified with duct locations on the plans but without specific duct surface areas (sizes and lengths) specified, the *Special Features Inspection Checklist* shall specify the default duct locations. To use DuctsCrawl or DuctsBsmt, all supply registers shall be in the floor or within two feet of the floor and the *Special Features Inspection Checklist* shall indicate that all supply registers are in the floor or within two feet of the floor. These two cases do not require field verification. All other cases require field verification.
- *Verified Duct Leakage*. If verified (tested) duct leakage is specified by the user, the requirement for diagnostic testing shall be reported in the *Hers Required Verification* listings on the CF-1R.

***Supply Duct System Details***

This listing shall be displayed any time credit for ducts in conditioned space, reduced duct surface area, and/or combinations of higher performance insulation (including ducts buried under the attic insulation) are specified. The portions of duct run located on the floor of the attic within 3.5 inches of the ceiling gypsum board and covered or partially covered with blown attic insulation of R-30 or greater in houses meeting the criteria for Insulation Installation Quality (Reference Residential Appendix RA3.5) may take credit for increased effective duct insulation. As many rows as necessary may be used to describe each duct run. These credits shall also be reported in the *Special Features Inspection Checklist*.

Information on the CF-1R may include:

- *Description (text):* Description given to each length of supply duct.
- *Location* (prescribed descriptor): The location of the duct. Permissible types: Listed in Table R3-34.
- *Duct Length (ft).* The length of the duct in feet.
- *Duct Diameter (in.)* The diameter of the duct in inches.
- *Duct Insulation R-value (hr-ft$^2$-°F/Btu)*. The nominal R-value of the duct insulation.

- *Buried Duct (prescribed descriptor).* The choices are 'Yes', 'No' or 'Deep'. 'No' means that the ducts are not buried and no credit is being taken. 'Yes' means that this duct is located on the floor of the attic within 3.5 inches of the ceiling gypsum board and will be covered or partly covered by blown ceiling insulation. 'Deep' applies when duct segment is deeply buried in lowered areas of ceiling and has at least 3.5" of blown insulation above the top of the duct.
- *Attic Insulation R-value (hr-ft$^2$-°F/Btu).* The nominal R-value of the attic insulation covering buried ducts
- *Attic Insulation Type (prescribed descriptor).* The choices are 'Fiberglass' for blown fiberglass or 'Cellulose' for blown cellulose.

### 3.13.7 Seasonal Distribution System Efficiency

Compliance software shall use the following algorithms to calculate duct and HVAC Seasonal Distribution System Efficiency for portions of the system with ducts in unconditioned zones not modeled with UZM.

The seasonal distribution system efficiency shall be calculated separately for the heating and cooling seasons using Equation R3-54 based on the seasonal delivery effectiveness from Equation R3-55 and the recovery factor from Equation R3-64. Note that $DE_{seasonal}$, $F_{recov}$ shall be calculated separately for cooling and heating seasons. Distribution system efficiency shall be determined using the following equation:

Equation R3-54

$$\eta_{dist,seasonal} = 0.98\,DE_{seasonal} \times F_{recov}$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass. $F_{recov}$ is calculated in Equation R3-65.

### 3.13.8 Seasonal Delivery Effectiveness

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using Equation R3-55. This value shall be calculated separately for the heating season and the cooling season.

Equation R3-55

$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$

Where:

$B_s$ = Conduction fraction for supply as calculated in Equation R3-56.

$B_r$ = Conduction fraction for return as calculated in Equation R3-57.

$\Delta T_e$ = Temperature rise across heat exchanger, ºF. This value changes for heating and cooling modes.

$\Delta T_r$ = Temperature difference between indoors and the ambient for the return, ºF. This value changes for heating and cooling modes.

$\Delta T_s$ = Temperature difference between indoors and the ambient for the supply, ºF. This value changes for heating and cooling modes.

$a_r$ = Duct leakage factor (1-return leakage) for return ducts. A value is selected from Table R3-39

$a_s$ = Duct leakage factor (1-supply leakage) for supply ducts. A value is selected from Table R3-39

Equation R3-56

$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 \times Q_e \times R_s}\right)$$

Equation R3-57

$$B_r = \exp\left(\frac{-A_{r,out}}{1.08 \times Q_e \times R_r}\right)$$

Where:

$A_{s,out}$ = Surface area of supply duct outside conditioned space, ft². See Section 3.13.13, 0.0.0 and 0.0.0.

$A_{r,out}$ = Surface area of return duct outside conditioned space, $ft^2$. See Section 3.13.13, 0.0.0 and 0.0.0.

$Q_e$ = Flow through air handler fan at operating conditions, cfm. This is determined from Equation R3-58

$R_r$ = The effective thermal resistance of return duct, h $ft^2$ F/Btu. See Section 3.13.3.

$R_s$ = The effective thermal resistance of supply duct, h $ft^2$ F/Btu. See Section 3.13.3.

The default fan flow for duct efficiency calculations shall be calculated as follows:

Equation R3-58

$$Q_e = CFMfactor \times A_{floor}$$

Where:

$A_{floor}$ = conditioned floor area served by the duct system (ft²).

CFMfactor = 0.70 for cooling and for heating with a heat pump for climate zones 8 through 15. 0.50 for cooling and heating with a heat pump for climate zones 1 through 7 and 16 and for forced air furnaces for all climate zones (cfm/ft²).

### 3.13.9 Calculation of Duct Zone Temperatures for Multiple Locations

The temperatures of the duct zones outside the conditioned space are determined for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures.

Equation R3-59

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out}}$$

Equation R3-60

$$T_{amb,r} = \frac{A_{r,attic}\ T_{attic} + A_{r,crawl} \times T_{crawl} + A_{r,base} \times T_{base}}{A_{r,out}}$$

The return ambient temperature, $T_{amb,r}$, shall be limited as follows:

- For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$.

- For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.

### 3.13.10 Temperature Difference Across Heat Exchanger

The temperature difference across the heat exchanger is determined by Equation R3-61:

For heating:

Equation R3-61 $$\Delta T_e = 55$$

And Equation R3-62 for cooling:

Equation R3-62 $$\Delta T_e = -20$$

### 3.13.11 Indoor to Duct Location Temperature Differences

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, $\Delta T_{s,}$ and return, $\Delta T_r$ , shall be calculated using the indoor and the duct ambient temperatures.

Equation R3-63 $$\Delta T_s = Tin - Tamb_{,s}$$

Equation R3-64 $$\Delta T_r = Tin - Tamb_r$$

### 3.13.12 Thermal Regain ($F_{regain}$)

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The thermal regain factors that are required to be used are provided in Table R3-40.

*Table R3-40 – Thermal Regain Factors*

| Supply Duct Location | Thermal Regain Factor [$F_{regain}$] |
|---|---|
| Attic | 0.10 |
| Crawl Space | 0.12 |
| Basement | 0.30 |
| Other | 0.10 |

### 3.13.13 Recovery Factor ($F_{recov}$)

The recovery factor, $F_{recov}$, shall be calculated based on the thermal regain factor, $F_{regain}$, and the duct losses without return leakage.

Equation R3-65 $$F_{recov} = 1 + F_{regain}\left(\frac{1 - a_s B_s + a_s B_s (1 - B_r)\frac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s)\frac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right)$$

## 3.14 Mechanical Ventilation

The Standards require mechanical ventilation that complies with ASHRAE Standard 62.2 to provide acceptable indoor air quality. ASHRAE Standard 62.2 provides several ways to comply with the requirement for mechanical ventilation and these will be described in the compliance manual.

For the purposes of estimating the energy impact of this requirement in compliance software, the minimum ventilation rate is met either by a standalone IAQ fan system or a central air handler fan system that can introduce outdoor air. In many cases, this energy is substantially compliance neutral because the standard design is typically set equal to the proposed design.

The simplest IAQ fan system is an exhaust fan like a bathroom fan that meets the criteria in ASHRAE Standard 62.2 for air delivery and low noise. More advanced IAQ fan systems that have both supply and exhaust fans are also possible. To calculate the energy use of standalone IAQ fan systems, the systems are assumed to be on continuously.

To calculate the energy use of Central Fan Integrated Ventilation the systems are assumed to be on for at least 20 minutes each hour as described below. The fan flow rate and fan power ratio may be different than the values used when the system is on to provide for heating or cooling depending on the design or controls on the IAQ ventilation portion of the system.

If the Central Fan Integrated Ventilation system is configured to mix the indoor air without introducing outdoor air, a standalone IAQ system must also be modeled.

The minimum ventilation rate for continuous ventilation is given in the equation below.

Equation R3-66

$$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

Where:

$Q_{fan}$ = fan flow rate in cubic feet per minute (cfm),

$A_{floor}$ = floor area in square feet ($ft^2$),

$N_{br}$ = number of bedrooms; not to be less than one.

### 3.14.1 Proposed Design

The proposed design shall incorporate a mechanical ventilation system. This requirement is a mandatory measure. The software user shall specify the following information:

- The continuous air flow rate in cfm equal to or larger than the value given by Equation R3-66. The default value shall be the value given in Equation R3-66.
- If a standalone IAQ fan system is installed then the fan system is assumed to be on continuously and the following would be entered:
  - The fan power ratio in W/cfm at the expected operating conditions, e.g. the static pressure of the duct system shall be considered. The default value shall be 0.25 W/cfm.
  - The fan system type such as “Unbalanced” for an exhaust or supply only system or “Balanced” for a system with both a supply and return fan. The default value shall be unbalanced.
  - If the stand alone ventilation system provides heat recovery, the sensible heat recovery effectiveness as a decimal fraction. For the purposes of calculating the impact of ventilation on

heating and cooling loads, the temperature of the incoming ventilation air shall be calculated using Equation R3-67.

Equation R3-67VentSupplyT = Outdoor Air Temp + (Room Air temp – Outdoor Air temp) * Effectiveness

- If a central air handler fan is used to introduce outdoor air to meet the IAQ ventilation requirement or to mix the indoor air, then the fan system is assumed to be on at least 20 minutes per hour. If the central air handler fan is on for more than 20 minutes during an hour to provide heating or cooling, then separate IAQ ventilation is not modeled for that hour. For this case, the following would be entered:
    - The central air handler flow rate in cfm when the system is operated to provide IAQ ventilation or mixing. The default value shall be the cooling system air flow. If there is no air conditioning, the default shall be the heating system air flow. If values other than the default is used, then the air flow rate must be tested and verified in accordance with Reference Residential Appendix RA3.3
    - The central air handler fan power ratio in W/cfm at the expected operating conditions, e.g. the static pressure of the duct system shall be considered. The default value shall be 0.8 W/cfm. If values other than the default value are used, then the air flow rate must be tested and verified in accordance with Reference Residential Appendix RA3.3
    - The fan system type such as “CentralOutdoor” for a central air handler system that introduces outdoor air or “CentralMix” for a system that mixes indoor air.
- If a central air handler fan that mixes indoor air but that does not introduce outside air is used, then the inputs for both the standalone IAQ fan system and the central air handler fan above must be entered.

### 3.14.2 Standard Design

The mechanical ventilation system in the standard design shall be the same as the proposed design. The air flow rate shall be equal to the proposed design. For standalone IAQ fan systems, the fan power ratio, shall be equal to the proposed design value or 1.2 W/cfm which ever is smaller. The sensible heat recovery effectiveness shall be 0. For central air handler fans, the fan power ratio is 0.58 W/cfm of central system airflow in ventilation mode.

### 3.14.3 Reporting Requirements on CF-1R

The required ventilation rate to comply with Standard 62.2 and the means to achieve compliance shall be indicated on the CF-1R.

*Table R3-41 – CF-1R Report – Indoor Air Quality*

| IAQ System Name | IAQ System Type | Airflow Rate (cfm) | Fan Power Ratio (W/cfm) |
|---|---|---|---|

## 3.15 Special Systems - Hydronic Distribution Systems and Terminals

This listing shall be completed for hydronic systems that have more than 10 feet of piping (plan view) located in unconditioned space. As many rows as necessary may be used to describe the piping system. Note that hydronic heating systems (combined or not) shall be reported in the *Special Features Inspection Checklist*. The entry for the *Special Features Inspection Checklist* shall indicate any additional listings that are reported for this feature so that the local enforcement agency can verify the additional information needed to check this special feature.

Information to be provided on the CF-1R may include:

*Piping Run Length (ft).* The length (plan view) of distribution pipe located in unconditioned space, in feet, between the primary heating/cooling source and the point of distribution.

*Nominal Pipe Size.* The nominal (as opposed to true) pipe diameter in inches.

*Insulation Thickness (in).* The thickness of the insulation in inches. Enter "none" if the pipe is uninsulated.

*Insulation R-value (hr-ft$^2$-°F/Btu).* The installed R-value of the pipe insulation. Minimum pipe insulation for hydronic systems is as specified in §150(j).

## 3.16 Water Heating

**Proposed Design**. Compliance software shall be able to model the basic types of water heaters listed in Table R3-47, the water heating distribution system choices (within the dwelling unit) listed in Table R3-42 (and Table R3-45), and the multiple dwelling unit recirculating system control choices listed in Table R3-43 (and Table R3-46). compliance software users shall specify the following information about each water heating system:

- The number of dwelling units served by the water heating system (needed only when the system serves multiple dwelling units).
- The number of water heaters that are a part of the system
- The performance characteristics of each water heater:
- For gas water heaters with an input rating of 75,000 Btu/h or less and for electric water heaters with an input rating of 12 kW or less, the energy factor (EF) is entered.
- For small instantaneous gas or oil water heaters as defined in the Appliance Efficiency Regulations, the Energy Factor (EF) is entered.
- For large instantaneous gas or oil water heaters as defined in the Appliance Efficiency Regulatios, the thermal efficiency (TE), pilot light energy (Pilot), standby loss (SBE or SBL), tank surface area (TSA), and R-value of exterior insulation wrap (REI) is entered.
- For large storage water heaters, the thermal efficiency (TE), and standby losses are entered. If an unfired tank is part of the system the standby may be calculated using the jacket loss equation in RACM Appendix E., .
- Information about any solar supplementary heating that is provided. See RACM Appendix E for details.
- The type of distribution system used within the dwelling unit. This is a selection from Table R3-42. For recirculation systems that serve multiple dwelling units, choose the type of control from Table R3-43).
- If multiple water heating systems serve a single dwelling unit, then the compliance software shall keep track of the conditioned floor area served by each water heating system.
- For water heating systems serving multiple dwelling units, the compliance software shall keep track of the dwelling units served by each system.

For systems serving multiple dwelling units, the characteristics of an average or typical dwelling unit, e.g. conditioned floor area and number of stories (within the dwelling unit), may be used in making calculations.

*Table R3-42 – Water Heater Distribution System Choices (Within the Dwelling Unit)*

| Distribution System Measure | Code |
|---|---|
| Pipe Insulation (kitchen lines) – Standard Case | STD |
| Pipe Insulation (all lines) | PIA |
| Standard pipes with no insulation | SNI |
| Point of Use | POU |
| Parallel Piping | PP |
| Un-insulated Pipe  below Grade | UPBG |
| Insulated and Protected pipe below grade | IPBG |
| Recirculation (no control) | RNC |
| Recirculation + timer control | RTm |
| Recirculation + temperature control | RTmp |
| Recirculation + timer/temperature | RTmTmp |
| Recirculation + manual demand control | RDRmc |
| Recirculation + demand photo sensor control | RDRmsc |
| Temperature Buffering Tank | TBT |

*Table R3-43 – Multiple Dwelling Unit Recirculating System Control Choices*

| Distribution System Measure | Code |
|---|---|
| No Control | NoCtrl |
| Timer Control | STD |
| Monitored Control Systems | MCS |

**Standard Design**. For multiple dwelling unit systems, the standard design shall have the same number of water heating systems as the proposed design. For single dwelling unit systems, the standard design shall have one water heating system, regardless of the number of systems in the proposed design. Each standard design water heating system shall have the characteristics specified in Table R3-44.

*Table R3-44 – Specification of Standard Design Water Heater*

<table>
<tr>
<td rowspan="4">Does the water heating system serve a single dwelling unit?</td>
<td>Yes</td>
<td colspan="5">Standard design is a 50 gallon gas or LPG storage type water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.<br>EF is equal to 0.575, which is the NAECA minimum for the 50 gallon basecase water heater. EF = 0.67 – 0.0019 V, where V is the volume in gallons.<br>A standard distribution system with no circulation system.</td>
</tr>
<tr>
<td rowspan="3">No</td>
<td rowspan="3">Does the proposed water heating system have a storage tank?</td>
<td rowspan="2">Yes</td>
<td rowspan="2">Is the input rating of each water heater in the proposed design less than or equal to 75,000 Btu/h or if electric, less than or equal to 12 kW.</td>
<td>Yes</td>
<td>Standard design is one or more NAECA gas or LPG water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.<br>If the total storage volume of the proposed design is less than 100 gallons, then the standard design is single water heater with a storage volume equal to the total storage volume of the proposed design.<br>If the total storage volume of the proposed design is larger than 100 gallons, then the standard design shall have multiple water heaters. The number of water heaters is equal to the total storage capacity of the proposed design divided by 100 and rounded up.<br>The EF of each 100 gallon water heater shall be 0.48, which is the NAECA minimum. If the standard design is less than 100 gallons, then the EF = 0.67 – 0.0019 V.<br>See specification of distribution system in the note below.</td>
</tr>
<tr>
<td>No</td>
<td>Standard design is composed of the same number of large storage gas or LPG water heaters as in the proposed design with a storage volumes the same as the storage volumes of the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.<br>The thermal efficiency is 0.80 and stand-by losses are as specified in The Appliance Efficiency Regulations<br>See specification of distribution system in the note below.</td>
</tr>
<tr>
<td>No</td>
<td colspan="3">Standard design is the same number of natural gas or LPG instantaneous water heaters as in the proposed design with input ratings equal to those in the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.<br>Thermal efficiency of the instantaneous water heaters shall be equal to the requirements in §111.<br>See specification of distribution system in the note below.</td>
</tr>
</table>

The *Standard Design* distribution system for systems serving multiple dwelling units is described in more detail below:

1. When the distribution system is a recirculating system, the standard design shall be a recirculating system with timer controls, e.g. the coefficients in RACM Appendix E Table RE-4 for “Timer Controls” shall be used in the calculation of energy use for the standard design, otherwise the standard design shall be a non-recirculating system.

2. Pipe length and location in the standard design shall be the same as the proposed design. There are three possible locations defined in RACM Appendix E.

3. The pipes in the recirculation system shall be insulated in accordance with §150(j).

4. The pumping head and motor size for the standard design shall be equal to the pumping head and motor size in the proposed design.

5. The motor efficiency of the recirculation pump in the standard design shall be equal to the requirements in the CEC Appliance Efficiency , e.g. NEMA high efficiency motors.

6. The distribution losses within the dwelling units shall be calculated based on one story and the average dwelling unit size for all the dwelling units served by the water heating system (see RACM Appendix E).

### 3.16.1 Water Heating

***Water Heating Systems***

The CF-1R shall include a listing about water heating systems. A water heating system may serve more than one dwelling unit, or a single dwelling unit may have more than one water heating system. A water heating system may also have more than one water heater, but for purposes of modeling, may have only one distribution system type. Each water heating system in the building is defined in one or more rows in the following two tables. Data in these tables is associated with data in the Water Heater/Boiler Equipment Detail Table. When there are multiple water heater types in a system, the last two columns may be repeated as necessary.

When compliance software models a water heating system that does not have a single separate water heater serving each dwelling unit, it shall be reported in the *Special Features Inspection Checklist* of the CF-1R. The *Special Features Inspection Checklist* shall cross-reference the listing below whenever multiple water heaters serve one or more dwelling units or when a single water heater serves more than one dwelling unit. Information concerning auxiliary energy systems, the performance and features of instantaneous gas, large storage gas and indirect gas water heaters, and combined hydronic equipment, if installed, shall also be included in the *Special Features Inspection Checklist* if energy credit is taken for such systems.

Reported elements of the water heating system may include:

Notes

- *System Name.* This is a user defined name for the water heating system that provides a link between the water heating systems table, the Water Heating Systems Credits table, and the Water Heater/Boiler Equipment Detail table.
- *Distribution System in Unit(s).* Several specific distribution systems are recognized for distributing water within each dwelling unit. The distribution system listed in this column should be selected from Table R3-45.
- *Recirculation System Control.* This is only used for systems that serve multiple dwelling units. Enter a type of control from Table R3-46.
- *Water Heater Name (text).* This is a user defined name that provides a link between the *Water Heater Systems Credit* table and the *Water Heater/Boiler Equipment Detail* table. This table may be repeated if different types of water heaters are used in the same system.
- *Number of WH in System.* The number of identical water heaters of this type in the system.

*Table R3-45 – Water Heating Distribution System (Within Dwelling Units) Descriptors*

| Distribution System Measure | Code | Description |
|---|---|---|
| Pipe Insulation (kitchen lines) – Standard Case | STD | Standard (non-recirculating) potable water heating system with tank storage remote from points of consumptive use. The portions of the pipe run from the water heater to the kitchen fixtures are insulated, as required by § 151 (f) 8 D. |
| Pipe Insulation (all lines) | PIA | All pipes from the water heater to the fixtures are insulated, |
| Standard pipes with no insulation | SNI | Standard water heating system with no insulation on pipes to the kitchen. |
| Point of Use | POU | Point-of-use potable water heating system, within 8' of fixtures |
| Parallel Piping | PP | A system of individual pipe runs from a manifold at the water heater to each fixture. This is also sometimes called homerun piping. |
| Uninsulated Pipe below Grade | UPBG | Below grade piping is installed with no insulation or protective covering. |
| Insulated and Protected pipe below grade | IPBG | Below grade piping is installed with insulations and a protective covering. |
| Recirculation (no control) | RNC | Recirculation system, with no control. The pump runs continuously. |
| Recirculation + timer control | RTm | Recirculation system, with timer control. The pump operates on a timeclock. |
| Recirculation + temperature control | RTmp | Recirculation system, with the pump controlled to maintain a minimum temperature in the circulation system. |
| Recirculation + timer/temperature | RTmTmp | Recirculation system, with combination timer control and temperature control. |
| Recirculation + demand manual control | RDmc | Recirculation system, with demand control using manual controls. |
| Recirculation + demand photo sensor control | RDmsc | Recirculation system, with demand control using motion sensor controls. |
| Temperature Buffering Tank | TBT | A small storage electric water heater installed in the distribution system. |

*Table R3-46 – Control Systems for Multi-Unit Distribution Systems*

| Type of Control | Code | Description |
|---|---|---|
| Uncontrolled Recirculation | NoCtrl | Circulation pump runs continuously. |
| Timer Control | STD | Recirculation system, with timer control. The pump operates on a timeclock. |
| Monitored Control Systems | MCS | Computer modulated boiler control or hourly system monitoring of flow. |

*Table R3-47 – Water Heater Types*

| Recommended Descriptor | Water Heater Reference |
|---|---|
| StoGas | Gas, propane, or oil-fired storage tank > 2 gal, input < 75,000 Btu/hr |
| LgStoGas | Gas, propane, or oil-fired storage tank, input > 75,000 Btu/hr |
| StoElec | electric-resistance-heated storage tank > 2 gal |
| InstGas | instantaneous gas-fired, storage < 2 gal |
| InstElec | instantaneous electric-resistance-heated, storage < 2 gal |
| StoHP | electric heat pump with storage tank |
| IndGas | storage tank indirectly heated by gas- or oil-fired source |
| Boiler | boiler dedicated solely to hydronic space heating |

*Table R3-48 – Pipe Conditions for Systems Serving Multiple Dwelling Units*

| System Name | Length of pipes inside the space | Insulation of pipe inside the space | Length of pipes in ambient air | Insulation of pipes in ambient air | Length of pipes underground | Insulation of pipes underground |
|---|---|---|---|---|---|---|
| System 1 | 88 | Standard | 32 | Extra | 0 | N/a |
| System 2 | 96 | Standard | 16 | Standard | 0 | N/a |

***Water Heater/Boiler Equipment Detail***

A listing shall provide information about the energy characteristics of the water heaters or boilers used to provide either domestic hot water or space heating through a combined hydronic (*CombHydro*) system. This table may be used for both NAECA and for non-NAECA water heaters (as specified by the Appliance Efficiency Regulations). This listing describes the equipment that serves the water heating system or systems. The information in the table will not be applicable to every water heater type. When the information is not applicable, "na" may be reported.

Included details on the CF-1R may include:

- *Water Heater Name (text):* Name of water heater specified in the Water Heating Systems listing. In the case of a hydronic system heater, the name shall be unique in order to distinguish it from other water heaters.
- *Water Heater Type (recommended descriptor).* The water heater type will be one of the following choices from Table R3-47. The large storage gas water heaters are larger than the 75,000 Btu/h maximum input rated by the National Appliance Energy Conservation Act (NAECA). Indirect gas water heaters are essentially a boiler with a separate storage tank. Additional data required for large storage gas and indirect gas types is entered later in the Water Heater/Boiler Equipment Detail table. "Gas" is used for propane as well as natural gas. If oil water heaters are used, the "gas" choices may be selected.
- *Efficiency.* The efficiency of the water heater.
- *Efficiency Units.* Enter the units used for efficiency. For NAECA water heaters the energy factor (EF) will be entered. Thermal efficiency is the performance measure for instantaneous gas water heaters (*InstGas*), large storage gas/oil water heaters (*LgStoGas*) and indirect gas/oil water heaters (*IndGas*). It is also required for storage gas/oil water heaters (*StoGas*) used in combined hydronic systems (*CombHydro*). The value is taken from the Commission's appliance databases or from Commission-approved trade association directories. If the value is omitted for NAECA regulated water heaters, then the default value will be assumed. When boilers are used to fire an indirect gas/oil water heater (*IndGas*), the value of the AFUE or Thermal Efficiency (see below) is used for the recovery efficiency.
- *Tank Size for Direct Fired Tanks (gal).* The storage tank capacity in gallons. This input is applicable to all storage type water heaters. For NAECA covered water heaters, the input is optional.

- *Tank Size for Indirect Fired Tanks (gal).* The indirect fired storage tank capacity in gallons. This input is applicable to all hot water storage tanks that do not have an integral heating element or burner.
- *Combined Hydronic Pump (watts).* This is needed only for electric combined hydronic systems. It is not needed for storage gas or heat pump combined hydronic systems.
- *Rated Input (kBtu/hr for gas and kW for electric):* The energy input rating from the above directories or from the manufacturer's literature. Entries are required for large storage gas/oil water heaters *(LgStoGas)*, indirect gas/oil water heaters (*IndGas*), and when storage gas water heaters (*StoGas/LgStoGas*) or heat pump water heaters (*StoHP*) are used in combined hydronic space heating systems (*CombHydro*).
- *Standby Loss (fraction):* The fractional storage tank energy loss per hour during non-recovery periods (standby) taken from the Commission's database cited above. Applicable only to large storage gas water heaters (*LgStoGas*).
- *Tank R-value (hr-ft$^2$-F/Btu):* The total thermal resistance of the internally-insulated tank and any external insulation wrap. Applicable to large storage gas/oil (*LgStoGas*) and indirect gas/oil (*IndGas*) water heaters only.
- *Pilot light (Btu/hr)*: The pilot light energy consumption rating from the Commission's database. Applicable only to instantaneous gas (*InstGas*) and indirect gas/oil (*IndGas*) water heaters.

Table R3-49 summarizes the applicability of the inputs for the water heater types recognized by the calculation method.

*Table R3-49 – Water Heater Input Summary*

| Input Item | NAECA Storage Gas | NAECA Storage Electric | NAECA Heat Pump | Instant. Gas | Instant. Electric | Large Storage Gas | Indirect Gas |
|---|---|---|---|---|---|---|---|
| Energy Factor | Yes | Yes | Yes | Yes | Yes | | |
| Pilot Input, Btu | | | | Yes | | | Yes |
| Efficiency, % | | | | Yes | | Yes | Yes |
| Standby Loss, Btu/hr | | | | | | Yes | |
| Tank Volume, gal. | Yes | Yes | Yes | | | Yes | Yes |
| Tank Insulation, R | | | | | | Yes | Yes |
| Ext. Insulation, R | | | | | | Yes | Yes |
| If Combined Hydronic System: | | | | | | | |
| Rated Input, kBtuh | Yes | | | | | Yes | Yes |
| Rated Input, kW | | Yes | Yes | | | | |
| Recovery Eff, % | Yes | | Yes | | | Yes | Yes |
| Pump Input, Watts | | Yes | | | | Yes | Yes |

***Special Water Heating System Credits***

This section includes information about water heating auxiliary energy credits, if used. These features are optional capabilities for compliance software and their use for performance compliance requires listing in the *Special Features Inspection Checklist* of the CF-1R. The *Special Features Inspection Checklist* shall cross-reference the applicable optional water heating capabilities modeled by the compliance software.

- *System Name.* This is a name corresponding to a system name defined in the Water Heating Systems table.
- *Solar Savings Fraction (SF) or Solar Energy Factor (SEF)*. If the water heating system has a solar system to provide part of the water heating, the SF or SEF is entered in this column. The SF shall be determined using the procedures defined with the optional modeling capability in Chapter 5.

- *SRCC Certification Number. Enter the SRCC certification number for the solar system (OG-300 rated) or the collectors (OG-100 rated). This number is issued by the SRCC when a product is certified.*
- *Combined Hydronic Pump (Watts):* Required only for electric combined hydronic *(Elec/*, *StoElec/ and InstElec/CombHydro*) systems. Not required for storage gas/oil or heat pump combined hydronic systems (*StoGas/, LgStoGas/, and StoHP/CombHydro*).

### 3.16.2 Water Heating Calculations

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards (see Section 3.15 for details). The calculation procedure is documented in Reference Residential Appendix RA4.4.

## 3.17 Additions and Alterations

There are three compliance approaches for additions to and alterations of existing buildings:

- Whole Building Approach
- Addition Alone Approach
- Existing + Addition + Alteration Approach

Each of these approaches and their accompanying rules are described in the following sections. The existing + addition + alteration approach is the most flexible.

### 3.17.1 Whole Building Approach

The entire proposed building, including all additions and/or alterations, is modeled the same as a newly constructed building. The building complies if the proposed design uses equal or less energy than the standard design.

Except in cases where the existing building is being completely remodeled, this is usually a difficult standard to meet as the existing building usually does not meet current standards and must be substantively upgraded.

***Proposed Design.*** Entire building (including additions, alterations and existing building) modeled the same as new construction as described throughout the RACM compliance softwaremanual.

***Standard Design.*** Entire building modeled the same as new construction as described throughout the RACM compliance software manual.

### 3.17.2 Addition Alone Approach

The proposed addition alone is modeled the same as a newly constructed building except that the internal gains are prorated to the size of the dwelling as described in Chapter 4 section 4.2.3 and any surfaces such as walls or ceilings that are between the existing building and the addition are modeled as adiabatic and not included in the calculations. Water heating is not modeled when using this approach. The addition complies if the proposed design uses equal or less space heating and space cooling TDV energy than the standard design.

The Addition Alone Approach shall not be used when alterations to the existing building are proposed or when there are proposed modifications to existing water heating or when additional water heaters are being added. Instead, the Existing + Addition + Alteration approach shall be used for these cases. Note that modifications to any surfaces between the existing building and the addition are part of the addition and are not considered alterations.

This approach works best when the energy features in the addition are similar to those in the prescriptive packages.

***Proposed Design.*** The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. The number of dwelling units shall be set to the fractional dwelling unit as specified in Section 4.2.3. Any surfaces that are between the existing building and the addition are not modeled or treated as an adiabatic surfaces. All other features of the addition shall be modeled as for a newly constructed building.

When an existing HVAC system is extended to serve the addition, the proposed design shall assume the same efficiency for the HVAC equipment as the standard design.

When a dual-glazed greenhouse window or a dual-glazed skylight is installed in an addition, the proposed design U-factor shall be the lower of the standard design U-factor or the NFRC rated U-factor for the greenhouse window or skylight

***Standard Design.*** The addition alone is modeled the same as newly constructed building as described throughout the RACM compliance software manual.

### 3.17.3 Existing + Addition + Alteration Approach

The proposed building, including all additions and/or alterations, is modeled with tags that describe each energy feature as part of the existing building or the addition or the alteration. The compliance software uses the tags to create an existing + addition + alteration (abbreviated e+ad+al) standard design in accordance with the rules in this section that takes into account whether altered components meet or exceed the prescriptive alteration levels. The energy use of the e+ad+al proposed design shall use equal or less energy than the e+ad+al standard design.

Valid tags include:

- Existing - building features that currently exist and will not be altered
- Altered – building features that are being altered from existing conditions but are not part of an addition
- Added - building features that are being added as part of an addition
- Deleted – existing building features that are being deleted as part of an addition or alteration

This section describes the case where the information about the e+ad+al is contained in a single input file using tags as needed for each zone, opaque surface, fenestration surface, mass surface, etc. Alternate input approaches that provide the information necessary to calculate and provide compliance documentation consistent with the descriptions in this section are allowed with approval from the Commission.

***Proposed Design.*** The user shall indicate that an e+ad+al is being modeled and shall enter the appropriate tags for surfaces or systems. Features to be altered will need to be paired by the compliance software with the existing feature it replaces. The compliance software shall clearly indicate each of the tags on the compliance documentation. To generate the proposed design, the compliance software shall run the calculations using the surfaces and systems that represent the building when the additions and/or alterations are complete. This includes building features that are tagged as existing, altered and added. Features that are being deleted are not included in the proposed design.

When modeling an existing building, the compliance software shall allow the use of the default assumptions specified in Table R3-50 for modeling the existing structure according to the vintage of the existing building. If the user enters higher U-factors, higher F-factors, higher SHGCs, lower efficiencies, or lower energy factors than the vintage defaults from.

Table R3-50 for the existing building's *proposed design*, the compliance software shall report such values as special features in the *Special Features Inspection Checklist*.

***Standard Design.*** Establishing the standard design for e+ad+al approach requires use of the tags entered by the user and, in some circumstances if there are alterations that involve fenestration, a simulation to determine if prescriptive shading requirements are met or exceeded. The resulting e+ad+al standard design is very different from the standard design for newly constructed buildings because it accounts for the energy use of the existing building and for altered features, and is dependent on whether altered features meet the prescriptive alteration requirements. The standard design is determined using the following rules:

- Existing features are included in the standard design
- Deleted features are included in the standard design
- Added features are assigned standard design values in the same manner as for an addition alone, as described above
- Altered features are modeled in the standard design as follows:
  *General Approach*. Each altered feature is compared to the prescriptive requirements in §152(b)1. Fenestration shading and area have additional modeling requirements described below:

If the altered feature meets or exceeds the prescriptive alteration requirements the standard design is the unaltered existing feature (note that the prescriptive alteration requirements are the mandatory requirements for all altered components plus additional prescriptive requirements for altered fenestration, HVAC equipment (refrigerant charge measurement or charge indicator display), and ducts);

Otherwise, the standard design is the prescriptive alteration requirement (i.e., the mandatory requirement for altered components other than altered fenestration, HVAC equipment and ducts, which have additional prescriptive requirements beyond the mandatory requirements).

*Fenestration Shading*. Determining whether the prescriptive alteration requirement for fenestration shading is met may require an annual TDV energy simulation as follows:

For climate zones with an SHGC requirement, where the annual TDV energy for the combination of the proposed altered fenestration and the shading of that altered fenestration by existing overhangs or sidefins is less than or equal to the annual TDV energy due to the prescriptive alteration fenestration shading requirement with no shading from overhangs or sidefins, the standard design is the unaltered existing feature (existing fenestration products plus existing shading). Otherwise, the standard design is the prescriptive alteration requirement.

For climate zones without an SHGC requirement, the standard design is the unaltered existing feature (existing fenestration products plus existing shading).

*Fenestration Area*. The standard design surfaces and areas for the existing plus alteration (fenestration area in an addition is not included in this section) is determined as follows:

If no fenestration area is being added, then the fenestration surfaces in the standard design are the existing fenestration surfaces.

If fenestration area is being added and the existing fenestration area is less than or equal to 20 percent of the existing floor area and the combination of the existing plus added fenestration is less than or equal to 20 percent of the existing plus additional floor area, then the fenestration area in the standard design is 20 percent of the existing plus additional floor area. The fenestration surfaces in the standard design are the existing fenestration surfaces plus the added fenestration surfaces with the added surface areas scaled so that the total area of existing plus added fenestration surfaces equals 20 percent of the existing plus additional floor area. For example, if the existing floor area is 1,600 square feet, the existing fenestration is 300 square feet, the added floor area is 400 square feet, and the added fenestration is 200 square feet, the scaling factor applied to each added fenestration surface would be:

$$\text{ScalingFactor} = \frac{(0.20x(\text{ExistingCFA} + \text{AddedCFA})) - (\text{ExistingFenArea})}{\text{AddedFenArea}}$$

Equation R3-68

$$= \frac{(0.20 \times 2000) - 300}{200} = 0.50$$

Thus, the square footage of each of the new fenestration surfaces would be scaled by a factor of 0.50 to determine the standard design.

Otherwise, if fenestration area is being added and the existing fenestration area is greater than 20 percent of the existing plus additional floor area, then the fenestration surfaces in the standard design are the existing fenestration surfaces.

The resulting standard design inputs are run as a single simulation and the results are compared to the Proposed Design. The energy use of the e+ad+al proposed design shall use equal or less energy than the e+ad+al standard design.

Conceptually, the e+ad+al approach can be described as follows where the right hand side term is calculated in a single simulation:

Equation R3-69

$$EU_{e+ad+al} \leq EU_e + EB_{ad} + EB_{al}$$

Where:

$EU_{e+ad+al}$ = the proposed design energy use of the existing building with all additions and alterations completed

$EU_e$ = the energy use for the unaltered portion of the existing building

$EB_{ad}$ = the standard design energy use for the addition alone

$EB_{al}$ = the standard design energy use of the altered features (= energy use of the unaltered existing feature when the prescriptive alteration requirements, including mandatory requirements, are met or energy use of the prescriptive alteration requirements when the prescriptive alteration requirements are not met).

### 3.17.4 Duct Sealing in Additions and Alterations

§152(a)1 establishes prescriptive requirements for duct sealing in additions and §152(b)1D and §152(b)1E establish prescriptive requirements for duct sealing and duct insulation for installation of new and replacement duct systems and duct sealing for installation of new and replacement space conditioning equipment. Table R3-39 provides Duct Leakage Factors for modeling of sealed and tested new duct systems, sealed and tested existing duct systems, and untested duct systems built prior to and after June 1, 2001. Reference Appendix RA3 provides procedures for duct leakage testing and RACM Table RA3.1.2 provides duct leakage tests and leakage criteria for sealed and tested new duct systems and sealed and tested existing duct systems. These requirements, factors, procedures, tests and criteria apply to performance compliance for duct sealing in Additions and Alterations.

| Condition | Proposed Design | Standard Design |
|---|---|---|
| Additions Served by Entirely New Duct Systems | The proposed design shall be either sealed and tested new duct systems or untested duct systems. | The standard design shall be sealed and tested new duct systems. |
| Additions Served by Extensions of Existing Duct Systems | The proposed design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems in homes built after June 1, 2001; or 4) untested duct systems in homes built prior to June 1, 2001. | The standard design shall be sealed and tested existing duct systems. |
| Alterations with Prescriptive Duct Sealing Requirements when Entirely New Duct Systems are Installed | The proposed design shall be either 1) sealed and tested new duct systems; 2) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001. | The Prescriptive Alteration Requirement is sealed and tested new duct systems. Determine the standard design by the standard design rules in Section 3.16.4. |
| Alterations with Prescriptive Duct Sealing Requirements when Existing Duct Systems are extended or replaced or when new or replacement air conditioners are installed | The proposed design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001. | Prescriptive Alteration Requirement is sealed and tested existing duct systems. Determine the standard design by the standard design rules in Section 3.16.4. |
| Alterations for which Prescriptive Duct Sealing Requirements do not apply | The proposed design shall be either 1) sealed and tested new duct systems, if the new duct system or the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001. | The standard design shall be either 1) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001. |

*Table R3-50 – Default Assumptions for Existing Buildings*

| | **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 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 –CrawlSp | 0.099 | 0.099 | 0.099 | 0.046 | 0.046 | 0.046 | 0.046 | 0.046 |
| Cool Roofing Products | 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 CrawlSp | 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 Table 116-A - Title 24, Part 6, Section 116 for all Vintages | | | | | | | |
| SHGC | Use Table 116-B - Title 24, Part 6, Section 116 for all Vintages | | | | | | | |
| Shading Dev. | Use **Table R3-28** for all Vintages | | | | | | | |
| 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 |

Roofs shall assume the properties of the proposed design.

Ceiling shall assume the properties of the proposed except the R-value shall be determined by the 1/U-factor for the value provided in the table above.

# 4. Minimum Capabilities Tests

This chapter describes the methods used to test the minimum modeling capabilities of candidate compliance software programs. There are separate tests for space conditioning tests and water heating tests. Most of the space conditioning tests are performed using a simple square building prototype (see Figure R4-7). The water heating tests are performed relative to two prototype water heating systems. Most of the tests are performed in only five climate zones, but some are performed in all sixteen climate zones. Tests may be modified, added, or requested to be preformed with fixed inputs to verify specific modeling features.

## 4.1 Overview

Two types of tests are performed: accuracy tests and standard design generator tests (or custom budget tests). While compliance software programs shall pass all these tests, the Energy Commission, at its discretion, may require additional tests to justify the accuracy of the candidate compliance software to confirm other required features.

### 4.1.1 Accuracy Tests

This section describes the general testing concept that is used for the accuracy tests. For the prototype buildings and the specified variations, candidate compliance software programs shall generate an estimate of TDV energy and this is compared to the TDV energy that is estimated with the reference method. The TDV energy of the candidate compliance software shall be within an acceptable tolerance of the reference method in order for the compliance software to pass the test. The margin of acceptability is defined below and may change for each group of tests. For the space conditioning tests, only the TDV energy for space conditioning is considered and for the water heating test only the TDV for water heating is considered.

#### 4.1.1.1 General Procedure

**Basecase**. Each test begins with a prototype building or system that exactly complies with the prescriptive criteria (package D); this is the basecase building or system. The basecase has a zero compliance margin, e.g. it exactly complies with the standard. In another parlance, it is the custom budget building.

**Discrete Modifications**. A set of discrete modifications are then made to the basecase building or system, e.g. the ducts are sealed, walls and ceilings are field verified for good construction quality or a different type of heating or cooling equipment is installed. The discrete modifications are defined for each test and may vary slightly for each climate zone identified for the test. The discrete modifications are selected to represent important compliance measures. The discrete modifications will either improve or degrade the TDV energy performance of the basecase building, e.g. the compliance margin of the modified basecase will become either positive or negative.

**Continuous Variable**. A continuous variable, which is identified for each test, is then increased or reduced so that the modified basecase complies by a specified tolerance and fails by a specified tolerance. The continuous variables have a predictable and continuous impact on the TDV energy of the proposed design. Examples are SEER, AFUE, and glass area (above 20 percent of the floor area). The value for the continuous variable that causes the modified basecase to pass by the specified tolerance is the "passing solution" and the value that causes failure by the specified tolerance is the "failing solution". The "failing solution" shall result in TDV energy as close as possible to the negative tolerance, but shall be greater than the negative tolerance. The "passing solution" shall result in TDV energy as close as possible to the positive tolerance but shall be less than the positive tolerance. The positive and negative tolerances are defined for each test, but in general they are 1.0 kTDV/ft²-y or 3 percent of the baseline TDV energy whichever is greater.

The procedure is illustrated in Figure R4-1 through Figure R4-4. In these diagrams, the base case building is represented by point "A". The vertical axis represents the compliance margin with a positive compliance margin (building or system passes) above the horizontal axis and a negative compliance margin (building or system fails) below the horizontal axis. Figure R4-1 and Figure R4-3show instances when the discrete modifications produce a positive compliance margin and Figure R4-2 and Figure R4-4 are examples of discrete modifications that produce a negative compliance margin. When the discrete modifications produce a change in TDV energy that is within the specified tolerances, the passing solution or failing solutions are equal to the basecase value of the continuous variable. This situation is illustrated in Figure R4-3 and Figure R4-4.

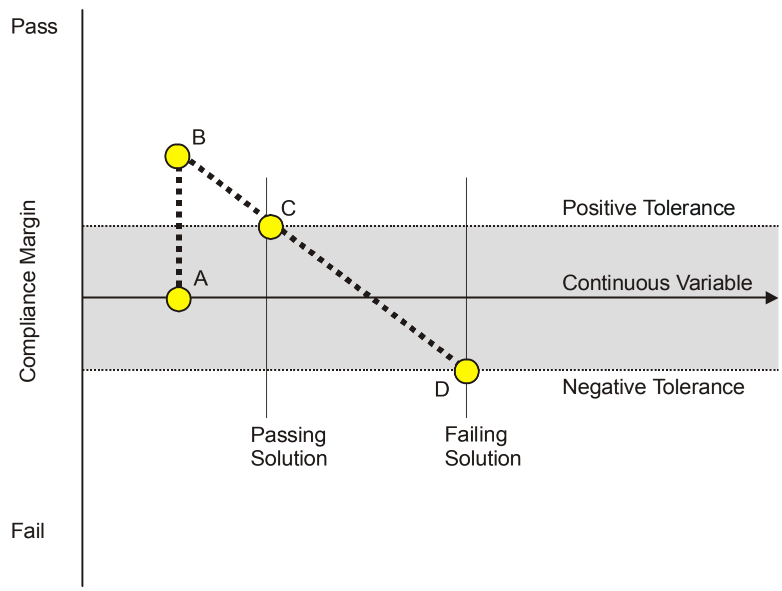



*Figure R4-1 – Testing Concept – Discrete Modifications Produce Positive Compliance Margin*
*The discrete modifications produce a positive compliance margin that exceeds positive tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.*

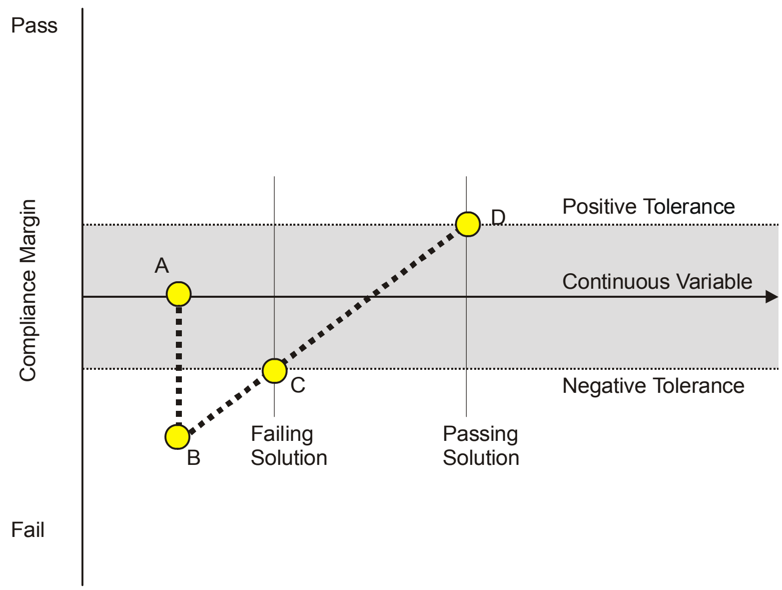



*Figure R4-2 – Testing Concept – Discrete Modifications Produce Negative Compliance Margin*
*The discrete modifications produce a negative compliance margin that exceeds negative tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.*

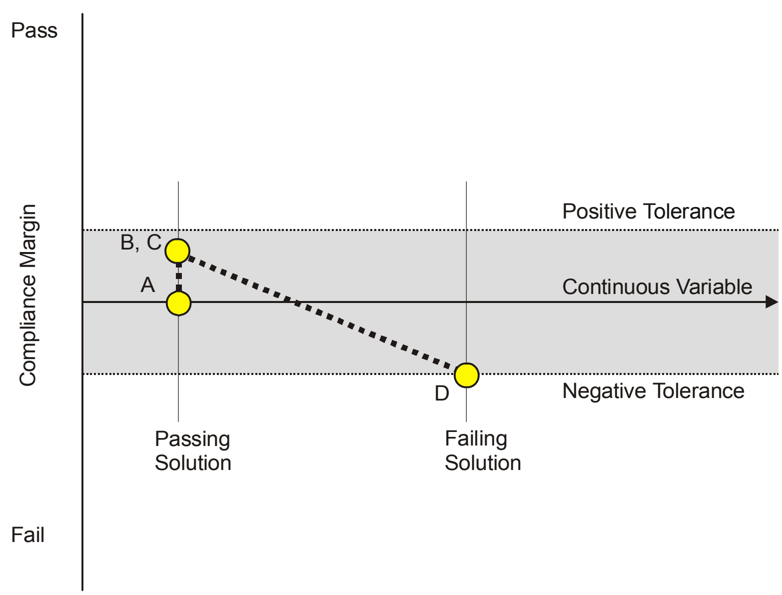



*Figure R4-3 – Testing Concept – Discrete Modifications Produce Positive But Small Compliance Margin*
*The discrete modifications produce a positive compliance margin that is less than the positive tolerance. The passing solution for the continuous variable is equal to the basecase; the failing solution is determined by the vendor..*

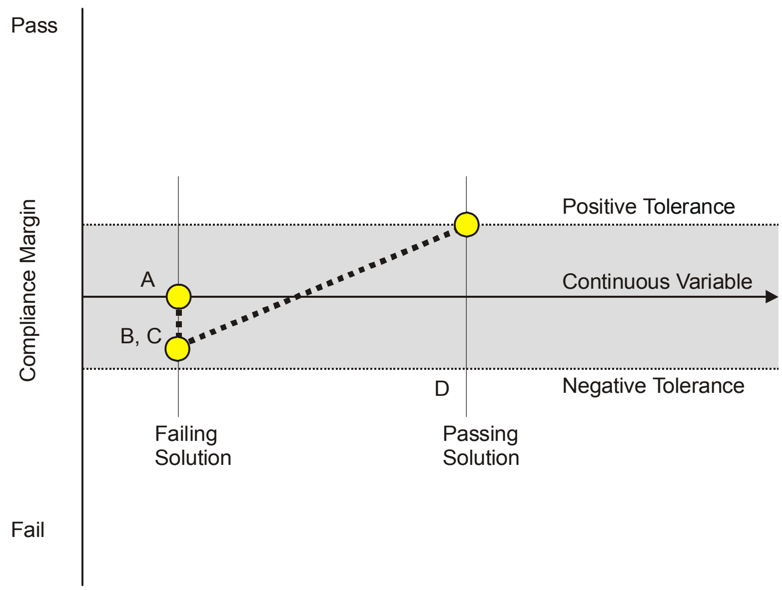



*Figure R4-4 – Testing Concept – Discrete Modifications Produce Negative But Small Compliance Margin*
*The discrete modifications produce a negative compliance margin that is within the negative. The failing solution for the continuous variable is equal to the basecase; the passing solution is determined by the vendor.*

#### *4.1.1.2 Acceptance Criteria*

For every test, the Energy Commission reference method shall pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered. The acceptance criteria shall be satisfied for all tests. In addition to producing estimates that are within the tolerances, the tests are also used to verify that the standard reports are correctly produced, as required in Chapter 2. For instance, many of the discrete modifications trigger measures that shall be listed in the "Special Features and Modeling Assumptions" section of the Certificate of Compliance. Finally, the tests will be used to verify that the standard design building is correctly defined, as specified in Chapter 3.

### 4.1.2 Standard Design Tests

The acceptance criteria for the standard design generator tests use a different approach from the accuracy tests. Two types of tests are used to verify that the standard design is created according to the rules specified in Chapter 3: These are defined below along with the acceptance criteria for each.

#### *4.1.1.3 Standard Design Equivalent Tests*

The standard design equivalent tests consist of matched pairs of computer runs: a proposed design and its standard design equivalent. The standard design equivalent is the proposed design reconfigured according to the standard design rules in Chapter 3 to be in exact compliance with the prescriptive requirements (package D). The compliance software vendor is required to create the proposed design and standard design equivalent input files and submit them with the application for approval.

Two Certificates of Compliance are produced: one for the proposed design and one for the standard design equivalent. The standard design TDV energy budget on the proposed design Certificate of Compliance shall be equal to the TDV energy use shown in both the standard design energy budget and proposed design columns of the standard design equivalent computer run. See Figure R4-5.

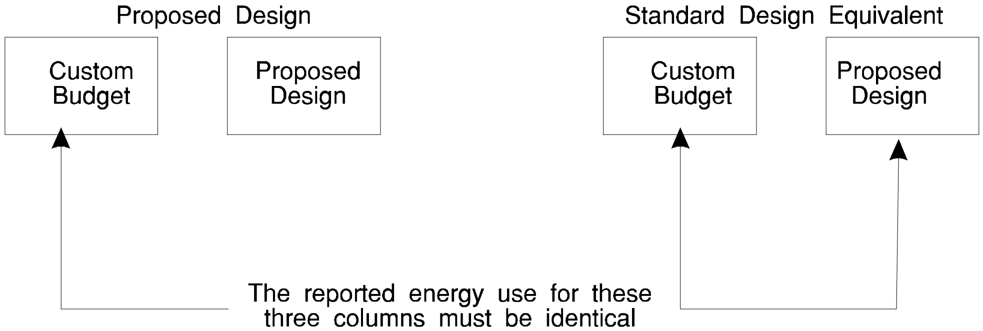



*Figure R4-5 – Custom Budget Tests*

#### *4.1.1.4 Neutral Variable Tests*

The second series of standard design equivalent tests are the neutral variable tests. Neutral variables are building features that are unchanged between the standard design and the proposed design. An example of a neutral variable is glass area, below the prescriptive limit of 20 percent. In this series of tests, a change is specified in one of the neutral variables and the compliance margin has to remain within a certain tolerance.

### 4.1.3 Labeling Tests and Computer Simulations

Each of the tests has a specific label that includes the test series, the number of the test, the prototype used in the test and the climate zone for which the test is performed. Using a precise designation to make it easier to keep track of the many computer simulations will ease the Energy Commission review process. The following labeling scheme described in Figure R4-6 shall be used:

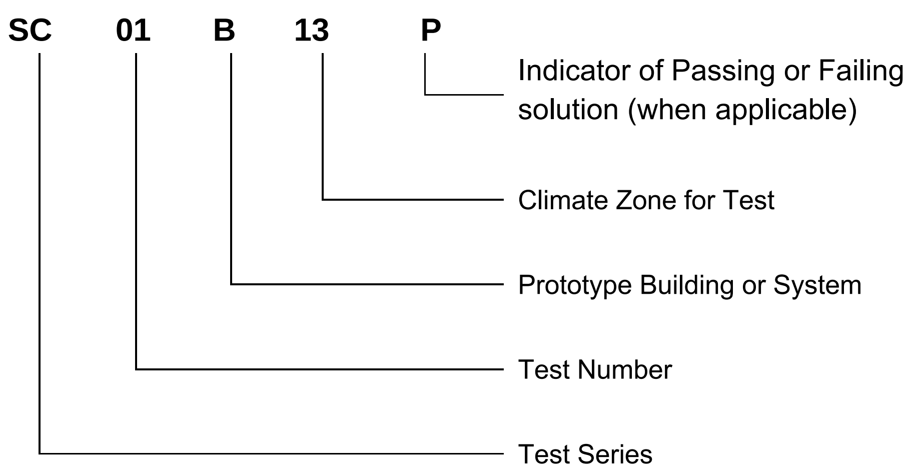



*Figure R4-6 – Labeling of Computer Simulations*

Compliance Software input and output files shall use the same labeling scheme, but with a “P” or “F” concatenated on the end to indicate if the file represents the passing or failing solution.

### 4.1.4 Documentation

The compliance software vendor shall record the results of the tests on the forms provided in RACM Appendix A- and provide electronic copies of the input files to the Energy Commission. The filenames shall include the test label (see below) with a “P” or “F” concatenated to the file name to indicate if the file represents the passing solution or the failing solution. The form (RACM Appendix A-) includes an entry for the TDV energy for the passing solution and the failing solution. The forms also include the continuous variable values for the passing and failing solutions as well as the compliance software filenames for the passing and failing cases.

## 4.2 Space Conditioning Tests

This section describes the space conditioning tests that shall be performed by the compliance software vendor. Three groups of tests are described. The first verify that space conditioning TDV energy is predicted with an acceptable tolerance of that predicted by the reference method. The second series of tests verify that the custom budget or standard design is correctly defined. The third series of tests verify that the compliance software calculates TDV energy correctly for additions and alterations to low-rise residential buildings.

### 4.1.5 Accuracy Tests (SC)

The accuracy tests verify that the candidate compliance software passes and fails buildings in a manner consistent with the reference method.

#### 4.2.1.1 Prototype Buildings

The space conditioning accuracy tests are performed with two prototype buildings. The geometry of the prototype buildings and other features are described below and illustrated in Figure R4-7. The attic is not shown in Figure R4-7 since the dimensions and configuration of the attic are determined by the ceiling area.

Both prototype A and B are a square box measuring 40 ft by 40 ft and 10 ft tall. A single 80 ft² window on each façade (total window area is 20 percent of the floor area). The facades face exactly north, east, south and west. The thermal performance of all building envelope elements is in exact compliance with the prescriptive requirements (package D in the standards). The prototypes have a gas furnace and a split system air conditioner with air distribution ducts located in the attic.

A Prototype A has a slab-on-grade.

B Prototype B has raised floor construction.

*Figure R4-7 – Prototype Buildings A and B*

#### 4.2.1.2 Test Descriptions

Table R4-51 describes each of the space conditioning tests that shall be performed. The space conditioning accuracy tests use the series designation “SC.”

*Table R4-51 – Summary of the Space Conditioning Tests*

| *Series* | *Number* | *Prototypes* | *Climates* | *Discrete Modification(s)* | *Continuous Variable* |
|---|---|---|---|---|---|
| SC | 0 | A, B | All | None | None |
| | | | | | |
| SC | 01 | A | 3, 9, 12, 14, 16 | **Ceiling U-factor**. Reduce the ceiling U-factor from the basecase condition to R-48. The U-factor for this condition shall be taken from Reference Joint Appendix JA4. Do not assume field verification for construction quality. Produces a positive compliance margin. | **South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution. |
| SC | 02 | A | 3, 9, 12, 14, 16 | **Wall U-factor**. Increase wall insulation to the equivalent of R-22 in a 2x6 wood framed cavity with R-14 continuous insulation. The U-factor for this condition shall be taken from Reference Joint Appendix JA4. Do not assume field verification for construction quality. Produces a positive compliance margin. | **West Glass Area**. Increase west glass area to find the Passing Solution and the Failing Solution. |
| SC | 03 | A | 12, 14, 16 | **Slab edge losses**. Add R-7 slab insulation for climate zones 12 and 14. In climate zone 16, increase slab edge insulation from the basecase R-7 to R-21. Produces a positive compliance margin. | **North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution. |
| SC | 04 | A | 3, 9, 12, 14, 16 | **Fenestration Type**. Replace the basecase fenestration with a super high performance product with a U-factor of 0.25 and a SHGC of 0.40. Produces a positive compliance margin. | **North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution. |
| SC | 05 | A | 3, 9, 12, 14, 16 | **Fenestration Type**. Replace the basecase fenestration with a product that fails to comply with the package D requirements. The replacement product shall have a U-factor of 0.90 and an SHGC of 0.70. Produces a negative compliance margin. | **AFUE**. Increase or reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| SC | 06 | A | 12, 14, 16 | **Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin. | **South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution. |
| SC | 07 | A | 3, 9, 12, 14, 16 | **South Overhangs**. Add a two foot projection from the surface of the south glass. Its bottom edge is located six inches above the top of the window. The window is assumed to be 6 ft 6 in. high and the overhang is assumed to extend an infinite distance beyond the sides of the windows (see Figure R4-8). Produces a positive compliance margin. | **South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution. |
| SC | 08 | A | 3, 9, 12, 14, 16 | **Building Envelope Sealing**. Reduce the building (SLA) from 4.9 to 2.9 through diagnostic testing and sealing. Produces a positive compliance margin. | **Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 09 | A | 3, 9, 12, 14, 16 | **Building Envelope Sealing and Mechanical Ventilation**. The building leakage (SLA) is reduced from 4.9 to 2.9 through diagnostic testing and sealing. In addition, mechanical ventilation is added that provides 80 cfm (0.375 air changes per hour) of continuous ventilation and consumes 20 watts of power continuously. Produces a positive compliance margin. | **Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 10 | A | 3, 9, 12, 14, 16 | **Construction Quality**. Assume that the proposed design has been field verified to have quality wall and ceiling insulation quality. Produces a positive compliance margin. | **AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| SC | 11 | A | 9, 12, 14 | **Cool Roofing Products / Radiant Barrier**. Remove the radiant barrier (or equivalent cool roof) from the proposed design. Produces a negative compliance margin. | **SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution. |

| *Series* | *Number* | *Prototypes* | *Climates* | *Discrete Modification(s)* | *Continuous Variable* |
|---|---|---|---|---|---|
| SC | 12 | A | 9, 12, 14 | **Side Fins**. For this test side fins are added to the east and west facades of prototype A. The side fins extend 40 feet from the surface of a window that is assumed to be 10 feet wide. The fins are 5 feet from the edge of the window. The top of the side fins are 20 feet above the top of the window. See Figure R4-9. Sidefins are expected to produce a positive compliance margin. | **SEER**. Vary the SEER (keep EER at the default) to find the passing solution and fail the failing solution. |
| SC | 13 | A | 9, 12, 14 | **Natural Ventilation**. Change the window types to increase the free ventilation area from the default of 10% of the total window area to 20% of the window area, and assume a 10 ft elevation difference between the air inlet and the outlet. Produces a positive compliance margin. | **SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution. |
| SC | 14 | A | 9, 12, 14 | **Roofing Type** Change roofing type from tile to composition shingles. Produces a negative compliance margin. | **Attic Ventilation**. Increase the attic ventilation to find the Passing Solution and the Failing Solution. |
| SC | 15 | A | 9, 12, 14 | **Deck Insulation** Add R-4 insulation to the roof deck.. Produces a positive compliance margin | **Ceiling Insulation**. Reduce the ceiling insulation to find the Passing Solution and the Failing Solution. |
| SC | 16 | A | 3, 9, 12, 14, 16 | **SEER**. Increase the cooling equipment efficiency (SEER) from the base case condition of 13.0 to 14.0. Use the default EER for both the SEER 13.0 and SEER 14.0 cases. Make no changes to the air distribution system or other HVAC system components. Produces a positive compliance margin. | **AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| SC | 1 | A | 3, 9, 12, 14, 16 | **EER**. Increase the cooling equipment efficiency (SEER) from the base case condition of 13.0 to 14.0. Use an EER 13 for the SEER 14.0 case. Make no changes to the air distribution system or other HVAC system components. Produces a positive compliance margin. | **SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 18 | A | 3, 9, 12, 14, 16 | **Duct Leakage**. Do not seal the ducts as required by the prescriptive standards. Produces a negative compliance margin. | **SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution. |
| SC | 19 | A | 3, 9, 12, 14, 16 | **Duct Surface Area.** Through diagnostic verification, reduce duct surface area from the default of 27% of the floor area to 10% of the floor area. Produces a positive compliance margin. | **SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution. |
| SC | 20 | B | 9, 12, 14 | **Duct Location.** Move the HVAC ducts from the crawlspace (the default for one story, raised floor buildings) to the attic. Produces a negative compliance margin. | **SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution. |
| SC | 21 | B | 9, 12, 14 | **Buried Ducts.** Change the status of the ducts to deep buried. Produces a positive compliance margin. | **AFUE**. Decrease the AFUE to find the Passing Solution and the Failing Solution. |
| SC | 22 | B | 9, 12, 14 | **Change HVAC type.** Replace the existing furnace with a heat pump. Change the HSPF to 9 and the SEER to 14. Produces a positive compliance margin. | **HSPF** Decrease the HSPF to find the Passing Solution and the Failing Solution. |
| SC | 23 | A | 9, 12, 14 | **Duct Insulation.** Reduce the duct R-value from the R-8 prescriptive requirement to R-4.2. Produces a negative compliance margin. | **SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution. |
| SC | 24 | A | 9, 12, 14 | **Energy Efficiency Ratio (EER)**. Instead of using the default EER of 10.415 for the default SEER 12 assume an EER of 11.5 with the same SEER of 12). Produces a positive compliance margin. | **SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 25 | A | 9, 12, 14 | **Charge Indicator Light / Charge Testing**. Do not install a Charge Indicator Light and do not field verify that the split system has the correct refrigerant charge. Produces a negative compliance margin. | **SHGC**. Reduce the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution. |

| *Series* | *Number* | *Prototypes* | *Climates* | *Discrete Modification(s)* | *Continuous Variable* |
|---|---|---|---|---|---|
| SC | 26 | A | 9, 12, 14 | **Airflow Across Evaporator Coil**. Verify through field verification that there is adequate airflow for compliance credit (350 cfm/ton for a wet coil) across the evaporator coil. Produces a positive compliance margin. | **SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 27 | A | 9, 12, 14 | **Air Conditioner Fan Power**. Reduce fan power through field verification. The default is 0.51 W/cfm. Reduce this to 0.20 W/cfm. Produces a positive compliance margin. | **SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution. |
| SC | 28 | A | 3, 9, 12 | **Electric Heat**. Replace the gas furnace and air distribution system in the basecase with electric resistance baseboards (no air distribution or duct losses). In addition, increase the ceiling insulation to R-60. The U-factor for this condition shall be taken from Reference Joint Appendix JA4 Do not assume field verification for construction quality. Produces a negative compliance margin. | **Fenestration U-factor**. Reduce the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution. |

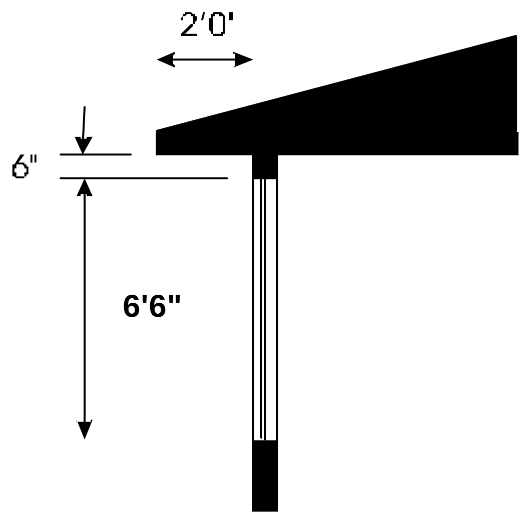



*Figure R4-8 – Overhang Characteristics*

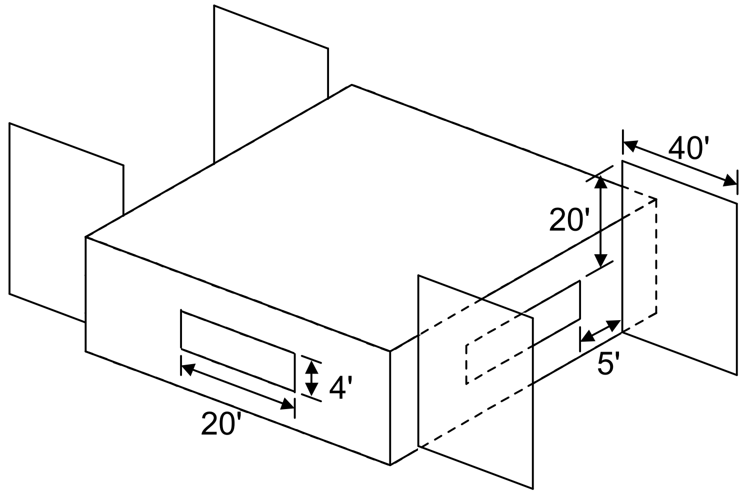



*Figure R4-9 – Side Fins for Optional Capabilities Test*
*The north and south façades are the ones that do not have the sidefins.*

#### *4.2.1.3 Acceptance Criteria*

The positive tolerance is the basecase TDV energy for space conditioning plus 3 percent or 1 kTDV/ft²-y, whichever is greater. The negative tolerance is the basecase TDV energy for space conditioning less 3 percent or 1 kTDV/ft²-y, whichever is greater. The Energy Commission reference method shall pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered.

In addition to producing estimates that are within the tolerances, the tests are also used to verify that the standard reports are correctly produced, as required in Chapter 2. For instance, many of the discrete modifications trigger measures that shall be listed in the "Special Features and Modeling Assumptions" section of the Certificate of Compliance.

### 4.1.6 Standard Design Generator Tests (*SD*)

This section describes the standard design tests that shall be performed by the compliance software vendor. The standard design tests use the series designation "SD." Compliance software shall automatically create the standard design building, as defined in Chapter 3. The standard design run is made automatically at the same time as the proposed design run, and the results are reported together on the Certificate of Compliance discussed in Chapter 2. The tests described in this section verify that the standard design is correctly defined for the proposed design and that the custom budget is correctly calculated. These tests supplement the SC tests, which also verify certain standard design features.

#### *4.2.1.4 Prototypes Buildings*

The custom budget tests use three prototype buildings as described below.

C Prototype C is a 2,100 ft², one -story, single-family detached home. Two versions of this prototype are used in the tests. One has a slab floor and one has a raised floor. Details are available from the Energy Commission.

D Prototype D is a 2,700 ft², two-story detached home. Details are available from the Energy Commission.

E Prototype E is an eight-unit, two-story multi-family building, with a total conditioned floor area of 6,960 ft². Details are available from the Energy Commission.

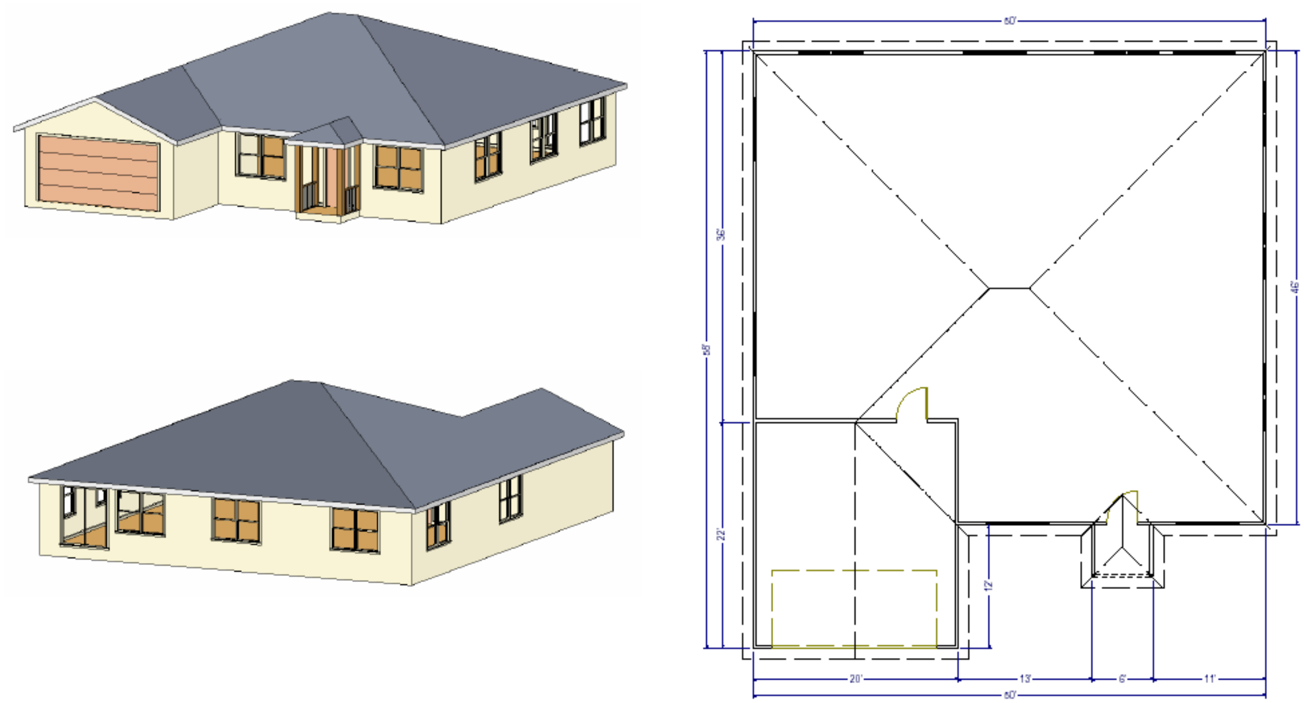



*Figure R4-10 – Prototype C*

Figure R4-11 – Prototype D

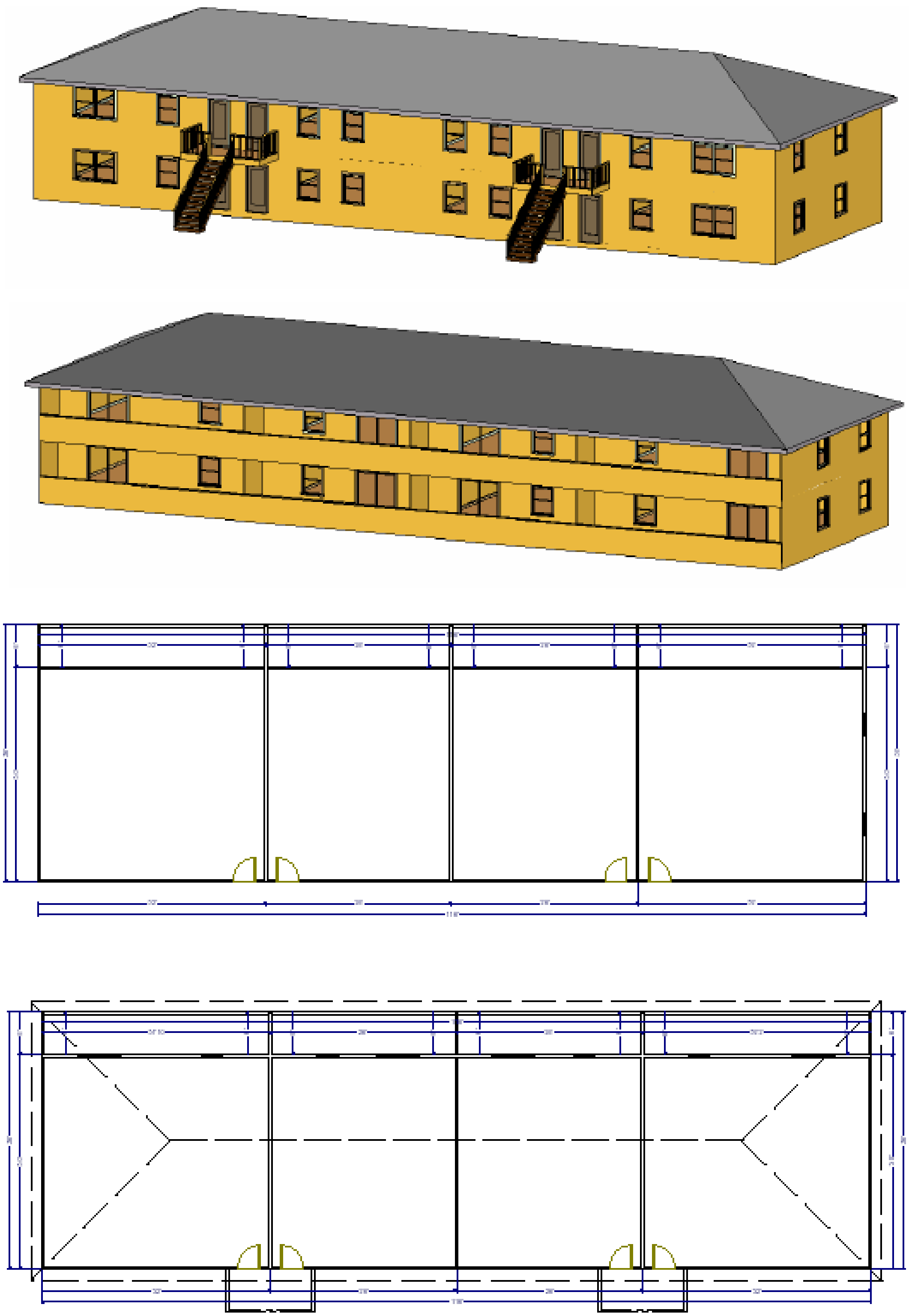


Figure R4-12 – Prototype E

#### 4.2.1.5 Standard Design Equivalent Tests

The standard design equivalent tests are described in Table R4-52. For each of these tests, the standard design equivalent budget and proposed design TDV energy shall equal each other. In addition, the TDV energy shall equal the budget TDV energy for the proposed building.

*Table R4-52 – Standard Design Tests*

| *Series* | *Number* | *Prototypes* | *Climates* | *Description* |
|---|---|---|---|---|
| SD | 00 | A, B | All | **Basecase Prototypes**. These tests were also performed in the SC series. For each of these tests, the standard design and proposed design TDV energy shall be equal. There is no proposed design case for these tests. |
| *SD* | 01 | C | All | **Slab-On-Grade**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using slab-on-grade designs. The “SC01C**” files are run in all 16 climate zones. |
| *SD* | 02 | D | All | **Raised Floor**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using raised floor buildings. The “SC01D**” files are run in all 16 climate zones. |
| *SD* | 03 | E | All | **Multi-Family.** The purpose of this test is to verify that the standard design generator correctly defines the standard design for multi-family buildings. The “SC01E**” files are run in all 16 climate zones. |
| *SD* | 04 | A | All | **Equipment Change Heating**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using non ducted mechanical systems. The “SC01D**” files are run in all 16 climate zones. Heating equipment is switched to Gas Wall heater with 0.62 AFUE no ducts. |
| *SD* | 05 | A | All | **Equipment Change Cooling**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using non ducted mechanical systems. The “SC01D**” files are run in all 16 climate zones. Cooling equipment is switched to Wall AC with a 10 EER. |

#### *4.2.1.6 Neutral Variable Tests*

The neutral variable tests are described in Table R4-53. For each of these tests, the compliance margin shall remain within one percent of zero.

*Table R4-53 – Neutral Variable Design Tests – Space Conditioning*

| *Series* | *Number* | *Prototypes* | *Climates* | *Description* |
|---|---|---|---|---|
| SD | 06 | A | 3, 9, 12, 14, 16 | **Window Area**. Reduce window area from 20% of the floor area to 15% of the floor area. Reduce the size of the window on each façade to 60 ft². Do not change any other features. |
| SD | 07 | A | 3, 9, 12, 14, 16 | **Wall Area.** Increase the gross wall area on each façade from 400 ft² to 600 ft². |

### 4.1.7 Additions and Alternations (AA)

This section describes the tests for alternations and additions that shall be performed by the compliance software vendor. The additions and alternations tests use the series designation “AA.”

Additions are treated as new buildings except that internal heat gains are allocated on a fractional dwelling unit basis. With the Addition + Existing + Alternation approach, energy credit may be taken for improvements to the existing building. This series of tests exercises the various default assumptions (see Table R3-50 in Section 3.16.4) based on the vintage of the existing building and the various reporting requirements for modeling an addition with an existing building. In addition, these tests verify the proper determination of the energy budget and compliance criteria for an addition with an improved existing building.

#### *4.2.1.7 Prototype Buildings*

The prototype used in these tests consists of an existing building and an addition. The existing building has the same physical configuration as Prototype A but the thermal performance of building envelope components is downgraded to be more typical of older existing buildings. Prototype E (Figure R4-12) has the thermal characteristics of 1977 construction practice and Prototype F has the thermal characteristics of 1989 construction practice. See the Additions and Alternations section of Chapter 3 for details on construction assemblies. Each window is 4 ft high and 20 ft wide centered on the façade. The addition is 12 ft deep by 40 ft long and 10 ft high and covers the whole west side of the existing building.

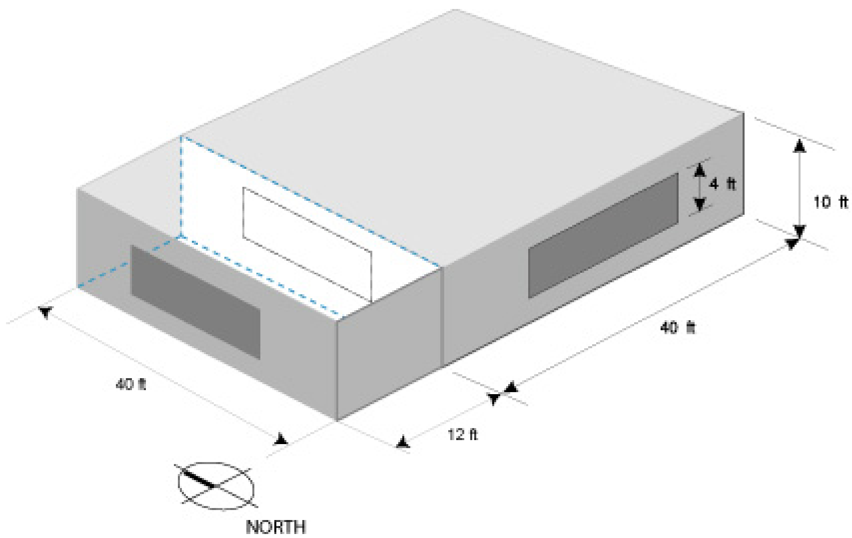



*Figure R4-13 – Prototypes E and F*

#### *4.2.1.8 Test Descriptions*

These tests are also be used to confirm that reporting requirements are met when modeling an addition with an existing building and that the appropriate budgets have been correctly determined. Two of the three compliance approaches for additions and alternations are evaluated with these tests: the addition-alone approach and the Existing + Addition + Alteration approach. The whole building approach is not evaluated since this is identical to new construction.  Table R4-54 describes the tests to perform with the Addition-Alone approach. Table R4-55 describes the tests to perform with the Existing + Addition + Alteration approach.

*Table R4-54 – Summary of the Addition-Alone Tests*

| Series | Number | Prototypes | Climates | Discrete Modification(s) | Continuous Variable |
|---|---|---|---|---|---|
| AA | 01 | E<br>1977 | 3, 9, 12, 14, 16 | **Baseline**. The features of the addition shall all exactly meet the prescriptive requirements. The addition is served by an HVAC system in the existing house. | **None**. This is a standard design generator test. |
| AA | 02 | E<br>1977 | 3, 9, 12, 14, 16 | **Increase Glass**. Increase fenestration area on the west side of the addition to 144 ft². This discrete change will fail compliance because the glass area exceeds 20% of the floor area. | **Fenestration Area U-factor**. Reduce the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution. |
| AA | 03 | F<br>1989 | 3, 9, 12, 14, 16 | **New HVAC**. Install a separate minimal efficiency HVAC split system gas/electric system for the addition that has no duct testing. This will create a negative compliance margin. | **Duct Testing/Insulation**. Change the assumption to duct testing and increase the duct insulation until a failing and passing compliance margin are met. |

*Table R4-55 – Summary Existing + Addition + Alternation Tests*

| Series | Number | Prototypes | Climates | Discrete Modification(s) | Continuous Variable |
|---|---|---|---|---|---|
| EA | 1 | E<br>1977 | 3, 9, 12, 14, 16 | **Baseline**. The features of the addition shall all exactly meet the prescriptive requirements. The addition is served by an HVAC system in the existing house. Remove 80 ft² from the existing west wall and include 80 ft² with the addition (no net increase in glass area) | **None**. This is a standard design generator test. |
| EA | 2 | E<br>1977 | 3, 9, 12, 14, 16 | **Increase Glass**. Increase fenestration area on the west side of the addition to 144 ft². This discrete change will fail compliance because the glass area exceeds 20% of the floor area. | **Fenestration U-factor**. Reduce the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution. |
| EA | 3 | F<br>1989 | 3, 9, 12, 14, 16 | **New HVAC**. Install a separate HVAC split system gas/electric system for the addition that has an SEER of 14 and an EER of 13. This will create a positive compliance margin. | **Fenestration U-factor**. Increase the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution. |
| EA | 04 | E<br>1977 | 3, 9, 12, 14, 16 | **New Ducts.** Install new ducts in an alteration with no duct testing and no duct insulation.. This will create a negative compliance margin. | **Duct Insulation.** Change the assumption to duct testing and increase the duct insulation until a failing and passing compliance margin are met. |

#### 4.2.1.9 Acceptance Criteria

For each test, the Energy Commission reference method shall pass the addition plus existing building when data for the passing solution is entered and fail the addition plus existing building when data for the failing solution is entered. The positive tolerance is the TDV space conditioning energy for the basecase plus 3 percent or 1 kBtu/ft²-y, whichever is greater, and the negative tolerance is also 3 percent or 1 kBtu/ft²-y, whichever is greater. In addition to producing estimates that are within the tolerances, the Energy Commission will also verify that the correct performance factors are used, based on the vintage of the existing building, and that the standard reports are correctly produced, as required in Chapter 2.

## 4.3 Water Heating Tests (WH)

This section describes the water heating tests that shall be performed by the compliance software vendor. The water heating tests use the series designation “WH”. The water heating tests are defined in a similar manner as the space conditioning tests, except that the tests are performed relative to a water heating system, not whole building TDV energy. See the Overview section of this chapter for a description of the procedures. For the water heating tests, only the TDV energy for water heating is considered in the comparison.

### 4.1.8 Prototype Systems

Two prototype water heating systems are used. The first is a system which serves the single family home represented by space conditioning prototype C (the water heating system also uses the “C” designation). The second is a system that serves the multi-family apartment building represented by prototype E (this uses the “E” designation). More information on the buildings served is provided above in the prototype descriptions for the space conditioning tests. The water heating systems for the two prototypes are described in Table R4-56.

*Table R4-56 – Base Case Water Heating Systems*

| Prototype | Prototype C | Prototype E |
|---|---|---|
| **Building Information** | | |
| Dwelling Units | 1 | 16 |
| Total Building Area | 2,100 ft² | 6,960 ft² |
| Average Dwelling Unit Size | 2,100 ft² | 870 ft² |
| **Water Heating Equipment** | | |
| Number of Water Heaters | 1 | 4 |
| Water Heater Type | Storage Gas (SG) | Large Storage Gas (SG) |
| Energy Factor/Thermal Eff/Standby | 0.575 | 0.80/700 Btu/h per unit4 |
| Tank Size | 50 | 4 @ 100 |
| Distribution System | Standard (PIK) | Recirculation with timer controls |
| **Multi-Family Recirculation System** | | |
| Linear Feet of Pipe (Note 1) | n.a. | 200 |
| PF Outdoor Air | n.a. | 0.10 |
| PF Ground | n.a. | 0.20 |
| PF Conditioned or semi-conditioned air within the building envelope | n.a. | 0.70 |
| Pipe Diameter for Recirculation System | n.a. | 1.5 in. |
| Recirculation Pipe Insulation | n.a. | 1.0 in. |
| Pump Size (brake horsepower) | n.a. | ½ hp |
| Pump Motor Efficiency | n.a. | 0.85 |
| Note 1. Total Linear feet used for recirculation between dwelling units (input to Section 3.15). PF is the fraction of the total linear feet that is used either outside, in the ground, or in the conditioned or semi-conditioned air within the building envelope, as defined in RACM Appendix E4. | | |

### 4.1.9 Accuracy Tests (WH)

As described in the Overview of this chapter, the compliance software vendor shall find the passing and failing solution for each test described in Table R4-57. The Energy Commission reference method shall then pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered. The acceptance criteria shall be satisfied for all tests. The water heating tests use a 2 percent passing tolerance and a 2 percent failing tolerance, or 1.0 kTDV/ft²-y, whichever is greater.

*Table R4-57 – Accuracy Tests – Water Heating*

| *Type* | *Test* | *Prototypes* | *Climates* | *Discrete Modification(s)* | *Continuous Variable* |
|---|---|---|---|---|---|
| WH | 0 | C, E | All | None | None |
| WH | 1 | C | | **Discribution Type** Add uncovered below grade plumbing to the distribution system. Produces a negative compliance. | **Energy Factor Increase** the EF for the water heater until the passing and failing solutions are reached |
| WH | 2 | C | 3, 9, 12, 14, 16 | **Electric Instantaneous Water Heater.** Change the water heater type from gas storage to electric Instantaneous and use a point of use (POU) distribution system. This produces a negative compliance margin. | **Solar Savings Fraction (SSF).** Increase the SSF to find the passing and failing solutions. |
| WH | 3 | C | 3, 9, 12, 14, 16 | **Recirculation Control.** Change the distribution system from the default to demand recirculation with manual control. This produces a positive compliance margin. | **Energy Factor.** Reduce the EF of the water heater until the passing and failing solutions are reached. |
| WH | 4 | E | 3, 9, 12, 14, 16 | **Recirculation Control.** Add monitored system controls (MCS) for the recirculating system. This produces a positive compliance margin. | **Thermal Efficiency**. Decrease thermal efficiency (recovery efficiency or AFUE) until the failing solution is reached. |
| WH | 5 | C | 3, 9, 12, 14, 16 | **Large Storage Water Heater.** Change water heater type to a 80 gallon large gas storage, SBL of 800 btuhr, thermal (recovery) efficiency= 0.80 | **Thermal Efficiency.** Increase thermal efficiency (recovery efficiency or AFUE) until the passing solution is reached. |
| | | | | | |
| WH | 7 | C | 3, 9, 12, 14, 16 | **Number of Water Heaters.** Use 2 water heaters for the single residence; both are the same size and performance as the basecase. This will produce a negative compliance margin | **Energy Factor.** Increase the energy factor of both water heaters together to find passing and failing solutions. |
| WH | 8 | E | 3, 9, 12, 14, 16 | **Pump Controls.** Baseline assumes timer pump controls. Change to no pump control. This produces a negative compliance margin. | **Thermal Efficiency.** Increase thermal efficiency (recovery efficiency or AFUE) until the passing and failing solution is reached. |

### 4.1.10 Standard Design Tests (WD)

This section describes a series of tests that verify that the standard design is being correctly defined for water heating systems. The acceptance criteria for these tests are different from the accuracy tests. For this series of tests, a change is defined, which according to the rules for defining the standard design should be neutral. Being neutral means that the change is reflected for both the standard design and the proposed design. The compliance margin shall be within plus or minus 2 percent of the standard design TDV energy for water heating (space conditioning is not considered). In addition, TDV energy for water heating shall move in the direction indicated in each test description.

#### *4.3.1.1 Standard Design Equivalent Tests*

For water heating the standard design equivalent tests consist of running the basecase water heating systems in all 16 climates. For each case, the standard design TDV energy shall equal the proposed design TDV energy. See Table R4-58.

*Table R4-58 – Standard Design Equivalent Tests – Water Heating*

| *Type* | *Test* | *Prototypes* | *Climates* | *Discrete Modification(s)* | *Continuous Variable* |
|---|---|---|---|---|---|
| WD | 0 | C, E | All | None | None |

### *4.3.1.2 Neutral Variable Tests*

The neutral variable tests are shown in Table R4-59. For these tests, the compliance margin shall remain at zero, unchanged.

*Table R4-59 – Neutral Variable Tests – Water Heating*

| *Type* | *Test* | *Prototypes* | *Climates* | *Discrete Modification(s)* |
|---|---|---|---|---|
| WD | 1 | C | 3, 9, 12, 14, 16 | **House Size**. Increase house size to 2,500 ft². TDV energy for both the *Standard Design* and the *Proposed Design* shall increase. |
| WD | 2 | C | 3, 9, 12, 14, 16 | **House Size**. Increase house size to 3,500 ft². The TDV energy for both the *Standard Design* and the *Proposed Design* shall equal the TDV energy for test 1. |
| WD | 3 | E | 3, 9, 12, 14, 16 | **Pipe Length**. Increase recirculation piping length to 400 ft. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase. |
| WD | 4 | E | 3, 9, 12, 14, 16 | **Pipe Location**. Move all the piping outdoors. PF ground and plenum become zero and PF outdoors becomes 1.00. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase. |
| WD | 5 | E | 3, 9, 12, 14, 16 | **Individual Water Heaters.** Replace the central water heating system with individual water heaters in each dwelling unit, which meet the basecase specification for single-family homes (see Table R4-56) |

# 5. Optional Capabilities Tests

## 5.1 Overview

This chapter of the Manual explains the tests that must be performed in order for residential compliance programs to be approved for optional capabilities. See the Overview section of Chapter 4 for details. There are two sets of optional capabilities. The first are for space conditioning and include hydronic heating systems, combined (with the water heater) hydronic heating, zonal control of space temperatures, sunspaces, side fins and exterior mass walls. The second set of capabilities relates to solar systems used for water heating applications and any newly added compliance feature. Tests may be modified, added, or requested to be preformed with fixed inputs to verify specific modeling features...

The optional capabilities tests for space conditioning are summarized in Table R5-1. These tests use the same labeling scheme, test procedures, and prototypes as the minimum modeling capabilities (see previous Chapter 4).

*Table R5-1 – Summary of the Optional Space Conditioning Tests*

| *Type* | *Test* | *Prototypes* | *Climates* | *Optional Capability (Discrete Modification(s))* | *Continuous Variable* |
|---|---|---|---|---|---|
| OC | 1 | A | 3, 9, 12, 14, 16 | **Dedicated Hydronic.** Replace the gas furnace and air distribution system with a gas boiler with hydronic baseboards and fan coils. See detailed description below. Produces a positive compliance margin. | **Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution. |
| OC | 2 | A | 3, 9, 12, 14, 16 | **Combined Hydronic, Gas Water Heater**. A 75 gallon storage gas water heater is used for both space conditioning and water heating. Hot water baseboards are used for heat distribution. Insulated pipes are used in unconditioned space. | **Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution. |
| OC | 3 | A | 3, 9, 12, 14 | **Combined Hydronic, Electric Resistance Water Heater**. An electric water heater is used for both space conditioning and water heating and air is distributed through a fan coil system that delivers air to ducts located in an attic. | **Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution. |
| OC | 4 | A | 3, 9, 12, 14, 16 | **Combined Hydronic, Heat Pump Water Heater**. An electric heat pump is used for both space conditioning and water heating. Distribution is provided through hot water baseboards. All pipes are located within conditioned space. | **Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution. |
| OC | 5 | B | 3, 9, 12, 14, 16 | **Control Vent Crawlspace**. See detailed description below. Produces a positive compliance margin. | **AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| OC | 6 | A | 3, 9, 12, 14, 16 | **Zonal Control**. See detailed description below. Produces a positive compliance margin. | **AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| OC | 7 | A | 3, 9, 12, 14, 16 | **Attached Sunspace**. See detailed description below. Produces a positive compliance margin. | **AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution. |
| OC | 8 | A | 3, 9, 12, 14, 16 | **Exterior Mass Walls**. See detailed description below. Produces a negative compliance margin. | **Wall R-value**. Increase the interior wall R-value to find the Passing Solution and the Failing Solution. |
| OC | 9 | A | 3, 9, 12, 14, 16 | **Gas Absorption Cooling.** Replace the base case cooling system with an absorption gas cooling system with a COP of 3.3. Produces a positive compliance margin. | **Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution. |
| OC | 10 | A | 6,9,12,14 | **Evaporatively-cooled Condensing Unit.** Replace the base case cooling system with an evaporatively-cooled split system with an EER of 13. Produces a positive compliance margin. | **Fenestration U-factor.** Increase the fenestration U-factor on all orientations to find the Passing Solution and Failing Solution. |
| OC | 11 | A | 9,12,14 | **Ice Storage DX Air Conditioning Unit.** Replace the base case cooling system with an ice storage air conditioning unit. Specify inputs XXX,YYY. Produces a positive compliance margin. | **Fenestration U-factor.** Increase the fenestration U-factor on all orientations to find the Passing Solution and Failing Solution. |

## 5.2 Dedicated Hydronic Systems

### 5.2.1 Measure Description

Dedicated hydronic systems have boilers or other heating devices which produce hot water that is distributed through the building for heating. The system is commonly used in other areas of the country. Its use in California is limited. Heat is transferred through the building by water instead of air. Terminal heating units include central fan coils (with ducts), local fan coils (without ducts), baseboards, radiators, radiant floors, or radiant ceilings. If large fan coils are used that distribute warm air through a conventional air distribution system, then the losses of the duct system must be accounted for in the same manner as gas furnaces.

### 5.2.2 Algorithms and Modeling Assumptions

Dedicated hydronic systems are modeled in a manner similar to a gas furnace, but the AFUE of the boiler is adjusted to account for pipes located outside the conditioned space. The compliance program vendor shall include inputs for pipes located in unconditioned spaces. Inputs shall include the pipe length, diameter and insulation, as described in Chapter 2.

Equation R5-1

$$AFUE_{eff} = AFUE - \frac{PL}{RI}$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas boiler that is providing space heat (unitless).

AFUE = The rated AFUE of the boiler (unitless) or thermal efficiency.

PL = Pipe losses (kBtu/h). This may be assumed to be zero when less than 10 feet of the piping (plan view) is located in unconditioned space. Pipe losses are calculated using the procedures described below.

RI = The rated input of the gas water heater (kBtu/h). This is available from the Energy Commission appliance directory and other sources.

If heat is distributed with a fan coil, then the energy of the fan shall be accounted for in the same manner as for furnaces. The default fan energy is 0.005 Wh/Btu of heat delivered by the fan coil (not the entire heating system).

Hydronic systems are permitted when the AFUE is known and can be entered. When water heaters are used in hydronic systems for space heating alone (a separate water heater for domestic service), the water heater functions as a boiler and is required by NAECA to have a minimum AFUE of 0.80. The AFUE of a water heater if tested as a boiler would be approximately equal to the average of the EF (energy factor) and the RE(recovery efficiency), and will generally not meet the minimum NAECA requirement. Water heaters proposed for use in hydronic systems for space heating only must be tested as a boiler using the DOE AFUE and appropriate safety standard test procedures.

### 5.2.3 Test Description

For prototype A, the basecase heating system, consisting of a gas furnace and a forced air distribution system, is replaced with a dedicated hydronic system. The boiler has an AFUE of 85 percent%. Twenty (20) ft of insulated pipe are located in unconditioned space. Heat is distributed with combination of fan coils (20 kBtu/h) and hydronic baseboards (40 kBtu/h). Water is circulated through the hydronic loop by a 1/8 hp pump. The pump motor meets the minimum efficiency requirements of the California Appliance

Efficiency Regulations. Substituting this system will produce a positive compliance margin. The fenestration U-factor is then reduced to find the passing solution and the failing solution, according to the procedures described in Chapter 4. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The compliance program vendor must also demonstrate that the software correctly produces the standard design. This requires that the vendor create a standard design equivalent building that matches the standard design for the system described above. When the standard design equivalent building is entered into the candidate compliance program, the proposed design and standard design TDV energy must equal each other. The standard design equivalent energy must also equal the standard design energy for the test case.

## 5.3 Combined Hydronic Space/Water Heating

### 5.3.1 Measure Description

Combined hydronic space/water heating is a system whereby a water heater is used to provide both space heating and water heating. Dedicated hydronic space heating systems are also an optional capability covered in Section 5.2. Space heating terminals may include fan coils, baseboards, and radiant surfaces (floors, walls or ceilings).

### 5.3.2 Algorithms and Modeling Assumptions

For combined hydronic systems, the water heating portion is modeled in the normal manner. For space heating, an effective AFUE is calculated for gas water heaters. For electric water heaters or heat pumps, an effective HSPF is calculated. The procedures for calculating the effective AFUE or HSPF are described below.

When a fan coil is used to distribute heat, the fan energy and the heat contribution of the fan motor must be considered. The algorithms for fans used in combined hydronic systems are the same as those used for gas furnaces and are described in Chapter 3.

If a large fan coil is used and air distribution ducts are located in the attic, crawlspace or other unconditioned space, then the efficiency of the air distribution system must be determined using methods consistent with those described in Chapter 3. Duct efficiency is accounted for when the distribution type is "ducts."

## 5.4 Large Storage Gas Water Heater

When storage gas water heaters are used in combined hydronic applications, then the effective AFUE is given by the following equation.

Equation R5-2

$$AFUE_{eff} = RE - \frac{PL}{RI}$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

RE = The recovery efficiency of the gas water heater. A default value of 0.76 may be assumed if the recovery efficiency is unknown. However, this value is generally available from the Energy Commission appliance directory.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation R5-6).

RI = The rated input of the gas water heater (kBtu/h). This is available from the Energy Commission appliance directory.

## *5.5 Storage Electric Water Heater*

The HSPF of storage water heaters used for space heating in a combined hydronic system is given by the following equations.

Equation R5-3

$$HSPF_{eff} = 3.413\left[1 - \frac{PL}{3.413kWi}\right]$$

Where:

$HSPF_{eff}$ = The effective HSPF of the electric water heater in satisfying the space heating load.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation R5-6).

kWI = The kilowatts of input to the water heater.

## *5.6 Heat Pump Water Heater*

The HSPF of heat pump water heaters used for space heating in a combined hydronic system is given by the following equations. If the system has a fan coil, the $HSPF_{eff}$ is used. $HSPF_{w/o\_fan}$ is used if there is no fan coil.

Equation R5-4

$$HSPF_{eff} = 3.413\left(\frac{RE_{hp}}{CZ_{adj}} - \frac{PL}{3.413kWi}\right)$$

Where:

$HSPF_{eff}$ = The effective HSPF of the heat pump water heater in satisfying the space heating load.

$CZ_{adj}$ = The climate zone adjustment (see RACM Appendix E Table RE-6).

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space (see Equation R5-6).

kWI = The kilowatts of input.

$RE_{hp}$ = The recovery efficiency of the heat pump water heater. Equation R5-5 may be used as a default if the recovery efficiency is not known.

Equation R5-5

$$RE_{hp} = \frac{1}{\frac{1}{EF_{DOE}} - 0.1175}$$

Where:

$EF_{DOE}$ = The energy factor of the heat pump water heater when tested according to the DOE test procedure.

## *5.7 Pipe Losses*

Pipe losses must be considered when pipes between the water heater storage tank and the fan coil or other heating element are located in unconditioned space. To simplify compliance, pipe losses can be ignored when no more than ten feet of pipe (in plain view) is located in unconditioned space. Hourly pipe loss rates (PLR) are given either from Equation R5-7 or from Table R5-2.

Equation R5-6

$$PL = \sum_{i=1}^{n} \frac{FT_i \times PLR_i}{8760}$$

PL = Hourly pipe loss (kBtu/h).

$PLR_i$ = The annual pipe loss rate per foot of length for the $i^{th}$ pipe (kBtu/y-ft).

$FT_i$ = The length in feet of the $i^{th}$ pipe located within unconditioned space. Can be assumed to be zero if less than ten feet in plain view.

n = The number of unique pipe size or insulation conditions.

The annual pipe loss rate per foot of length (PLRi) is calculated from the following equation

Equation R5-7

$$PLR_i = 8.76 \left( \frac{T_s - T_a}{\frac{\ln\left(\frac{D_{io}}{D_{po}}\right)}{2\ p\ Ki} + \frac{1}{p\ ha\ D_{io}}} \right)$$

Where:

8.76 = Conversion factor from Btu/h to kBtu/y

$T_s$ = Supply Temperature. This is assumed to be a constant 135 F.

$T_a$ = Ambient Temperature. This is assumed to be 60.3 in all California climate zones.

$D_{io}$ = Outside diameter of insulation. ft (actual not nominal).

$D_{po}$ = Outside diameter of pipe, ft (actual not nominal).

Ki = Insulation conductivity, constant 0.023 Btu/h-ft-F

ha = Air film coefficient, constant 1.65 Btu/h-ft² -F

*Table R5-2 – Annual Pipe Loss Rates (kBtu/y-ft)*

| | Insulation Thickness | | |
|---|---|---|---|
| Nominal Pipe Size | 1/2 inch | ¾ inch | 1 inch |
| 1/2 inch | 71.6 | 60.9 | 54.2 |
| 3/4 inch | 91.1 | 75.8 | 66.6 |
| 1 inch | 109.9 | 90.1 | 78.1 |
| 1 - 1/2 inch | 146.7 | 117.5 | 100.3 |
| 2 inch | 182.9 | 144.3 | 121.7 |

### 5.7.1 Test Description

The tests for combined hydronic systems are based on modifications to prototype A. Three different systems are added as discrete modifications. The test systems are described in Table R5-3

*Table R5-3 – Combined Hydronic System Specifications*

| | | Test Number | | |
|---|---|---|---|---|
| | | OC2A | OC3A | OC4A |
| Water Heater Type | | SG | SE | HP |
| Recovery Efficiency | Unitless | 0.76 | n.a. | n.a. |
| Rated Input | Btu/h | 60,000 | n.a. | n.a. |
| Rated Input | KW | n.a. | 5.00 | n.a. |
| Wpump | W | n.a. | 60.0 | n.a. |
| EF | Unitless | n.a. | n.a. | 2.00 |
| Pipe Length in Unconditioned Space | Ft | 100.0 | n.a. | n.a. |
| Annual Pipe Loss Rate | kBtu/y-ft | 71.6 | n.a. | n.a. |

For this series of tests, only the TDV energy for space conditioning is considered. The combined hydronic systems described above are added to the Prototype A building to replace the gas furnace. The compliance program vendor shall change the fenestration U-factor on all orientations of the prototype to find the passing solution and the failing solution. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

In addition, the compliance program vendor shall demonstrate that the software correctly defines the standard design for combined hydronic. This is achieved by creating and running the standard design equivalent building. For the standard design equivalent building, the TDV energy for the proposed design and the standard design must be equal. The standard design equivalent TDV energy must also equal the TDV energy for the standard design case of this test.

## *5.8 Controlled Ventilation Crawl Spaces (CVC)*

### 5.8.1 Measure Description

A controlled ventilation crawlspace has insulation installed in the side walls of the crawlspace, instead of in the floor that separates conditioned space from the crawlspace. In addition, special dampers are used to provide the required ventilation for the crawlspace which open when it is warm and close when it is cold.

Eligibility criteria for this measure are presented in the Reference Residential Appendix RA4.

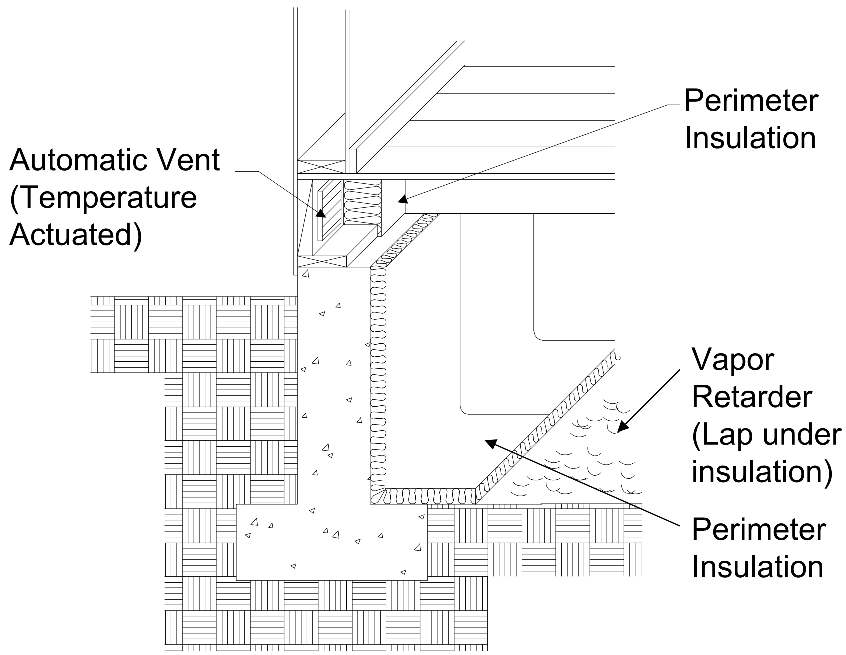



*Figure R5-1 – Section at Crawlspace Perimeter*

### 5.8.2 Algorithms and Modeling Assumptions

CVC requires that the compliance program have the capability of modeling two thermal zones. The house itself if modeled as a conditioned zone and the crawlspace is modeled as an unconditioned zone.

### 5.8.3 Test Description

To test this optional capability the compliance program vendor shall model prototype B in climate zones 3, 9, 12, 14, and 16. The CVC to be modeled shall have the following features:

- The CVC unconditioned zone has an exterior perimeter length and floor area (i.e., the ground area) equal to the prototype building B. Crawlspace volume is 3,467 $ft^3$.
- CVC infiltration is modeled using the air changes per hour method and uses 0.22 air changes per hour.
- The floor separating the crawl space from conditioned space is an inter-zone boundary with a U-value of 0.238, representing an uninsulated floor (see Table 4.4.2-A1 from Reference Joint Appendix JA4).

- Insulation that meets the floor insulation requirements used for compliance is placed in the perimeter walls of the crawl space.
- The crawl space vents are modeled with automatic temperature operated louvers. When the building is in a heating mode, the vents are assumed to be closed (inlet and outlet are zero). When the building is in a cooling mode, the vents are assumed to be open and the total vent area is 1/150 of the crawlspace floor area or 10.67 $ft^2$. Half of this is inlet and half outlet.
- The ventilation height difference between the inlets and the outlets is zero. Only wind effects apply. Wind speed is reduced to 25 percent of that on the weather tape to account for ground level conditions.
- Heat capacity in the crawlspace is 1.4 Btu/F-$ft^2$ of crawlspace area.

This system is expected to produce a positive compliance margin. The heating equipment AFUE is then reduced to find the passing solution and the failing solution. The Energy Commission reference method must pass the passing solution and fail the failing solution.

In addition, the vendor shall demonstrate that the compliance program correctly defines the standard design building and calculates the custom budget. The vendor shall create and run the standard design equivalent building for climate zone 12. The proposed design and standard design TDV energy for the be equal. The TDV energy from the standard design equivalent must also equal the standard design TDV energy for this test.

## 5.9 Sunspaces

### 5.9.1 Measure Description

A sunspace is a passive solar system consisting of an unconditioned space facing south or near south. The sunspace has a great deal of fenestration that collects solar energy and stores the energy in thermal mass elements such as a slab floor. The compliance program must be capable of modeling two thermal zones in order for the sunspace feature to be approved.

Eligibility criteria for this measure are presented in the Reference Residential Appendix RA4.

### 5.9.2 Algorithms and Modeling Assumptions

Sunspaces shall be modeled as a separate, unconditioned thermal zone. An interzone vent separating the house from the sunspace is controlled to open only when temperature (T) conditions are $T_{house} < T_{desired}$ and $T_{sunspace} > T_{house}$ (in heating mode).

Assumptions for infiltration, heat capacity, solar gain targeting, and zone thermostat temperature settings vary from the conditioned zone. Internal gains in the sunspace are assumed to be zero. Sunspace zone infiltration is modeled using the air changes per hour method and the same infiltration of 0.50 air changes per hour. There are no restrictions on targeting solar gains that enter unconditioned spaces such as sunspaces.

### 5.9.3 Test Description

For this test, an unconditioned sunspace is added to the south side of Prototype A as illustrated in Figure R5-2 and Figure R5-3. The wall and window separating the sunspace and the house remain the same as in the base case, but the surfaces and vent openings of this wall are changed from exterior types to interzone types. The performance characteristics of sunspace envelope components are the same as for the base case prototype. Total vent area is assumed to be 40 $ft^2$ with an eight foot height difference

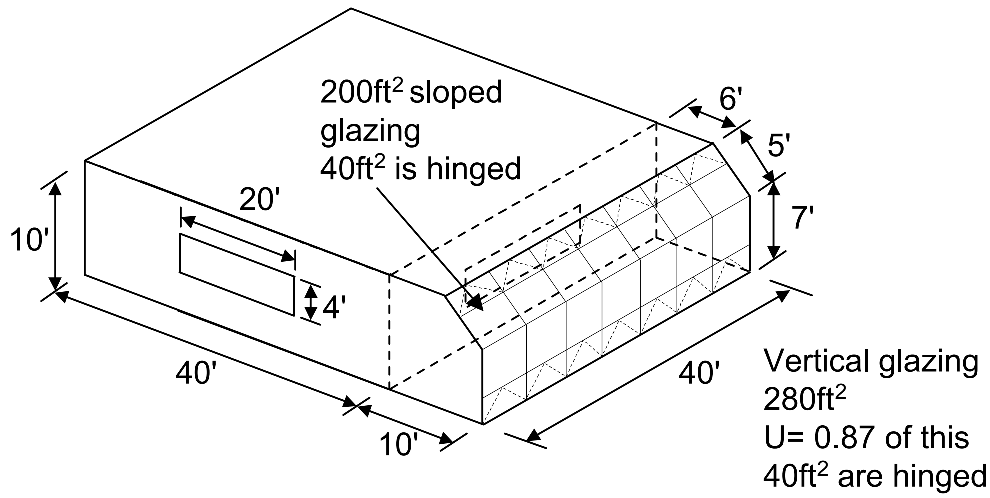



*Figure R5-2 – Sunspace Prototype*

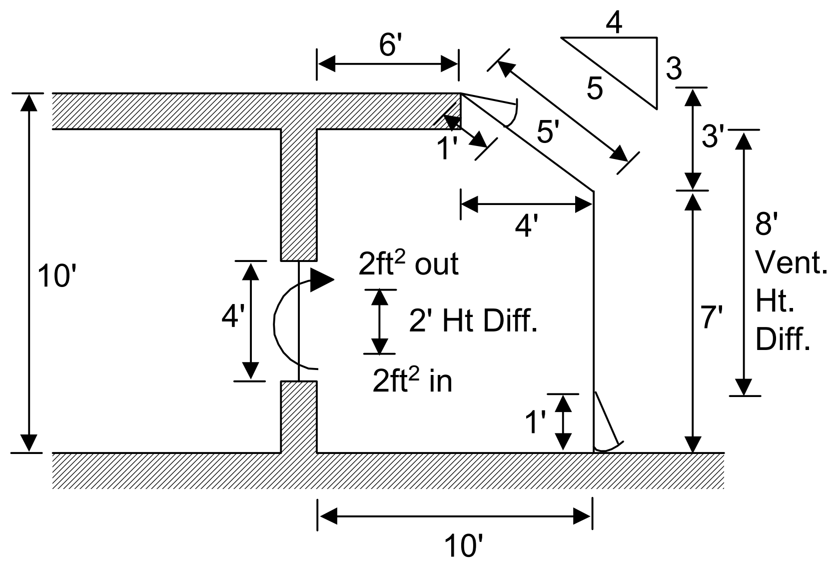



*Figure R5-3 – Sunspace Section*

The vendor must find the passing solution and failing solution in climates 3, 9, 12, 14, and 16 by varying the heating equipment AFUE. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

The vendor shall also demonstrate that the compliance program correctly defines the standard design building and calculates the space conditioning custom budget. The vendor shall create and run a standard design equivalent building for climate zone 12. The standard design equivalent proposed design TDV energy must equal the standard design equivalent standard design TDV energy. These values shall also equal the standard design TDV energy for this test.

## 5.10 Exterior Mass Walls

### 5.10.1 Measure Description

Exterior mass walls are walls that are built with a heavy material that absorbs heat as the sun strikes it and releases the heat into the conditioned space after a period of time. Thermal mass has the effect of both dampening and delaying heat transfer.

### 5.10.2 Algorithms and Modeling Assumptions

The compliance program must have the capability to model heat storage in exterior walls. The compliance program must accept inputs on the thermal storage capacity of walls. For the Energy Commission reference method, this input is heat capacity (HC) which is entered as Btu/ºF-ft². However, compliance programs may take the input in other ways acceptable to the Energy Commission.

### 5.10.3 Test Description

The test for exterior mass walls is made using prototype A in five climate zones: 3, 9, 12, 14, and 16. All of the exterior walls of the building are assumed to be of mass construction: The mass is assumed to be 12 inches thick with a volumetric heat capacity of 10 Btu/F-ft³ and a conductivity of 1.064. The outside surface of the mass wall is modeled with a U-value of 2.63 (R = 0.38) to approximate the effect of an air film. Insulation is assumed to be on the inside surface of the wall. The compliance program vendor shall find the passing solution and the failing solution by varying the R-value of the interior insulation. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The compliance program vendor shall also demonstrate that the compliance program correctly defines the standard design building and calculates the custom budget. The compliance program vendor shall create and run a standard design equivalent building for climate zone 12. For the standard design equivalent building, the TDV energy for both the standard design and proposed design cases must be equal. They must also equal the TDV energy for the standard design case in this test.

## 5.11 Gas Cooling

### 5.11.1 Measure Description

Gas cooling provides an opportunity to reduce peak electric demand.  With gas absorption, a chemical process is used to provide cooling.

As a minimum capability, compliance programs must be able to accept a COP input, and report the use of gas cooling in the *Special Features and Modeling Assumptions* section of the reports. The compliance program user shall also attach manufacturer's equipment specifications showing the COP95, CAP95 and PPC of the equipment.

### 5.11.2 Algorithms and Modeling Assumptions

See Chapter 3.

#### 5.11.3 Test Description

To determine the accuracy of modeling cooling the compliance program vendor shall perform the test listed in Table R5-1. The passing and failing solutions are determined by varying the fenestration U-factor.

## 5.12 Solar Water Heating

This section describes the acceptable methods for calculating the solar savings multiplier (SSM). Two methods are provided here and compliance programs can become certified for one or both.

- The first method has limited scope. It may only be used for water heating systems serving individual dwelling units. In addition the solar system has to be rated by the Solar Rating and Certification Corporation (SRCC) with the OG 300 method.
- The second method is more general in scope and may be used for any active solar water heating systems in single family or multi-family buildings.

Energy benefits of solar water heating systems shall be calculated using the procedures described in Reference Residential Appendix RA4.4.10-. When a credit is taken for nondepletable energy, the compliance program standard input reports must flag this and include a statement in the *Special Features and Modeling Assumptions* section of the reports. The compliance program user must also attach SRCC documentation for the system or collectors used and either Commission approved worksheets if the OG 300 method is used or an F-Chart computer run printout if the second method is used.

Solar water heating calculation procedures may be integrated in residential compliance programs or they may be stand-alone calculation procedures. The descriptions, algorithms, and test procedures described in this section apply to either case. Contact the Energy Commission for information on how to obtain approval of a stand-alone solar water heating calculation procedure.

#### 5.12.1 Individual Dwellings Rated with the OG 300 Procedure

#### 5.12.2 Measure Description

Residential solar systems can include many types of systems. The simplest system is the integrated collector storage (ICS) system which is basically a dark colored tank mounted behind glazing. Thermosiphon systems have a storage tank mounted above the collectors so that the fluid (usually water) can circulate naturally as it is heated in the collectors. Forced circulation systems use a pump to circulate a fluid from the storage tank to the collector. For forced circulation systems, the collectors may be located remotely from the storage tank.

All of these residential scale solar systems are rated by the Solar Rating and Certification Corporation (SRCC). The SRCC OG 300 procedure tests a complete system put together by the manufacturer, including the collectors, the pumps, controls, storage tanks and backup system (SRCC refers to the backup system as the auxiliary system). The OG 300 procedure uses the TRNSYS computer program to calculate the rating for the system as a whole and produces a Solar Energy Factor (SEF). The SEF is a unitless term and is meant to be compared to the energy factor (EF) published for conventional water heaters. Since the rated system includes the backup water heater, the SEF depends on whether the system was rated with electric or gas backup. It also accounts for the efficiency of the backup system. The SRCC publishes data on all systems and collectors hat have been rated.

#### 5.12.3 Algorithms and Modeling Assumptions

Modeling assumptions and algorithms are documented in Reference Residential Appendix RA4.4.10.

#### 5.12.4 Eligibility Criteria

Eligibility criteria for solar water heating systems are in Reference Residential Appendix RA4.4.10

#### 5.12.5 Test Description

To determine the accuracy of modeling solar systems using the OG 300 method the compliance program vendor shall perform the test listed in Table R5-4. The compliance program vendor modifies the gas water heating base case and reports the solar savings fraction (SSF) for both the proposed design and the standard design. The Energy Commission reference method shall predict SSF energy within 5 percent of the candidate compliance program.

*Table R5-4 – OG-300 Solar Systems Tests*

| *Type* | *Test* | *Prototypes* | *Climates* | *Optional Capability (Discrete Modification(s))* |
|---|---|---|---|---|
| SS | 1 | A | 3, 9, 12, 14, 16 | **Solar System with Electric Backup.** Add a solar system with electric backup that has a SEF of 2.0. |
| SS | 2 | A | 3, 9, 12, 14, 16 | **Solar System with Gas Backup.** Add a solar system with gas backup that has a SEF of 1.0 |

### *5.13 Individual Dwellings or Multi-Family Buildings Based on Collector Tested Using the OG-100 Procedure*

#### 5.13.1 Measure Description

The solar systems described in this section have general applicability for water heating applications. They may be used for multi-family or single family water heating systems. Any solar water heating system that uses forced circulation, and collectors rated under the SRCC OG-100 method can use this approach. Situations where this approach might be used are: a single family residences with large hot water demand, solar water heating systems for multi-family buildings.

A report shall be created that includes the parameters listed in Table R5-5 and Table R5-6.

#### 5.13.2 Prototype

For this series of tests thermal loads and water heating budget shall be based on water heating prototype E (see chapter 4).

*Table R5-5 – Prototype Solar System*

| Parameter | Value |
|---|---|
| Collector Slope | 4:12 |
| Collector Azimuth | 180 º (due south) |
| Collector Area | Four collectors as described below. |
| Collector Performance (OG 100) | SRCC Certification Number 100-1998-0018<br>Yint = 0.530, Slope = -0.250 Btu/h-ft²-ºF, A = 32.9 ft² |
| Storage Tank Size | 500 gallons |
| Pumping | ¼ hp pump between collectors and storage tank |
| Freeze Control | Drain-down |

### 5.13.3 Algorithms and Modeling Assumptions

The Energy Commission reference method is based on the F-Chart procedure, which is available from multiple sources. Modeling inputs and limits for the F-Chart reference method are defined in Appendix RG-.

### 5.13.4 Test Description

To determine the accuracy of modeling solar systems using the SRCC OG100 method, the vendor of the integrated compliance program or stand-alone solar application shall perform the test listed in Table R5-6. The integrated compliance program or stand-alone solar application shall predict a solar savings fraction (SSF) for the cases in Table R5-6 within plus or minus 3 percent of the SSF predicted by the Energy Commission reference method.

*Table R5-6 – OG 100 Solar System Tests*

| *Type* | *Test* | *Prototypes* | *Climates* | *Optional Capability (Discrete Modification(s))* |
|---|---|---|---|---|
| SS | 3 | ºF | All | **Basecase.** The basecase solar system with the schedule of loads shall be simulated in all climate zones. |
| SS | 4 | ºF | 3, 9, 12, 14, 16 | **Collector Orientation.** Vary the orientation of the collectors from due south (the basecase) to 45 degrees east of south. |
| SS | 5 | ºF | 3, 9, 12, 14, 16 | **Collector Slope.** Change the collector slope from the 4:12 pitch in the basecase to 12:12. |
| SS | 6 | ºF | 3, 9, 12, 14, 16 | **Collector Performance. Substitute the following collector.**<br>SRCC Certification Number 100-1981-0085A<br>Yint = 0.737, Slope = -0.805 Btu/h-ft²-ºF, A = 32.3 ft² |
| SS | 7 | ºF | 3, 9, 12, 14, 16 | **Collector Area.** Double the number of collectors |
| SS | 8 | ºF | 3, 9, 12, 14, 16 | **Storage Tank Size.** Reduce the storage tank size To 200 gallons. |
| SS | 10 | ºF | 3, 9, 12, 14, 16 | **Circulation Pump.** Increase the size of the circulation pump from ¼ hp to ½ hp. |
| SS | 11 | ºF | 3, 9, 12, 14, 16 | **Freeze Control.** Change the freeze control from drain-down to glycol. |

## 5.14 Evaporatively Cooled Condensing Units

### 5.14.1 Measure Description

Evaporatively cooled condensers work by replacing the outdoor unit of a standard air cooled air conditioner with a water cooled unit. These are not swamp coolers and do not introduce any humidity to the conditioned space. From the outdoor unit to the air handler, these systems are the same as conventional air conditioners. Evaporatively cooled condensers take advantage of the fact that the wet bulb temperature is lower than the dry bulb temperature, reducing the energy consumption of the compressor. Compliance savings in cooling climates typically range around 40 percent of the cooling budget.

### 5.14.2 Algorithms and Modeling Assumptions

The calculation of the hourly cooling electricity consumption shall be determined using Equation R3-35 and Equation R3-37. Equation R5-10, Equation R5-8, and Equation R5-9 shown below shall replace Equation R3-38 and Equation R3-41, respectively. Equation 3-36, Equation R3-39, and Equation R3-42 do not apply to evaporatively cooled condensing units.

Equation R5-8 $$EERnfa = (1.0452 * EERa + 0.0115 * EERa\^{}2 + 0.000251 * EERa\^{}3) * Ftxv * Fair * Fsize$$

Equation R5-9 $$EERnfb = (1.0452 * EERb + 0.0115 * EERb\^{}2 + 0.000251 * EERb\^{}3) * Ftxv * Fair * Fsize$$

Where:

$EER_a$ = EER at 75o F wet bulb listed with ARI

EERb = EER at 65o F wet bulb published by the manufacturer in accordance with ARI guidelines

Ftxv = TXV factor (Default value of Ftxv is 0.96. If TXV installation is verified, Ftxv = 1.0)

Fair = Air flow factor (Default value of Fair is 0.925. If air flow is verified, Fair = 1.0)

Fsize = Sizing factor (Default value of Fsize is 0.95. If the equipment is sized using the method in Reference Residential Appendix RA4.3.2, Fsize = 1.0)

Equation R5-10 $$CEt = EERnfa - ((EERnfa - EERnfb) * 7.5) + ((EERnfa - EERnfb)/10)xTwb$$

Where:

Twb = Outdoor wet bulb temperature taken from the Energy Commission weather file.

CEt = Energy efficiency ratio at a particular wet bulb temperature. EERnfa and EERnfb are calculated using equation R5-8(eca) and R5-9(ecb).

Compliance software developers must cause inputs to be linked between the credit for evaporatively cooled condensing units and duct sealing so that errors cannot be made by the program user. If the user chooses evaporatively cooled condensing units, the user must be notified that duct sealing is also required, and compliance results must not be determined until both measures are properly selected.

Compliance software programs also must also automatically list “Evaporatively Cooled Condensing Unit” as a Special Feature and provide both the EERa (measured at outdoor wetbulb temperature of $75^o$ F) and EERb (measured at outdoor wetbulb temperature of $65^o$ F). Compliance software programs also must automatically list “Evaporatively Cooled Condensing Unit” and “Duct Sealing” on page 4 of the CF-1R in the list of “Special Features Requiring HERS Rater Verification when the user chooses to take compliance credit for evaporatively cooled condensing units.

### 5.14.3 Test Description

None

## 5.15 Ice Storage Air Conditioners (ISAC)

### 5.15.1 Measure Description

The ISAC system consists of a water tank containing refrigerant coils that cool the water and convert it into ice. To ensure good heat transfer, the ice tank coils are made of copper. These Helical copper coils can accommodate expansion and contraction resulting from the change in the water/ice tank temperature. The refrigerant is compressed in a compressor and then cooled in an air-cooled condenser. The liquid refrigerant then is directed through the coils in the water tank to make ice or to the air handler coils to cool the building. The compressor runs continuously as long as there is demand for cooling and/or demand for making ice. During peak periods, if there is enough ice capacity, the compressor remains turned off. At night, the compressor usually runs to make ice. However, if there is a cooling load on the building at night, which can occur in the hot central valley or inland regions and the deserts of Southern California, the compressor can alternate between ice making and cooling the building. A valve in the refrigeration management system is the only other moving part. The ice tank is insulated and this compliance option takes into account the energy losses from the tank surface. The tank is made of corrosion resistant material. Water quality in the ice tank does not change with the operation of the system.[i]

Eligibility criteria for this measure are presented in the Reference Residential Appendix RA4.3.1

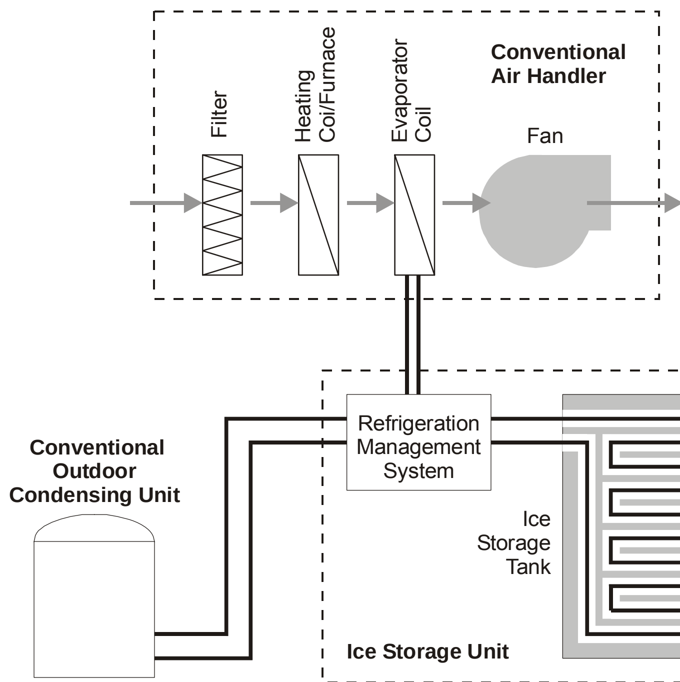



*Figure R5-4 – Ice Storage Air Conditioners (ISAC)*

### 5.15.2 Algorithms and Modeling Assumptions

The algorithms and modeling assumptions for low-rise residential buildings are located in Appendix C of "Ice Storage Air Conditioners, Compliance Options Application, Staff Report", May 2006, CEC-400-2006-006-SF.

Compliance software developers must cause inputs to be linked between the credit for ISAC systems and duct sealing and no credit for Thermostatic Expansion Valve so that errors can not be made by the program user. If the user chooses ISAC systems, the user must be notified that duct sealing is also required, and compliance results must not be determined until both measures are properly selected.

Compliance software also must automatically list "Ice Storage Air Conditioning Systems" as a Special Modeling Feature and shall automatically generate the CF-6R form. Samples of the modified forms are in Appendix A of "Ice Storage Air Conditioners, Compliance Options Application, Staff Report, May 2006, CEC-400-2006-006-SF.

Since the initial application, several modifications have been made to the residential model.

- The ability to specify the peak months and a peak melting start time has been added. The algorithm now reads and uses the peak month specifications (see PeakMonth to OpStMeltHour below) from the nonresidential portion of the description file to determine the melt start hour
- The model can now model a backup (second) compressor. If the variable IBBackup is set to true, the system is assumed to have a second compressor, allowing the primary compressor to provide the maximum possible ice make cycle.
- The model can now default to the compliance program SEER 13 model when there is no ice stored. If the variable IBSEER13 is set to true, the model uses the EER passed through from the compliance program algorithm for air conditioners for the zero ice stored case instead of the zero row case from the description file.
- Several changes were made to enable the algorithm to account for the tank losses when the tank is empty during the operating season and to remove the double counting of the 0.88 sensible heat multiplier on the gross cooling output that is already accounted for in the calling program.

The compliance program calculates the hourly cooling electricity consumption for ice storage air conditioning systems using Equation R5-11. This equation is of the same form as Equation R3-35 used to calculate the electricity consumption of standard air conditioners.

Equation R5-11

$$ACkWh = (FanWh + CompWh + PPCWh) / 1{,}000$$

Where:

ACkWh = Air conditioning kWh of electricity consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

FanWh= Fan watt-hours for a particular hour of the simulation. This is calculated using Equation R3-49.

CompWh= Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R3-37.

PPCWh= Parasitic Power watt-hours for a particular hour of the simulation. This is calculated using Equation R3-44.

### 5.15.3 Test Description

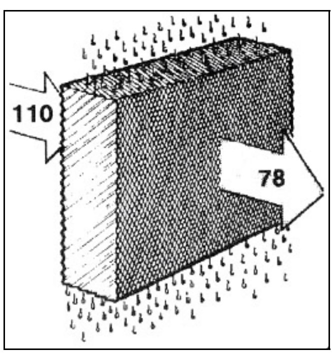
None.

## 5.16 Evaporative Coolers

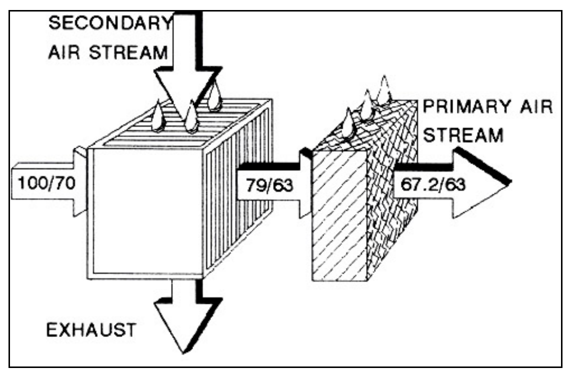
### 5.16.1 Measure Description

Evaporative cooling offers significant energy and demand benefits over conventional vapor compression cooling by substituting blower(s) and pump(s) for energy intensive compressors and air handling components. The technology is best suited for dry climates where direct and/or indirect cooling of the supply air stream can occur without compromising indoor comfort. Evaporative cooling can fully eliminate air conditioning in mild climates or in intelligently designed homes in more severe cooling climates. The potential of evaporative cooling to play a key role in California's energy future is improving as newer homes increasingly incorporate measures reducing cooling loads, allowing evaporative coolers to meet the load.

Direct evaporative coolers are the most common system types currently available. These systems generally provide less comfort and deliver more moisture to the indoor space than indirect or indirect-direct units. Due to concerns about indoor humidity, evaporative cooler compliance credit is offered only for indirect and indirect-direct evaporative coolers. Direct coolers are treated as a standard 13 SEER air conditioning unit.




Direct Evaporative Cooler




Indirect-Direct Evaporative Cooler

*Figure R5-5 – Evaporative Coolers*

### 5.16.2 Algorithms and Modeling Assumptions

Evaporative coolers shall be modeled on an hourly basis using Title 20 performance parameters (effectiveness, airflow, and power) for the proposed equipment and the algorithms presented in this section. Evaporative cooler saturation effectiveness defines what fraction of the outdoor wet bulb depression range can be achieved by an evaporative cooler. Saturation effectiveness, $\varepsilon$, is defined as shown in Equation R5-12.

Equation R5-12 $$\varepsilon = \frac{t_{db} - t_s}{t_{db} - t_{wb}}$$

Where:,

$t_{db}$ and $t_{wb}$ = outdoor dry and wet bulb temperatures, respectively, and

$t_s$ = supply air temperature

The evaporative cooler modeling methodology addresses two performance issues. The first issue relates to rising indoor relative humidity during periods with extended cooler operation. Since modeling of indoor air moisture levels is a complicated process beyond the capability of standard building simulation models, a simplified algorithm is used to prohibit evaporative cooler operation during load hours when operation is expected to contribute to uncomfortable indoor conditions. The algorithm disallows cooler operation when outdoor wet bulb temperatures are 70$^{o}$ F, or above.

The second performance issue relates to evaporative cooler capacity limitations. Since evaporative coolers are 100 percent outdoor air systems, their capacity is limited by the outdoor wet bulb temperature. Each hour with calculated cooling load, the algorithm will verify that the cooling capacity (“ClgCap” in Equation R5-13) is greater than the calculated house cooling load.

Equation R5-13 $$ClgCap = 1.08 \times Q \times (Tin \ \ (Tdb - \varepsilon \times (Tdb - Twb)\ )$$

Where:

Q = airflow (cfm)

Tin = indoor dry bulb temperature

Tdb = outdoor dry bulb temperature

$\varepsilon$ = system effectiveness (fraction) expressed in terms of “media saturation efficiency” or “cooling efficiency”, depending upon equipment type, according to Title 20 Appliance Efficiency Regulations

Twb = outdoor wet bulb temperature

If either the outdoor wet bulb filter or the cooling capacity filter disallows cooler operation, the compliance software assumes that the hourly cooling load is met by a 13 SEER air conditioner (i.e. zero evaporative cooler credit for that hour). If evaporative cooler operation is not precluded by the above conditions, a fixed efficiency of 13 Btu/Wh (or EER) is applied to determine hourly energy use. This fixed 13 EER assumption is used for both indirect and indirect-direct evaporative coolers and should not be degraded for any temperature or part load effects. Calculated hourly energy use is then valued based on the TDV value for that hour. The flow chart shown in Figure R5-6 depicts the modeling approach.

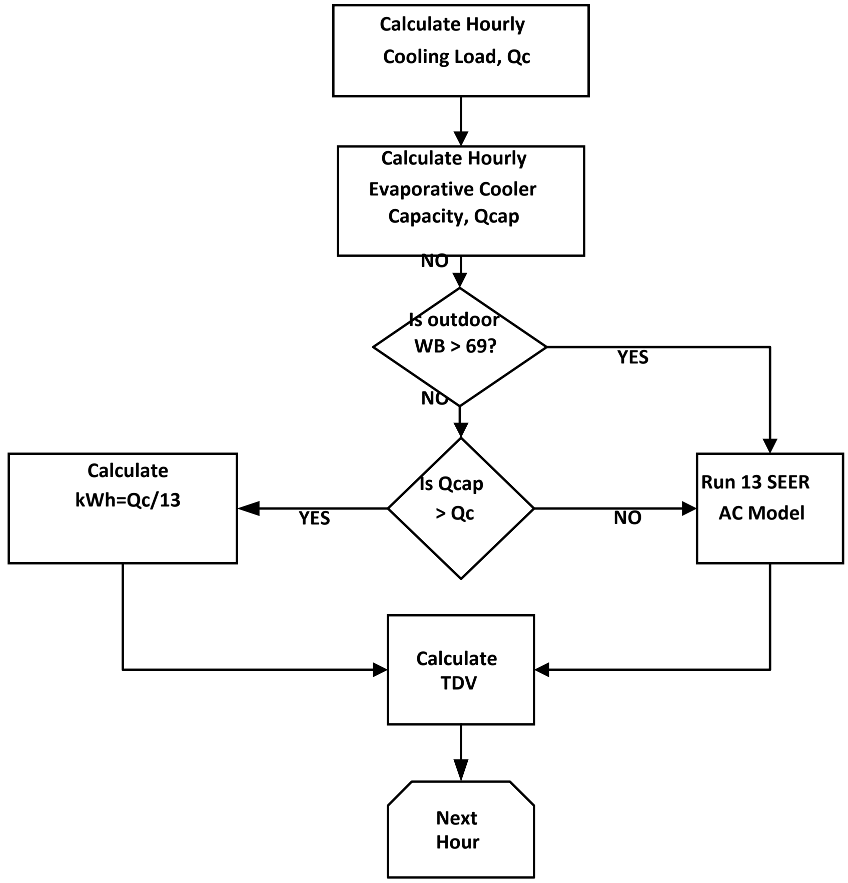



*Figure R5-6 – Evaporative Cooler Calculation Flow Chart*

The proposed modeling methodology deviates from the current compliance software modeling approach for conventional air conditioning by requiring the user to model a specific evaporative cooler unit for Title 24 compliance. If the specified equipment is significantly undersized, or of low evaporative effectiveness, the compliance run results will demonstrate a reduced compliance credit. The proposed methodology provides feedback insuring that the specified equipment is both adequately sized and of sufficient efficiency for the intended load.

### 5.16.3 Test Description

None.

## *5.17 New Solar Home Partnership (NSHP) Compliance Option*

This compliance option requires above code energy efficiency along with installation of photovoltaic systems. It aligns with the requirements of the NSHP program which provides expected performance based incentive for photovoltaic installations on new residential construction.

### 5.17.1 Measure Description

The builder can choose to comply with either of two tiers of energy efficiency measures as described in the current New Solar Homes Partnership Guidebook.

A report shall be created that includes the Tier I or II achieved and a HERS verification notification will be printed for all measures used to achieve this level, irrespective of credit taken for any special HERS verification measures (as described in Chapter 2). Field verification of measures will be required to be consistent with current Title 24 Standards field verification procedures and protocols. Solar water heating may be used to assist in meeting the energy efficiency requirements of either Tier I or Tier II. Only energy efficiency documentation completed by persons who are Certified Energy Plans Examiners (CEPE) by the California Association of Building Energy Consultants (CABEC) will be accepted.

### 5.17.2 Algorithms and Modeling Assumptions

The modeling assumptions and results will be consistent with the current Title 24 standards.

## *5.18 Photovoltaic Performance Calculation*

See RACM Appendix B

### 5.18.1 Measure Description

Under the NSHP compliance option the expected performance of PV systems will be reported. To qualify under this measure the PV systems will be at least 1 KW AC capacity and installed in conjunction with higher energy efficiency requirements as stated above. The equipment used will need to be certified and tested under the standards as specified in the NSHP Guidebook Appendix 3 and listed with the Energy Commission as eligible equipment. The annual production calculated is weighted with TDV multipliers on an hourly basis to encourage systems which are installed to address the peak load mitigation. Additionally, third-party field verification will be conducted to assess whether systems have been installed consistent with the characteristics used to determine estimated performance. An expected performance table is generated for each system specifically which is used to ensure minimum performance at given conditions.

### 5.18.2 Prototype

No tests for this measure, just the review of appropriate incorporation of the PV calculator.

### 5.18.3 Algorithms and Modeling Assumptions

The Energy Commission reference method is based on the CECPV engine, which is available from the commission upon request. Modeling inputs and limits for the PV calculator are defined in RACM Appendix B-2008.

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i Description is taken from Ice Storage Air Conditioners, Compliance Options Application, Staff Report, May 2006, CEC-400-2006-006-SF