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California Energy Commission

STAFF REPORT

2016 DRAFT

RESIDENTIAL ALTERNATIVE CALCULATION METHOD REFERENCE MANUAL

For the 2016 Building Energy Efficiency Standards

CALIFORNIA
ENERGY COMMISSION

Edmund G. Brown Jr., Governor

AUGUST 2015

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CALIFORNIA ENERGY COMMISSION

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ACKNOWLEDGMENTS

The Building Energy Efficiency Standards (Standards) were first adopted and put into effect in 1978 and have been updated periodically in the intervening years. The Standards are a unique California asset and have benefitted from the conscientious involvement and enduring commitment to the public good of many persons and organizations along the way. The 2016 Standards development and adoption process continued that long-standing practice of maintaining the Standards with technical rigor, challenging but achievable design and construction practices, public engagement and full consideration of the views of stakeholders.

The revisions in the 2016 Standards were conceptualized, evaluated and justified through the excellent work of Energy Commission staff and consultants. This document was created with the assistance of Energy Commission staff including Todd Ferris, Larry Froess, P.E., Jeff Miller, P.E., Dee Anne Ross, Peter Strait, and Danny Tam.

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ABSTRACT

The 2016 Building Energy Efficiency Standards for Low-Rise Residential Buildings allow compliance by either a prescriptive or performance method. Performance compliance uses computer modeling software to trade off efficiency measures. For example, to allow more windows, the designer will specify more efficient windows, or to allow more west-facing windows they will install a more efficient cooling system. Computer performance compliance is typically the most popular compliance method because of the flexibility it provides in the building design.

Energy compliance software must be certified by the Energy Commission, following rules established for the modeling software. This document establishes the rules for the process of creating a building model, describing how the proposed design (energy use) is defined, how the standard design (energy budget) is established, and ending with what is reported on the Certificate of Compliance (CF1R). This document DOES NOT specify the minimum capabilities of vendor-supplied software. The Energy Commission reserves the right to approve vendor software for limited implementations of what is documented in this manual.

This Residential Alternative Calculation Methods (ACM) Reference Manual explains how the proposed and standard designs are determined. If the minimum heating system has 78% AFUE and the proposed building has a 92% AFUE furnace, the standard design is based on 78% and the proposed design gets credit for a 92% AFUE furnace. The desired result is a positive compliance margin showing how the building performs as compared to the standard design for heating, cooling, water heating, indoor air quality/ventilation, and water heating.

The 2016 Compliance Manager is the simulation and compliance rule implementation software specified by the Energy Commission. The Compliance Manager, called California Building Energy Code Compliance (CBECC), models all features that affect the energy performance of the building. This document establishes the process of creating a building model. Each section describes how a given component, such as a wall, is modeled for the proposed design, standard design, and ends with what is reported on the Certificate of Compliance (CF1R) for verification by the building enforcement agency.

Keywords: ACM, Alternative Calculation Method, Building Energy Efficiency Standards, California Energy Commission, California Building Energy Code Compliance, CBECC, Certificate of Compliance, CF1R, compliance manager, compliance software, computer compliance, energy budget, energy standards, energy use, performance compliance, design, proposed design, standard design

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1 Introduction

1.1 Purpose

This manual documents the rules used for modeling residential buildings for performance compliance under California's 2016 Building Energy Efficiency Standards for Low-Rise Residential Buildings, similar to the Alternative Calculation Methods (ACM) used in the past to document software rules. This document explains how the proposed design (energy use) and standard design (energy budget) isare established for a given building.

The 20136 Compliance Manager is the simulation and compliance rule implementation software specified by the Energy Commission. Beginning wWith the 2016 standards, compliance software requires greater modeling detail for buildings than previous compliance software programs. For example, attics, crawl spaces, basements, and attached unconditioned spaces (garages and storage) are defined in the building modeling software.

Documentation of detailed calculation algorithms is contained in the companion volume:

Appendix C, 2016 Residential Alternative Calculation Method Algorithms

This document is designed to establish the process of creating a building model. Each section describes how the proposed design (energy use) is defined, how the standard design (energy budget) is established, and ending with what is reported on the Certificate of Compliance (CF1R).

This Reference Manual documents the compliance analysis modeling rules for all aspects of the Energy Commission's ACM Reference Method. This document DOES NOT specify the minimum capabilities of vendor-supplied software. The Energy Commission reserves the right to approve vendor software for limited implementations of what is documented in this manual.

1.2 Other Documents

The basis of this document is the 2016 Building Energy Efficiency Standards. Documents also relied on include the Reference Appendices for the 2016 Building Energy Efficiency Standards, and the 2016 Residential Compliance Manual.

Detailed modeling information for the software user can be found in the California Building Energy Code Compliance (CBECC) User Manual.

2 The Proposed Design and Standard Design

2.1 Overview

This chapter describes how the proposed design is modeled and how the standard design is established.

2.1.1 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 is 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 are 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 is consistent with the actual building design and configuration.

2.1.2 Standard Design

For ~~newly constructed~~ low-rise residential buildings, the standard design building, from which the energy budget is established, is in the same location and 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 additions and alterations, the standard design shall have the same wall and fenestration areas and orientations as the proposed building. The details are described below.

The ~~space conditioning~~ energy budget for the residential standard~~s~~ design is the energy that would be used by a building similar to the proposed design if the proposed building met the requirements of the prescriptive standards. The process of generating the standard design is performed automatically by the compliance software, based on fixed and restricted inputs and assumptions. 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 basis of the standard design is prescriptive Package A (from §150.1(c) of the standards, Table 150.1-A). Package A requirements ~~(not repeated here)~~ vary by climate zone. Reference Joint Appendix JA2, Table 2-1, contains the 16 California climate zones and their representative cit~~y~~ies. The climate zone can be found by city, county and zip code in JA2.1.1.

The following sections present the details on how the proposed design and standard design are determined. For many modeling assumptions, the standard design is the same as the proposed design. When a building has special features, for which the Commission has established alternate modeling assumptions the standard design features will differ from the proposed design so the building receives appropriate credit for its efficiency. Typically, these measures require verification. Alternate features, such as zonal control, are documented as *Special Features* on the Certificate of Compliance. Verified features are also documented on the CF1R.

2.2 The Building

Proposed Design

The building is defined through entries for zones, surfaces, and equipment. Zone types include attic, conditioned space, crawl space, basements, and garages. The roof (such as asphalt shingles or tile) is defined as either part of the attic or as part of a cathedral ceiling (also called a rafter roof). Surfaces separating conditioned space from exterior or unconditioned spaces (such as garage or storage) are modeled as interior ~~walls~~ surfaces adjacent to the unconditioned zone. ~~, as well as the e~~Exterior surfaces of an attached garage or storage space are ~~(~~modeled as part of the ~~an~~ unconditioned zone~~)~~.

The input file will include entries for floor areas, wall, door, roof and ceiling areas, and fenestration areas, as well as the water heating, space conditioning, ventilation, and distribution systems.

Each surface area is entered along with performance characteristics, including building materials, U-factor and SHGC. The orientation and tilt (see Figure 2-1) is required for envelope elements.

Building elements are to be consistent with the actual building design and configuration.

Standard Design

To determine the standard design for ~~newly constructed~~low-rise buildings, a building with the same general characteristics (number of stories, attached garage, climate zone) with wall and window areas are distributed equally between the four main compass points (north, east, south and west) is created by the software. Energy features are set to be equal to §150.1(c) and Table 150.1-A. For additions and alterations, the standard design for the existing building shall have the same wall and fenestration areas and orientations as the proposed building. The details are described below.

Verification & Reporting

All inputs that are used to establish compliance requirements are reported on the CF1R for verification.

2.2.1 Climate and Weather

Proposed Design

The user specifies ~~either the zip code or~~ the climate zone based on the zip code of the proposed building. ~~If the zip code is specified, the software selects the climate zone.~~ Compliance requirements, weather, design temperatures, and Time Dependent Valuation (TDV) of energy factors are a function of the climate zone. Compliance software assumes that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter.

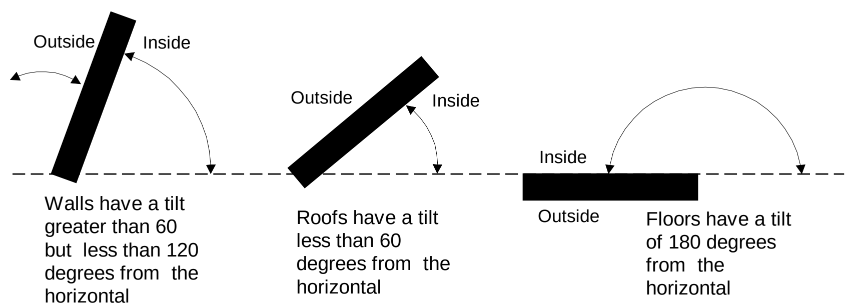
STANDARD DESIGN

The standard design climate zone is the same as the proposed design.

VERIFICATION & REPORTING

The zip code and climate zone of the proposed design is reported on the CF1R for verification.

Figure 2-1: Surface Definitions



2.2.2 Standards Version

This input determines ~~which~~ the appropriate federal appliance efficiency requirements for the standard design to compare with the proposed design. ~~for cooling equipment apply to the project. It allows the user to choose compliance that will be valid only before the federal requirements change or compliance that will be valid both before and after the change in January 2015. Eligibility for solar electric system credit is only allowed with Compliance 2015.~~

PROPOSED DESIGN

The user inputs ~~a choice of:~~ Compliance ~~2014~~2017. ~~valid only through December 2014 (with current federal air conditioning efficiency requirements)~~

~~Compliance 2015: valid any time (with 2015 federal air conditioning requirements) and solar credit.~~

STANDARD DESIGN

The standard design cooling equipment efficiency is based on the ~~specified version of the~~ federal requirements. ~~If Compliance 2015 is selected, a~~A minimum SEER and (if applicable) ~~an~~ EER that meet~~s~~ the ~~2015~~current standard for the type ~~and size~~ of equipment is modeled.

VERIFICATION & REPORTING

Compliance version is reported on the CF1R.

2.2.3 PV System Credit

The compliance credit available for photovoltaic (PV) systems is dependent on the climate zone and dwelling unit size. The credit may be used to tradeoff any efficiency measure, with limits as described below. The PV system must meet the eligibility requirements of Residential Appendix RA4.6.1 and must meet the minimum system size described below.

The PV compliance credit for both single and multi-family buildings is calculated by the compliance software and is equal to:

Equation 1: $PV_{credit} = TDV_{std} * PV_{maxpct} / 100.0$

Where:

PV_{credit} = PV compliance credit (kTDV/ft^2)
TDV_{std} = Standard Design Compliance Total (kTDV/ft^2)
PV_{maxpct} = Maximum PV Credit Percentage from Table 2-1

The minimum PV system size for compliance credit is calculated by the compliance software and is equal to:

Equation 2: $PV_{minsize} = ROUND((PV_{threshold} + PV_{addedsize}) * N_{dwellingunits}, 0.1)$

For average dwelling units less than or equal to $CFA_{threshold}$:

Equation 3: $PV_{addedsize} = 0$

For average dwelling units larger than $CFA_{threshold}$:

Equation 4: $PV_{addedsize} = PV_{credit} * (CFA_{dwellingunit} – CFA_{threshold}) / PV_{genrate}$

Where:

$PV_{minsize}$ = Minimum PV System Size (kWdc) for compliance credit
$PV_{threshold}$ = Threshold PV System Size per dwelling unit (kWdc) from Table 2
$N_{dwellingunits}$ = Number of dwelling units
$PV_{addedsize}$ = Added PV System Size (kWdc) required
$CFA_{dwellingunit}$ = Average Conditioned floor area per dwelling unit (ft^2)
$CFA_{threshold}$ = Average Threshold Conditioned floor per dwelling unit (ft^2) from Table 2
$PV_{generate}$ = PV Generation Rate (kTDV/kWdc) from Table 1

If the PV size entered by the user is less than PV minimum size then there is no compliance credit:

Equation 5: $PV_{credit} = 0$ when $PV_{usersize} < PV_{minsize}$

Where:

$PV_{minsize}$ = Minimum PV System Size (kWdc) for compliance credit
$PV_{usersize}$ = PV size entered by user (kWdc)

Table 2-1: PV Credit Calculation Factors

Climate Zone	PV Generation Rate (kTDV/kWdc)	Maximum PV Credit for Single Family	Maximum PV Credit for Multi Family
01	26762	7.8%	5.0%
02	30021	7.1%	3.9%
03	31137	7.8%	3.3%
04	30935	20.1%	11.8%
05	33490	8.5%	2.4%
06	30081	0.0%	0.0%
07	30701	0.0%	0.0%
08	29254	27.7%	9.3%
09	29889	26.3%	10.7%
10	30200	23.9%	10.1%
11	29693	18.1%	9.0%
12	29328	23.2%	9.9%
13	29553	20.9%	9.4%
14	31651	16.9%	8.4%
15	29177	16.3%	7.4%
16	30930	16.7%	9.0%

Table 2-2: PV Threshold Factors

Dwelling Type	PV threshold (kWdc)	CFA threshold (ft^2)
Single Family	2.0	2000
Multi Family	1.0	1000

For the design ratings, the user entered system size is used to calculate the system output.

[Energy Design Ratings NOT YET IN CBECC-Res ALPHA VERSION]

Equation 6: $PV_{designratingcredit} = PV_{usersize} * PV_{genrate} / CFA_{dwellingunit}$

Where:

$PV_{designratingcredit}$ = PV design rating credit (kTDV/ft^2)
$PV_{usersize}$ = PV size entered by user (kWdc)
$PV_{generate}$ = PV Generation Rate (kTDV/kWdc) from Table 1
$CFA_{dwellingunit}$ = Average Conditioned floor area per dwelling unit (ft^2)

If the design rating goes below zero when the solar credit is applied, the design rating is set to zero.

PROPOSED DESIGN

The software allows the user to input the rated power output of the solar system in kilowatts DC. If the rated system is greater than or equal to the minimum PV system size, the software calculates the solar credit and subtracts it from the proposed design. If the rated system is less than the minimum PV system size, the software sets the solar credit to zero and displays a message to the user that the minimum PV system size criteria was not met.

STANDARD DESIGN

The standard design has no PV system.

VERIFICATION AND REPORTING

A solar credit is reported as a *Special Feature* on the CF1R.

~~For users with single family and town house projects in climate zone 9 through 15 who select Compliance 2015 to comply under the updated federal appliance standards, there is a credit available for photovoltaic (PV) systems that meet the eligibility requirements of Residential Appendix RA4.6.1. The PV systems must be 2 kWdc or larger. The credit is the smaller of:~~

~~PV Generation Rate (kTDV/kWdc) * kWdc~~

~~Max PV Cooling Credit * Standard Design Cooling Energy (kTDV)~~

~~Where the factors are shown in Table 2-1.~~

~~**Table 2-1: PV Credit Calculation Factors**~~

- Climate Zone	- PV Generation Rate (kTDV/kWdc)	Max PV Cooling Credit (% of Standard Design Cooling kTDV/ft2)
09	30269	13%
10	30342	15%
11	29791	18%
12	29556	17%
13	29676	17%
14	31969	16%
15	29536	19%

~~**PROPOSED DESIGN**~~

~~For users in the applicable climate zone with the appropriate project type and standards version, the software allows the user to input the rated power of the solar system in kilowatts DC. The software automatically calculates the solar credit.~~

~~**STANDARD DESIGN**~~

~~The standard design has no PV system~~

~~**VERIFICATION AND REPORTING**~~

~~A solar credit is reported as a *Special Feature* on the CF1R.~~

2.2.4 Existing Condition Verified

[NOT IN CBECC-Res ALPHA VERSION]

These~~is~~ inputs are~~is~~ used for additions and alterations. The standard design assumption for existing conditions vary based on whether the existing conditions are verified by a HERS rater prior to construction. See Section 2.10.3 for more information.

PROPOSED DESIGN

The user inputs either yes or no. Yes indicates that the existing building condition~~s were~~is verified by a HERS rater. Default assumption is no.

STANDARD DESIGN

The standard design assumption~~s~~ ~~are~~is based on §150.2(b), Table 150.2-~~B~~C. If the user input is no~~, or if less than two of the listed components are being altered,~~ the standard design for ~~all~~the existing component~~s~~ is based on the value~~s~~ in the second column. If the proposed design response is yes ~~and two or more of the listed components are being altered,~~ the standard design value for ~~all~~the existing components is the value in the third column.

VERIFICATION & REPORTING

Verification of existing conditions is a special feature and is reported in the *HERS Required Verification* listings on the CF1R.

2.2.5 Air Leakage and Infiltration

Air leakage is a building level characteristic. The compliance software distributes the leakage over the envelope surfaces in accordance with the building configuration and constructs a pressure flow network to simulate the air flows between the conditioned zones, unconditioned zones and outside.

2.2.5.1 Building Air Leakage and Infiltration (~~cfm50 and~~ ACH50)

The air flow through a blower door test at 50 Pascal (Pa) of pressure measured in cubic feet per minute is called cfm50. Cfm50 x 60 minutes divided by the volume of conditioned space is the air changes per hour at 50 Pa, called ACH50. ~~Either cfm50 or ACH50 can be used to describe the building air leakage depending on the circumstances.~~

Specific data on ACH50 may be entered if the single family house or townhouse will have verified building air leakage testing. In multi-family buildings, due to the lack of an applicable measurement standard, ACH50 is fixed at the above defaults.

~~User input of an ACH50 less than the default value is a Special Feature that requires post-construction verification of building infiltration testing.~~

PROPOSED DESIGN

ACH50 defaults to 5 for new construction in single family buildings and townhomes and 7 for all other buildings that have heating and/or cooling system ducts outside of conditioned space and for buildings with no cooling system. In single-family buildings and townhomes with no heating and/or cooling system ducts in unconditioned space the default ACH50 is 4.4 and 6.2 for all others.

Specific data on ACH50 may be entered if the single family house or townhouse will have verified building air leakage testing. User input of an ACH50 that is less than the default value ~~is~~becomes a Special Feature that requires HERS verification.

~~In multi-family buildings, d~~Due to the lack of an applicable measurement standard, ACH50 is fixed at the above defaults and is not a compliance variable in multi-family buildings.

STANDARD DESIGN

The standard design shall have 5 ACH50 for single family buildings and 7 for other buildings (ducted space conditioning).

VERIFICATION AND REPORTING

When the user chooses verified building air leakage testing (any value less than the standard design), diagnostic testing for reduced infiltration, with the details and target values modeled in the proposed design, is reported in the HERS Required Verification listing on the CF1R.

2.2.5.2 Defining Air Net Leakage

The compliance software creates an air leakage network for the proposed and standard design using the building description. Air leakage is distributed across the envelope surfaces according to the factors in Table 2-3. The air network is insensitive to wind direction. For buildings modeled with multiple conditioned zones, either a 20 square foot open door or 30 square foot open stairwell (in a multi-story building) is assumed between any two conditioned zones.

The only difference between the air network for the proposed and standard designs is the ACH50 if the user specifies a value lower than the default.

Multi-family buildings that have floors between dwelling units~~,~~ must define each floor as a separate zone or each dwelling unit as a separate zone.

Table 2-3: Air Leakage Distribution

	% of Total Leakage by Surface			
Configuration	**Ceilings**	**Floors**	**Exterior Walls**	**House to Garage Surfaces**
Slab on grade	50	0		
Raised Floor	40	10		
No Garage			50	0
Attached Garage			40	10

2.2.6 Insulation Construction Quality

The compliance software user may specify either standard (unverified) or improved (verified high quality insulation installation, also called Quality Insulation Installation or QII)) for the proposed design. Buildings with standard insulation installation are modeled in the program with lower performing cavity insulation in framed walls, ceilings and floors and with added winter heat flow between the conditioned zone and attic to represent construction cavities open to the attic (see Table

2-4). Standard insulation does not affect the performance of continuous sheathing in any construction.

PROPOSED DESIGN

The compliance software user may specify improved quality insulation installation at the building level. The default is unverified/standard insulation installation. See Section 2.3.3 for information on modeling spray foam insulation.

STANDARD DESIGN

The standard design is modeled with standard insulation installation quality.

VERIFICATION AND REPORTING

The presence of improved/verified high quality insulation installation is reported in the HERS Required Verification listings on the CF1R. Improved quality insulation installation is certified by the installer and field verified to comply with RA3.5. Credit for verified quality insulation installation is applicable to ceilings/attics, knee walls, exterior walls and exterior floors.

Table 2-4: Modeling Rules for Standard Insulation Installation Quality

Component	Modification
Walls	Multiply the cavity insulation R-value/inch by 0.7
Ceilings/Roofs	Multiply the blown and batt insulation R-value/inch by 0.96-0.00347*R
Ceiling below attic	Add a heat flow from the conditioned zone to the attic of 0.015 times the area of the ceiling below attic times (the conditioned zone temperature - attic temperature) whenever the attic is colder than the conditioned space

For alterations to existing pre-1978 construction, if existing wall construction is assumed to have no insulation, no wall degradation is assumed for the existing wall.

2.2.7 Number of Bedrooms

PROPOSED DESIGN

The number of bedrooms in a building is used to establish the indoor air quality (IAQ) mechanical ventilation requirements and to determine if a building qualifies as a compact building for purposes of incentive programs.

STANDARD DESIGN

The standard design shall have the same number of bedrooms as the proposed design.

VERIFICATION AND REPORTING

The number of bedrooms is reported on the CF1R for use in field verification.

2.2.8 Dwelling Unit Types

Internal gains and indoor air quality (IAQ) ventilation calculations depend on the conditioned floor area and number of bedrooms. For multi-family buildings with individual IAQ ventilation systems, each different combination of bedrooms and conditioned floor area has a different minimum ventilation cfm that must be verified. A dwelling unit type is one or more dwelling units in the building, each of which has the same floor area, number of bedrooms and appliances.

PROPOSED DESIGN

For each dwelling unit type the user inputs the following information:

- Unit name
- ~~Number~~ Quantity of this unit type in building
- Conditioned floor area (CFA) in square feet per dwelling unit
- Number of bedrooms

STANDARD DESIGN

The standard design shall have the same number and type of dwelling units as the proposed design.

VERIFICATION AND REPORTING

The number of units of each type and minimum IAQ ventilation for each unit is reported on the CF1R for use in field verification.

2.2.9 Front Orientation

The input for the building front orientation is the actual azimuth of the front of the building. This will generally be the side of the building where the front door is located. The orientation of the other sides of a building viewed from the outside looking at the front door are called front, left, right, back, or a value relative to the front, and the compliance software calculates the actual azimuth from this input. Multiple orientation compliance can be selected for newly constructed buildings only.

PROPOSED DESIGN

The user ~~chooses~~specifies whether compliance is for ~~all~~multiple orientations or for a site-specific orientation. For site-~~the~~ specific orientation ~~case, input~~ the user inputs the actual azimuth of the front in degrees from true north.

STANDARD DESIGN

The compliance software constructs a standard design building that has 25 percent of the proposed model's wall and window area facing each cardinal orientation regardless of the proposed model's distribution of wall and window area.

VERIFICATION AND REPORTING

A typical reported value would be "290 degrees (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 reported in parenthesis, e.g., north, northeast, east, southeast, south, southwest, west or northwest. When compliance is shown for multiple orientations, "all orientations" or “cardinal” is reported as a Special Feature on the CF1R and the energy use results are reported for four orientations including North, East, South and West.

2.2.10 Natural Gas Availability

The user specifies whether natural gas is available at the site. This is used to establish the TDV values from Reference Appendices JA3 used by the compliance software in determining standard and proposed design energy use.

PROPOSED DESIGN

The user specifies whether natural gas is available at the site.

STANDARD DESIGN

The standard design for space heating provided by gas is either natural gas, if available, or propane. The standard design for space heating provided by electricity is natural gas, if available, otherwise it is electricity. The standard design for water heating is always natural gas.~~has natural gas space and water heating if natural gas is available at the site; otherwise it is propane~~.

VERIFICATION AND REPORTING

Whether natural gas is or is not available is reported on the CF1R.

2.2.11 Attached Garage

The user specifies whether there is an attached garage. The garage zone is modeled as an unconditioned zone (see Section 2.8).

PROPOSED DESIGN

The user specifies whether there is an attached unconditioned garage.

STANDARD DESIGN

The standard design has the same attached garage assumption as the proposed design.

VERIFICATION AND REPORTING

The presence of an attached garage is reported on the CF1R.

2.2.12 Lighting

The user specifies interior lighting and exterior lighting which are accounted for in internal gain assumptions. There are no tradeoffs between lighting and other building features.

Proposed Design

Fraction of portable lighting, power adjustment multiplier and the exterior lighting power adjustment multiplier (Watts/ft2).

Standard Design

The standard design lighting is set equal to the proposed lighting.

Verification and Reporting

No lighting information is reported on the CF1R.

2.2.13 Appliances

Appliance data is available for projects other than for Title 24, Part 6 compliance, such as design ratings. The information impacts internal gains with no effect on the Title 24 energy compliance margin.

Proposed Design

The user specifies whether the following appliances are in the building, their fuel consumption or fuel type, and the zone that contains the appliance:

- Refrigerator (default or a specified kWh/yr)
- Dishwasher (default based on number of bedrooms or a specified kWh/yr)
- Clothes washer
- Clothes dryer
- Cooking appliances

Standard Design

The standard design appliances are set equal to the proposed appliances.

Verification and Reporting

No appliance information is reported on the CF1R.

2.3 Building Materials and Construction~~Envelope~~

2.3.1 Materials

Only materials approved by the Commission may be used in defining constructions. Additional materials may be added to the Compliance Manager. Table 2-5 shows partial list of the materials currently available for construction assemblies.

Table 2-5: Materials List

Material Name	Thickness (in.)	Conductivity (Btu/h-°F-ft)	Coefficient for Temperature Adjustment of Conductivity (°F(-1))	Specific Heat (Btu/lb-°F)	Density (lb/ft3)	R-Value per Inch (°F-ft2-h/Btu-in)
Gypsum Board	0.5	0.09167	0.00122	0.27	40	0.9091
Wood layer	~~0.5~~varies	0.06127	0.0012	0.45	41	1.36
R4 Synth Stucco	1	0.02083	0.00418	0.35	1.5	4
3 Coat Stucco	0.875	0.4167		0.2	116	0.2
Carpet	0.5	0.02		0.34	12.3	4.1667
Light Roof	0.2	1		0.2	120	0.0833
5 PSF Roof	0.5	1		0.2	120	0.0833
10 PSF Roof	1	1		0.2	120	0.0833
15 PSF Roof	1.5	1		0.2	120	0.0833
25 PSF Roof	2.5	1		0.2	120	0.0833
TileGap	0.75	0.07353		0.24	0.075	1.1333
SlabOnGrade	3.5	1		0.2	144	0.0833
Earth		1		0.2	115	0.0833
~~Crawl~~	~~12~~	~~0.16667~~		~~0.24~~	~~0.075~~	~~0.5~~
SoftWood		0.08167	0.0012	0.39	35	1.0204
Concrete		1		0.2	144	0.0833
Foam Sheathing	varies	varies	0.00175	0.35	1.5	varies
Ceiling Insulation	varies	varies	0.00418	0.2	1.5	varies
Cavity Insulation	varies	varies	0.00325	0.2	1.5	varies
Vertical Wall Cavity	3.5	0.314	0.00397	0.24	0.075	
GHR Tile	1.21	0.026	0.00175	0.2	38	
ENSOPRO	0.66	0.03	0.00175	0.35	2	
ENSOPRO Plus	1.36	0.025	0.00175	0.35	2	
Door						
~~R1 Sheathing~~	~~1~~	~~0.08333~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~1~~
~~R2 Sheathing~~	~~1~~	~~0.04167~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~2~~

Material Name	Thickness (in.)	Conductivity (Btu/h-°F-ft)	Coefficient for Temperature Adjustment of Conductivity (°F(-1))	Specific Heat (Btu/lb-°F)	Density (lb/ft3)	R-Value per Inch (°F-ft2-h/Btu-in)
~~R3 Sheathing~~	~~1~~	~~0.02778~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~3~~
~~R4 Sheathing~~	~~1~~	~~0.02083~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~4~~
~~R5 Sheathing~~	~~1~~	~~0.01667~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~5~~
~~R6 Sheathing~~	~~1~~	~~0.01389~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~6~~
~~R7 Sheathing~~	~~1~~	~~0.0119~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~7~~
~~R8 Sheathing~~	~~1~~	~~0.01042~~	~~0.00418~~	~~0.35~~	~~1.5~~	~~8~~

MATERIAL NAME

The material name is used to select the material for a construction.

THICKNESS

Some materials, such as 3-coat stucco, are defined with a specific thickness (not editable by the compliance user). The thickness of other materials, such as softwood used for framing, is selected by the compliance user based on the construction~~s~~ ~~in~~of the building.

CONDUCTIVITY

The conductivity of the material is the steady state heat flow per square foot, per foot of thickness, or per degree Fahrenheit temperature difference. It is used in simulating the heat flow in the construction.

COEFFICIENT FOR TEMPERATURE ADJUSTMENT OF CONDUCTIVITY

The conductivity of insulation materials varies ~~hourly~~ with their temperature according to the coefficient listed. Other materials have a coefficient of 0 and their conductivity does not vary with temperature.

SPECIFIC HEAT

The specific heat is the amount of heat in Btu it takes to raise the temperature of one pound of the material one degree Fahrenheit.

DENSITY

The density of the material is its weight in pounds per cubic foot.

R-VALUE PER INCH

The R-value is the resistance to heat flow for a 1-inch thick layer.

2.3.2 Construction Assemblies

Constructions are defined by the compliance user for use in defining the building. The user assembles a construction from one or more layers of materials as shown in Figure 2-2. For framed constructions there is a framing layer that has parallel paths for the framing and the cavity between the framing members. The layers that are allowed depend on the surface type. The Compliance Manager calculates a winter design U-factor which is compared to a construction that meets the prescriptive standard. The U-factor is displayed as an aid to the user. The calculations used in the energy simulation are based on each individual layer and framing rather than the U-factor.

Figure 2-2: Example Construction Data Screen

ASSEMBLY TYPES

The types of assemblies are:

Exterior wall
Interior wall
Underground walls
~~Demising~~Interior wall
~~Knee wall~~
Attic roof
Cathedral roof
Ceiling below attic
Interior ceiling
Interior floor
Exterior floor (over unconditioned space or exterior)
Floor over crawl space

CONSTRUCTION TYPE:

1. Ceiling below attic (the roof structure is not defined here, but is part of the attic), wood or metal framed. In a residence with a truss roof, the ceiling is where the insulation is located. The structure above that is encompassed by the term attic or roof deck. The roof or attic consists of (moving from inside to outside) the radiant barrier, below deck insulation, framing, above deck insulation, and the roofing product, such as asphalt or , tile roofing. See more in Section 2.4.5.

2. Cathedral ceiling (with the roof defined as part of the assembly), wood or metal framed. Since there is no attic, the roof structure is connected to the insulated assembly at this point.

3. Roof, structurally insulated panels (SIP).

4. Walls (interior, or exterior, underground), wood or metal framed, or SIP.

5. Floors (over exterior, over crawl space, or interior).

CONSTRUCTION LAYERS:

All assemblies have a cavity path and a frame path.

Spray foam insulation may use either default values with no special inspection requirements, or higher values when supported by an ICC report (see details Section 2.3.3 and RA3.5) verified by a HERS rater.

As assemblies are completed, the screen displays whether the construction meets the prescriptive requirement for that component.

PROPOSED DESIGN

The user defines a construction for each surface type included in the proposed design. Any variation in insulation R-value, framing size or spacing, interior or exterior sheathing or interior or exterior finish requires the user to define a different construction. Insulation R-values are based on manufacturer's rated properties rounded to the nearest whole R-value. Layers such as sheetrock, wood sheathing, stucco and carpet whose properties are not compliance variables are included as generic layers with standard thickness and properties.

Walls separating the house from an attached unconditioned attic or garage are modeled as interior walls with unconditioned space as the adjacent zone, which the compliance manager recognizes as a demising wall. Floors over a garage are modeled as floor over exterior. The exterior walls, floor, ceiling/roof of the garage are modeled as part of the unconditioned garage zone.

STANDARD DESIGN

The compliance software assembles a construction that meets the prescriptive standards for each user-defined construction or assembly.

VERIFICATION AND REPORTING

All proposed constructions, including insulation, frame type, frame size, and exterior finish or exterior condition are listed on the CF1R. Non-standard framing (e.g., 24" on center wall framing, advanced wall framing) is reported as a special feature.

2.3.3 Spray Foam Insulation

The R-values for spray applied polyurethane foam insulation differs depending on whether the product is open cell or closed cell.

Table 2-6: Required Thickness Spray Foam Insulation

Required R-values for SPF insulation	R-11	R-13	R-15	R-19	R-21	R-22	R-25	R-30	R-38
Required thickness closed cell @ R5.8/inch	2.00 inches	2.25 inches	2.75 inches	3.50 inches	3.75 inches	4.00 inches	4.50 inches	5.25 inches	6.75 inches
Required thickness open cell @ R3.6/inch	3.0 inches	3.5 inches	4.2 inches	5.3 inches	5.8 inches	6.1 inches	6.9 inches	8.3 inches	10.6 inches

Additional documentation and verification requirements for a value other than default values shown in Table 2-6 is required (see RA3.5.6).

2.3.3.1 Medium Density Closed-Cell SPF Insulation

The default R-value for spray foam insulation with a closed cellular structure is R-5.8 per inch, based on the installed nominal thickness of insulation. Closed cell insulation has an installed nominal density of 1.5 to less than 2.5 pcf pounds per cubic foot (pcf).

2.3.3.2 Low Density Open-Cell SPF Insulation

The default R-value for spray foam insulation with an open cellular structure is calculated as an R-3.6 per inch, calculated based on the nominal required thickness of insulation. Open cell insulation has an installed nominal density of 0.4 to 1.5 pounds per cubic foot (pcf).

PROPOSED DESIGN

The user will select either typical values for open cell or closed cell spray foam insulation or higher than typical values, and enter the total R-value (rounded to the nearest whole value).

STANDARD DESIGN

The compliance software assembles a construction that meets the prescriptive standards for each assembly type (ceiling/roof, wall, and floor).

VERIFICATION AND REPORTING

When the user elects to use higher than typical R-values for open cell or closed cell spray foam insulation, a special features note is included on the CF1R requiring documentation requirements specified in RA4.1.7. Additionally, a HERS verification requirement for the installation of spray foam insulation using higher than default values is included on the CF1R.

2.4 Building Mechanical Systems

TheA space conditioning system (also referred to as HVAC system) is made up of the heating subsystem (also referred to as heating unit or heating equipment or heating system), cooling subsystem (also referred to as cooling unit or cooling equipment or cooling system) (if any), the distribution subsystem details and fan subsystem. The building vVentilation cooling systems and indoor air quality ventilation systems are also defined at the building level for single family dwellings or as part of the dwelling unit information infor multi-family buildings (see also Sections 2.4.9 and 2.4.10).

2.4.1 Heating Subsystems

The heating subsystem describes the equipment that supplies heat to an HVAC S space conditioning system. Heating subsystems are categorized according to the types show in Table 2-7.

Table 2-7: HVAC Heating Equipment ~~Descriptors~~Types

~~Recommended Descriptor~~Name	Heating Equipment ~~Reference~~Description
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]~~
WallFurnaceGravity	Non-central gas- or oil-fired wall furnace, gravity flow. Equipment has varying efficiency requirements by capacity. Distribution is ductless. [Efficiency metric: AFUE]
WallFurnaceFan	Non-central gas- or oil-fired wall furnace, fan-forced. Non-central gas- or oil-fired wall furnace, gravity flow. Equipment has varying efficiency requirements by capacity. Distribution is ductless. [Efficiency metric: AFUE]
FloorFurnace	Non-central gas- or oil-fired floor furnace. Equipment has varying efficiency requirements by capacity. Distribution is ductless. [Efficiency metric: AFUE]
GroundSourceHeatPump	A water-to-air heat pump or water-to-water heat pump using fluid flowing through underground piping as a heat source/heat sink, that provides heating, cooling, or heating and cooling conditioning with forced air or hydronic distribution. May also provide heat for domestic hot water.
RoomHeater	Non-central gas- or oil-fired room heaters. Non-central gas- or oil-fired wall furnace, gravity flow. Equipment has varying efficiency requirements by capacity. Distribution is ductless. [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 is listed under “Equipment Type” in the HVAC Systems listing. [Efficiency metric: AFUE]
SplitHeatPump	Heating side of a split heat pump heating system that has one or more outdoor units supply heat to each habitable space in the dwelling unit. Heat is at least partly distributed using one of the ducted systems. [Efficiency metric: HSPF]
DuctlessHeatPump~~System~~	One or more heat pump outdoor units that use refrigerant to transport heat to at least one terminal in each habitable space in the dwelling unit. These include small ductless mini-split and multiple-split heat pumps and packaged terminal (commonly called “through-the-wall”) units. Heat is not distributed using ducts either inside or outside of the conditioned space. [Efficiency metric: COP]
RoomHeatPump	Same as DuctlessHeatPumpSystem except that heat is not supplied to each habitable space in the dwelling unit. [Efficiency metric: COP]
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 is one of the ducted systems.
LrgPkgHeatPump	Heating side of large packaged units rated at or above 65,000 Btu/hr (heating mode). Distribution system is one of the ducted systems. These include water source and ground source heat pumps. [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.
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).
AirToWaterHeatPump	An air-source heat pump that uses hydronic distribution to provide heating, cooling, or heating and cooling conditioning. May also provide heat for domestic hot water.

PROPOSED DESIGN

The user selects the type and supplies inputs for the heating subsystem in the heating system data screen shown in Figure 2-3. The user inputs the appropriate rated heating efficiency factor. Except for heat pumps, ~~T~~the rated heating capacity is not used as a compliance variable ~~and is calculated for~~

~~use in the simulation~~ by the compliance software ~~for all systems except heat pumps~~. For heat pumps the user inputs the rated heating capacity at 47°F and 17°F for the heat pump compressor to be installed and the software sizes the backup electric resistance heat for use in the simulation.

~~Systems rated with a Coefficient of Performance (COP) only must calculate the Heating Seasonal Performance Factor (HSPF) for use in performance compliance:~~

~~Equation 1 HSPF = (3.2 x COP) – 2.4~~

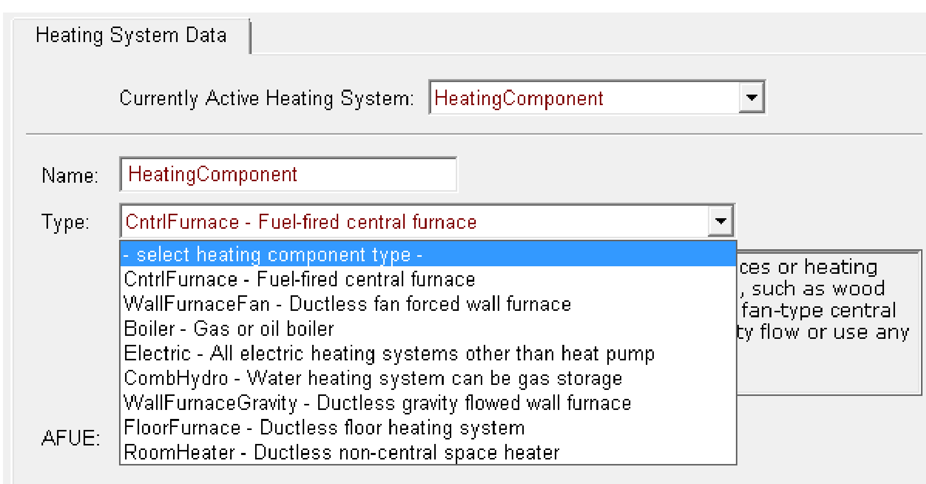
Until there is an approved compliance option for ductless heat pumps (ductless mini-split, multi-split, and VRF systems) ~~they~~ are simulated as a minimum efficiency split system equivalent to the standard design and with default duct conditions.

STANDARD DESIGN

When electricity is used for heating, the heating equipment for the standard design is an electric split system heat pump with a Heating Seasonal Performance Factor (HSPF) meeting the Appliance Efficiency Regulations requirements for split systems with default ducts in the attic. The standard design heat pump compressor size is determined by the software ~~based on~~as the compressor size calculated for ~~the~~ air conditioning ~~system~~or the compressor with a 47 degree F rating that is 75% of the heating load (at the heating design temperature), whichever is larger.

When electricity is not used for heating, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and 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 is a gas furnace.

Figure 2-3: Heating System Data Screen



VERIFICATION AND REPORTING

The proposed heating system type and rated efficiency are reported in the compliance ~~reports~~documentation. The rated heating capacity of each proposed heat pump is reported on the

CF1R ~~so that installed size can be~~ to verify~~ied~~ that installed capacity is equal or larger~~to be at least as large~~.

2.4.2 Combined Hydronic Space/Water Heating

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 a~~n optional~~ modeling capability. Space heating terminals may include fan coils, baseboards, and radiant surfaces (floors, walls or ceilings).

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.

Combined hydronic space conditioning cannot be combined with zonal control credit.

PROPOSED DESIGN

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, the efficiency of the air distribution system must be determined using methods consistent with those described in Section 2.4.6. Duct efficiency is accounted for when the distribution type is ducted.

2.4.2.1 Large or Small Storage Gas Water Heater

When storage gas water heaters are used in combined hydronic applications, the effective AFUE is given by the following equation:

Equation 7 $$AFUE_{eff} = RE - \left[\frac{PL}{RI} \right]$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

RE = The recovery efficiency (or thermal efficiency) of the gas storage water heater. A default value of 0.70 may be assumed if the recovery efficiency is unknown. This value is generally available from the Energy Commission appliance directory.

[Pipe Losses NOT IN CBECC-Res ALPHA VERSION]

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation __

RI = The rated input of the gas water heater (kBtu/h) available from the Energy Commission's appliance directory.

2.4.2.2 Instantaneous Gas Water Heater

[NOT YET IN CBECC-Res ALPHA VERSION]

When instantaneous gas water heaters are used in combined hydronic applications, the effective AFUE is given by the following equation:

Equation 8
$$AFUE_{eff} = EF$$

Where:

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

EF = The rated Energy Factor of the instantaneous gas water heater.

~~2.4.2.2~~2.4.2.3 *Storage Electric Water Heater*

[NOT YET IN CBECC-Res ALPHA VERSION]

The HSPF of storage water heaters used for space heating in a combined hydronic system is given by the following equations.

Equation 9
$$HSPF_{eff} = 3.413\left[1 - \frac{PL}{3.413kWi}\right]$$

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 piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation __).

~~RI~~kWi = The kilowatts of input to the water heater available from the Energy Commission's appliance directory.

~~2.4.2.3~~2.4.2.4 Heat Pump Water Heater

[NOT YET IN CBECC-Res ALPHA VERSION]

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 HSPFeff is used. HSPFw/o_fan is used if there is no fan coil.

Equation 10

$$HSPF_{eff} = 3.413\left[\frac{RE_{hp}}{CZ_{adj}} - \frac{PL}{3.413kWi}\right]$$

Where:

$HSPF_{eff}$ = The effective HSPF of the electric water heater in satisfying the space heating load.

CZ_{adj} = The climate zone adjustment (see Appendix E Table RE-3).

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation __).

~~RI~~kWi = The kilowatts of input to the water heater available from the Energy Commission's appliance directory.

RE_{hp} = The recovery efficiency of the heat pump water heater. Equation 14 may be used as a default if the recovery efficiency is not known.

Equation 11

$$RE_{hp} = \frac{1}{\frac{1}{EF_{DOE}} - 0.1175}$$

Where:

EF_{DOE} = The energy factor of the heat pump water heater when tested according to the DOE test procedure.

STANDARD DESIGN

When electricity is used for heating, the heating equipment for the standard design is an electric split system heat pump with a Heating Seasonal Performance Factor (HSPF) meeting the Appliance Efficiency Regulations requirements for split systems~~, unless the proposed design is a room heat pump, in which case the standard design is the same~~. The standard design heat pump compressor size is determined by the software based on the compressor size calculated for the air conditioning system.

When electricity is not used for heating, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and 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 is a gas furnace.

~~When propane is used for a combined hydronic system, the water heater is electric.~~

2.4.3 Special Systems – Hydronic Distribution Systems and Terminals

PROPOSED DESIGN

This listing is 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.

STANDARD DESIGN

The standard design is established for a hydronic system in the same way as for a central system, as described in Section 2.4.1.

VERIFICATION AND REPORTING

A hydronic or combined hydronic system is reported in the *Special Features* listing on the CF1R.

Other information reported includes:

- *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 (in.).* 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-ft²- °F/Btu).* The installed R-value of the pipe insulation. Minimum pipe insulation for hydronic systems is as specified in §150.~~1~~0(j).

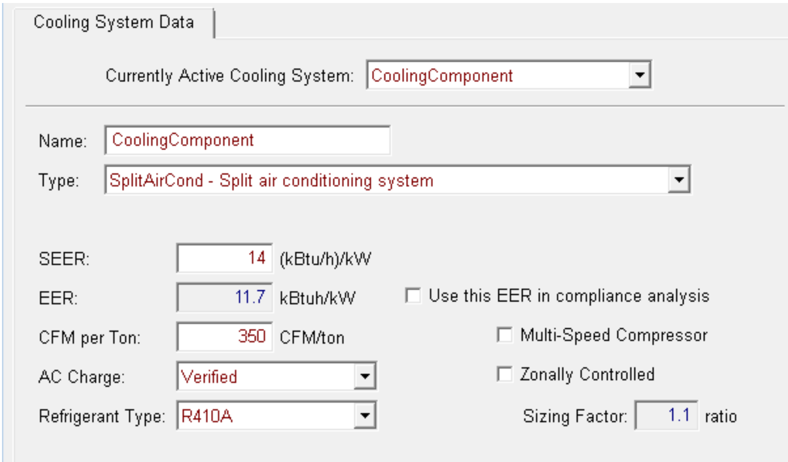
2.4.4 Ground Source Heat Pump

~~Until there is an approved compliance option for~~ A ground source heat pump system~~s to accurately represent this system~~, which uses the earth as a source of energy for heating and as a heat sink for energy when cooling, is simulated as a minimum efficiency split system equivalent to the standard design with default duct conditions ~~is~~in place of ~~substituted for~~ the proposed system. The mandatory efficiencies for ground water source heat pumps are a minimum Coefficient of Performance (COP) for heating and EER for cooling.

2.4.5 Cooling Subsystems

The cooling subsystem describes the equipment that supplies cooling to a~~n HVAC S~~ space conditioning system.

Figure 2-4: Cooling System Data



Proposed Design

Cooling subsystems are categorized according to the types shown in Table 2-8. The user selects the type of cooling equipment ~~from Table 2-7~~ and enters basic information to model the energy use of the equipment. ~~At a minimum, e~~Enter the cooling equipment type and additional information based on the equipment type and zoning, such as the ~~descriptor, zoning type (Table 2-8), and~~ SEER and EER. For some types of equipment, the user may also specify that the equipment has a multi-speed compressor and if the system is zoned or not via checkboxes. ~~The default is NotZonal.~~ For ducted cooling systems the cooling air flow from the conditioned zone through the cooling coil is an input. The rated cooling capacity is not a compliance variable.

Until there is an approved compliance option for ductless heat pumps (ductless mini-split, multi-split, and VRF systems) are simulated as a minimum efficiency split system equivalent to the standard design with default duct conditions.

See sections below for the details of specific inputs.

Standard Design

The cooling system for the standard design building is a non-zonal control split system air conditioner or heat pump meeting the minimum requirements of ~~§150.1(c) and Table 150.1-A~~the Appliance Efficiency Regulations. The standard design system shall assume verified refrigerant charge in climate zones 2 and 8 through 15 for all ducted split systems, ducted package systems, ~~and~~ mini-split, multi-split, and VRF systems. Mandatory fan efficacy is assumed in all climate zones.

Verification and Reporting

Information shown on the CF1R includes cooling equipment type, cooling efficiency (SEER and/or EER). Measures requiring verification are listed on the in the HERS Verification section of the CF1R.

2.4.5.1 Verified Refrigerant Charge or ~~Charge~~Fault Indicator Display

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. Software calculations set the compressor efficiency multiplier to 0.90 to account for the impact of improper refrigerant charge or 0.96 for proper charge.

PROPOSED DESIGN

The software allows the user to indicate if systems will have diagnostically tested refrigerant charge or a field verified ~~charge~~ fault indicator display (~~CID~~FID). This applies only to ducted split system and packaged air conditioners and heat pumps~~, as well as mini-split heat pumps~~.

STANDARD DESIGN

The standard design building is modeled with either diagnostically tested refrigerant charge or a field verified ~~charge indicator display~~ FID if the building is in climate zone 2 or 8-15, and refrigerant charge verification is required by §150.1(c) and Table 150.1-A for the proposed cooling system type.

VERIFICATION AND REPORTING

These features require field verification or diagnostic testing and are reported in the *HERS Required Verification* listings on the CF1R. Details on refrigerant charge measurement are discussed in Reference ~~Appendices,~~ Residential Appendix RA3.2. Information on the requirements for ~~charge indicator displays~~ FIDs is located in Reference ~~Appendices,~~ Joint Appendix JA6.1.

Table 2-8: HVAC Cooling Equipment ~~Descriptors~~Types

~~Recommended Descriptor~~Name	Cooling Equipment ~~Reference~~Description
NoCooling	Entered when the proposed building is not cooled 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 section 2.4.8.3). [Efficiency metric: SEER]
SplitAirCond	Split air conditioning systems. Distribution system is 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 is 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 is one of the ducted systems. [Efficiency metric: EER]
DuctlessSplitAirCond~~System~~	One or more split air conditioning outdoor units that use refrigerant to transport cooling to at least one terminal in each habitable space in the dwelling unit. These include small ductless mini-split and multiple-split heat air conditioners and packaged terminal (commonly called "through-the-wall") units. Cooling is not distributed using ducts either inside or outside of the conditioned space. [Efficiency metric: EER]
RoomAirCond	Same as DuctlessSplitAirCond~~System~~ except that cooling is not supplied to each habitable space in the dwelling unit. [Efficiency metric: EER]
SplitHeatPump	Cooling side of split heat pump systems. Distribution system is 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 is 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 is 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).~~
DuctlessHeatPump~~System~~	One or more heat pump outdoor units that use refrigerant to transport cooling to at least one terminal in each habitable space in the dwelling unit. These include small ductless mini-split and multiple-split heat pumps and packaged terminal (commonly called "through-the-wall") units. Cooling is not distributed using ducts either inside or outside of the conditioned space. [Efficiency metric: EER]
RoomHeatPump	Same as DuctlessHeatPump~~System~~ except that cooling is not supplied to each habitable space in the dwelling unit. [Efficiency metric: EER]
AirToWaterHeatPump	An air-source heat pump that uses hydronic distribution to provide heating, cooling, or heating and cooling conditioning. May also provide heat for domestic hot water.
GroundSourceHeatPump	A water-to-air heat pump or water-to-water heat pump using fluid flowing through underground piping as a heat source/heat sink, that provides heating, cooling, or heating and cooling conditioning with forced air or hydronic distribution. May also provide heat for domestic hot water.
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. Requires air flow and media saturation effectiveness from the CEC directory.
EvapIndirect	Indirect cooling systems. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. Assume energy efficiency ratio of 13 EER. Requires air flow and media saturation effectiveness from the CEC directory.
EvapCondenser~~/CC~~	Evaporatively Cooled Condensers. A split mechanical system, with a water-cooled condenser coil. [Efficiency metric: EER]

~~Table 2-8: Cooling Zonal Control Descriptors~~

~~Zoning Type~~	~~Description~~
~~ZonalSingleSpeed~~	~~A ducted cooling system with a single speed compressor and zone control dampers~~
~~ZonalMultiSpeed~~	~~A ducted cooling system with a multiple speed or variable speed compressor and zone control dampers~~
~~ZonalSingleSpeedBypass~~	~~A zonally controlled HVAC system with a bypass duct~~
~~ZonalSingleSpeedNoBypass~~	~~A zonally controlled HVAC system with no bypass duct~~
~~NotZonal~~	~~Any cooling system that has no zone control dampers~~

Table 2-9: Summary of Air Conditioning Measures Requiring Verification

Measure	Description	Procedures (Need Update)
Verified Refrigerant Charge	Air-cooled air conditioners and air-source heat pumps be diagnostically tested to verify that the system has the correct refrigerant charge. The system must also meet the system airflow requirement.	RA3.2, RA1.2
Verified ~~Charge~~Fault Indicator Display	A ~~Charge~~ Fault Indicator Display can be installed as an alternative to refrigerant charge testing.	RA3.4.2
Verified System Airflow	When compliance requires verified System Airflow greater than or equal to a specified criterion.	RA3.3
Verified Air-handling Unit Fan Efficacy	To verify that Fan Efficacy (Watt/cfm) is less than or equal to a specified criterion.	RA3.3
Verified EER	Credit for increased EER by installation of specific air conditioner or heat pump models.	RA3.4.3, RA3.4.4.1
Verified SEER	Credit for increased SEER.	RA3.4.3, RA3.4.4.1
Evaporatively Cooled Condensers	Must be combined with duct leakage testing, refrigerant charge, and verified EER.	RA3.1, RA3.1.4.3, RA3.2, RA1.2, RA3.4.3, RA3.4.4.1

2.4.5.2 Verified System Airflow

Adequate airflow from the conditioned space is required to allow ducted air conditioning systems to operate at their full efficiency and capacity. Efficiency is achieved by the air distribution system design by improving the efficiency of motors or air distribution systems with less resistance to airflow. Software calculations account for the impact of airflow on sensible heat ratio and compressor efficiency.

A value less than 350 cfm/ton (minimum 150 cfm/ton) is a valid input only if zonally controlled equipment is selected and multi-speed compressor is not selected.

The mandatory requirement in §150.0(m)13 is for an air-handling unit with a verified airflow rate greater than or equal to 350cfm/ton. Credit for a higher airflow rate requires diagnostic testing using procedures in Reference Residential Appendix RA3.3.

For Single Zone Systems:

- Installers may elect to use an alternative to HERS verification of 350 cfm/ton: HERS verification of a return duct design that conforms to the specification given in Table 150.0-B or C.
- The return duct design alternative is not an input to the compliance software, but must be documented on the Certificate of Installation.
- If a value greater than 350 cfm/ton is modeled for compliance credit, the alternative return duct design method using Table 150.0-B or C is not allowed for use in demonstrating compliance.
- Multispeed or variable speed compressor systems must verify airflow rate (cfm/ton) for system operation at the maximum compressor speed and the maximum air handler fan speed.

For Zonally Controlled Systems:

- The Table 150.0-B or C return duct design alternative is not allowed for zonally controlled systems.
- Multispeed, variable speed and single speed compressor systems must all verify airflow rate (cfm/ton) by operating the system at maximum compressor capacity and maximum system fan speed with all zones calling for conditioning.
- Single speed compressor systems must also verify airflow rate (cfm/ton) in every zonal control mode.

PROPOSED DESIGN

The default cooling airflow is 150 cfm/ton for a system with zonally controlled selected and multi-speed compressor not selected (single speed). The default cooling airflow is 350 cfm/ton for all other ducted cooling systems. Users may model a higher-than-default airflow and receive credit in the compliance calculation if greater verified system airflow is diagnostically tested using the procedures of Reference ~~Appendices,~~ Residential Appendix RA3.3.

~~If no cooling system is installed, this value is assumed to be 16.8 cfm/1000 Btu furnace nominal output specified by the manufacturer.~~

STANDARD DESIGN

The standard design shall assume a system that complies with mandatory (§150.0) and prescriptive (§150.1) requirements for the applicable climate zone.

VERIFICATION AND REPORTING

The airflow rate verification compliance target (cfm or cfm/ton) is reported in the *HERS Required Verification* listings of the CF1R. When there is no cooling system it is reported on the CF1R as a special feature.

2.4.5.3 Verified Air Handling Unit Fan Efficacy

The mandatory requirement in §150.0(m)13 is for an air-handling unit fan efficacy less than or equal to 0.58 Watts/cfm as verified by a HERS rater. Users may model a lower fan efficacy (W/cfm) and receive credit in the compliance calculation if the proposed fan efficacy value is diagnostically tested using the procedures in Reference Residential Appendix RA3.3.

For Single Zone Systems:

- Installers may elect to use anThe alternative to HERS verification of 0.58 Watts/cfm: is HERS verification of a return duct design that conforms to the specification given in Table 150.0-CB or DC.
- The return duct design alternative is not an input to the compliance software, but must be documented on the Certificate of Installation.
- However, iIf a value less than 0.58 Watts/cfm is modeled by the software user for compliance credit, the system fan efficacy value modeled by the user shall be verified by a HERS Rater, and the alternative return duct design method using Table 150.0-B or C(m)13 is not allowed for use in demonstrating compliance.
- Multispeed or variable speed compressor systems must verify fan efficacy (Watt/cfm) for system operation at the maximum compressor speed and the maximum air handler fan speed.

For Zonally Controlled Systems:

- The Table 150.0-B or C return duct design alternative is not allowed for zonally controlled systems
- Multispeed, variable speed and single speed compressor systems must all verify fan efficacy (Watt/cfm) by operating the system at maximum compressor capacity and maximum system fan speed with all zones calling for conditioning.
- Single speed compressor systems must also verify fan efficacy in every zonal control mode.

PROPOSED DESIGN

The software shall allow the user to enter the fan efficacy. The default mandatory value is 0.58 W/cfm. However, users may specify a lower value and receive credit in the compliance calculation if verified and diagnostically tested using the procedures of Reference Appendices, Residential Appendix RA3.3.

If no cooling system is installed a default value of 0.58 W/cfm is assumed.

STANDARD DESIGN

The standard design shall assume a verified fan efficacy complying with the mandatory requirement for less than or equal to 0.58 Watts/cfm.

VERIFICATION AND REPORTING

For user inputs lower than the default mandatory 0.58 Watts/cfm, fan efficacy is reported in the *HERS Required Verification* listings of the CF1R.

For default mandatory 0.58 Watts/cfm, the choice of either Fan Efficacy or Alternative Return duct design according to Table 150.0-C or -D is reported in the *HERS Required Verification* listings of the CF1R.

When there is no cooling system it is reported on the CF1R as a special feature.

2.4.5.4 Verified Energy Efficiency Ratio (EER)

PROPOSED DESIGN

Software shall allow the user the option to enter an EER rating for central cooling equipment in "compliance 2014" mode (a HERS verified measure). For equipment that is rated only with an EER (some evaporative coolers, room air conditioners), the user will enter the EER as an SEER. For "compliance 2015," tThe Appliance Efficiency Regulations require a minimum SEER and EER for central cooling equipment. When using compliance 2015, oOnly if a value higher than a default minimum 11.7 EER is used shown for central cooling equipment, is it reported as a HERS verified measure.

STANDARD DESIGN

The standard design for 2014 does not include an EER rating for cooling equipment. For compliance 2015, tThe standard design for central air conditioning equipment is 11.7 EER.

VERIFICATION AND REPORTING

Verified EER is reported in the HERS Required Verification listings on the CF1R for 2014 compliance. For 2015, EER verification is only required if higher than 11.7 EER is modeled. The EER rating is verified using rating data from AHRI Directory of Certified Product Performance at www.ahridirectory.org or another directory of certified product performance ratings approved by the Commission for determining compliance.

2.4.5.5 Verified Seasonal Energy Efficiency Ratio (SEER)

PROPOSED DESIGN

The software allows the user to specify the SEER value.

STANDARD DESIGN

The standard design is based on the default minimum efficiency SEER for the type of cooling equipment modeled in the proposed design, based on the applicable Appliance Efficiency Regulations. For central cooling equipment, the minimum efficiency ~~becomes~~ is 14 SEER and 11.7 EER ~~in 2015~~.

VERIFICATION AND REPORTING

If a SEER higher than the default minimum efficiency is modeled in software, the SEER requires field verification. The higher than minimum SEER rating is verified using rating data from AHRI Directory of Certified Product Performance at www.ahridirectory.org or another directory of certified product performance ratings approved by the Commission for determining compliance. Verified SEER is reported in the *HERS Required Verification* listings on the CF1R.

2.4.5.6 Verified Evaporatively-Cooled Condensers

PROPOSED DESIGN

Software shall allow users to specify an evaporatively-cooled condensing unit. The installation must comply with the requirements of RA4.3.2 to ensure the predicted energy savings are achieved. This credit must be combined with verified refrigerant charge testing, EER, and duct leakage testing.

STANDARD DESIGN

The standard design is based on a split system air conditioner meeting the requirements of §150.1(c) and Table 150.1-A.

VERIFICATION AND REPORTING

An evaporatively-cooled condensing unit, verified EER, and duct leakage testing are reported in the *HERS Required Verification* listings on the CF1R.

2.4.5.7 Evaporative Cooling

[NOT IN CBECC-Res ALPHA VERSION]

Evaporative cooling technology is best suited for dry climates where direct and/or indirect cooling of the supply air stream can occur without compromising indoor comfort. Direct evaporative coolers are the most common system types currently available, but provide less comfort and deliver more moisture to the indoor space. They are assumed to be equivalent to a minimum split system air conditioner. The evaporative cooling modeling methodology addresses two performance issues. The first performance issue is rising indoor relative humidity during periods with extended cooler operation. Since modeling of indoor air moisture levels is beyond the capability of 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°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 is greater than the calculated house cooling load.

PROPOSED DESIGN

Software shall allow users to specify one of three types of evaporative cooling: (1) direct evaporative cooler is the most commonly available system type, (2) indirect, or (3) indirect-direct. Product specifications and other modeling details are found in the Energy Commission appliance directory for evaporative cooling. Direct system types are assigned an efficiency of 1~~3~~4 SEER (or minimum appliance efficiency standard for split system cooling). The default system type is evaporative direct. For indirect or indirect-direct, select the appropriate type, from the Energy Commission appliance directory and input a 13 EER as well as the air flow and media saturation effectiveness or cooling effectiveness from the Energy Commission appliance directory.

STANDARD DESIGN

The standard design is based on a split system air conditioner meeting the requirements of §150.1(c) and Table 150.1-A.

VERIFICATION AND REPORTING

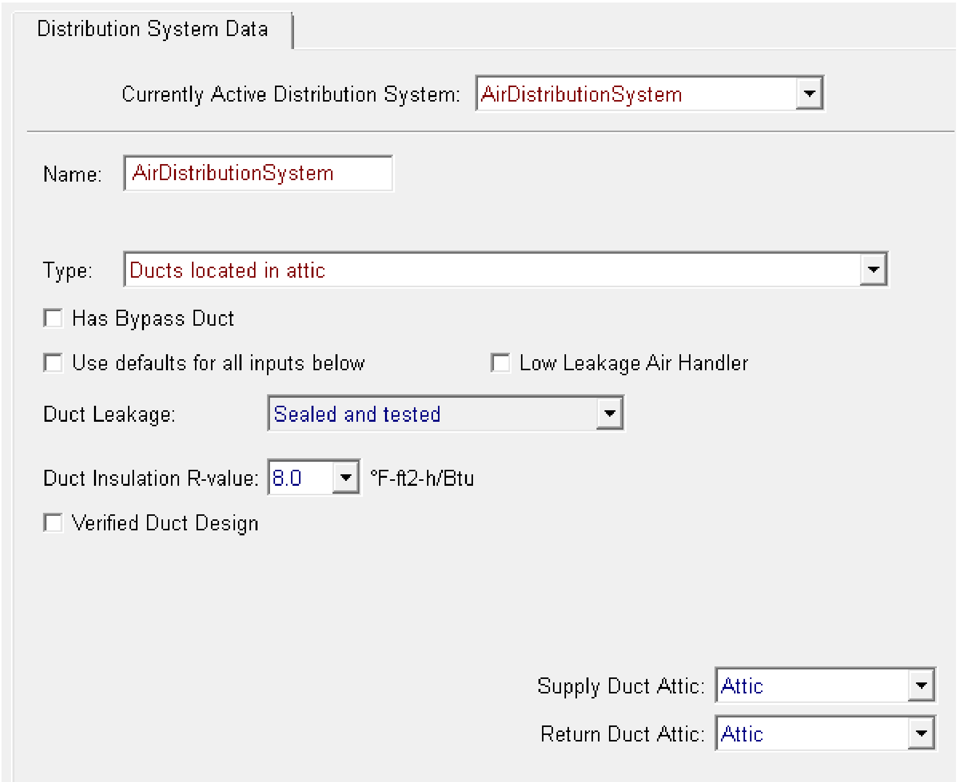
When a direct evaporative cooling system is modeled, the system type and minimum efficiency are shown in the appropriate section of the CF1R. When indirect or indirect-direct evaporative cooling is modeled, the EER verification is shown in the HERS verification section of the CF1R along with the system type, air flow and system effectiveness.

2.4.6 Distribution Subsystems

If multiple HVAC distribution systems serve a building, each system and the conditioned space it serves may be modeled in detail separately or the systems may be aggregated together and modeled as one large system. If the systems are aggregated together they must be the same type and all meet the same minimum specifications.

For the purposes of duct efficiency calculations, the supply duct begins at the exit from the furnace or air handler cabinet.

Figure 2-5: Distribution System Data



2.4.6.1 Distribution Type

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 is calculated. R-value and duct location are specified when a ducted system is specified.

PROPOSED DESIGN

The compliance software shall allow the user to select from the basic types of HVAC distribution systems and locations listed in Table 2-10. For ducted systems, the default location of the HVAC ducts and the air handler are in conditioned space for multi-family buildings and in the attic for all other buildings.

The software will allow users to select default assumptions or specify any of the verified or diagnostically tested HVAC distribution system conditions in the proposed design (see Figure 2-5 and Table 2-11), including duct leakage target, R-value, supply and return duct area, diameter and location.

~~Until there is an approved compliance option for ductless heat pumps (mini-split, multi-split VRF systems) they are simulated as a split system equivalent to the standard design with default duct conditions.~~

Table 2-10: HVAC Distribution Type and Location Descriptors

Recommended DescriptorsName	HVAC Distribution Type and Location ReferenceDescription
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 is calculated. R-value is specified in "Duct R-value" column when a ducted system is specified
Ducts located in unnditioned attic	Ducts located overhead in the unconditioned attic space.
Ducts located in a crawl space	Ducts located under floor in the crawl space.
Ducts located in a garage	Ducts located in an unconditioned garage space.
Ducts located within the conditioned space (except < 12 lineal ft)	Ducts located within the conditioned floor space except for less than 12 linear feet of duct, furnace cabinet and plenums - typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space.
Ducts located entirely in conditioned space	HVAC unit or systems with all HVAC ducts (supply and return) 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 is modeled as leakage to outside the conditioned space.
Distribution system without ducts (none)	Air distribution systems without ducts such as ductless split system air conditioners and heat pumps, window air conditioners, through-the-wall heat pumps, wall furnaces, floor furnaces, radiant electric panels, combined hydronic heating equipment, electric baseboards or hydronic baseboard finned-tube natural convection systems, etc.
Ducts located in outdoor locations	Ducts located in exposed locations outdoors.
Verified low leakage ducts located entirely in conditioned space	Duct systems for which air leakage to outside is equal to or less than 25 cfm when measured in accordance with Reference Appendices, Residential Appendix RA3.1.4.3.8.
Ducts located in multiple places	Ducts with different supply and return duct locations.

Table 2-11: Summary of Verified Air Distribution Systems

Measure	Description	Procedures
Verified Duct Sealing	Mandatory measures require that space conditioning ducts be sealed. Field verification and diagnostic testing is required to verify that approved duct system materials are utilized and that duct leakage meets the specified criteria.	RA3.1.4.3
Verified Duct Location, Reduced Surface Area and R-value	Compliance credit can be taken for improved supply duct location, reduced surface area and R-value. Field verification is required to verify that the duct system was installed according to the duct design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts.[1] For buried ducts measures Verified Insulation Construction Quality (QII) is required as well as duct sealing.	RA3.1.4.1, 3.1.4.1.1
Low Leakage Ducts in Conditioned Space	When the Standards specify use of the procedures in Section RA3.1.4.3.8 to determine if space conditioning system ducts are located entirely in directly conditioned space, the duct system location is verified by diagnostic testing. Compliance credit can be taken for verified duct systems with low air leakage to the outside when measured in accordance with Reference Appendices, Residential Appendix Section RA3.1.4.3.8. Field Verification for ducts in conditioned space is required. Duct sealing is required.	RA3.1.4.3.8
Low Leakage Air-handling Units	Compliance credit can be taken for installation of a factory sealed air handling unit tested by the manufacturer and certified to the Commission to have met the requirements for a Low Leakage Air-Handling Unit ~~achieved~~. Field verification of the air handler's model number is required. Duct Sealing is required.	RA3.1.4.3.9
Verified Return Duct Design	Verification to confirm that the return duct design conforms to the criteria given in Table 150.0-C or Table 150.0-D. as an alternative to meeting 0.58 W/cfm fan efficacy of §150.0(m)0.	RA3.1.4.4
Verified Air Filter Device Design	Verification to confirm that the air filter devices conform to the requirements given in §150.0(m)12.	RA3.1.4.5
Verified Bypass Duct Condition	Verification to determine if system is zonally controlled, and confirm that bypass ducts condition modeled matches installation.	RA3.1.4.6

1. Compliance credit for increased duct insulation R-value (not buried ducts) may be taken without field verification if the R-value is the same throughout the building, and for supply ducts located in crawl spaces and garages where all supply registers are either in the floor or within 2 feet of the floor. These two credits may be taken subject only to enforcement agency inspection.

STANDARD DESIGN

The standard heating and cooling system for central systems is modeled with non-designed air distribution ducts located as described in Table 2-12, with verified tested duct leakage (see Table 2-15). The standard design duct insulation is determined by Package A (assuming attic option B) as R-6 in climate zones 3 and 5-7~~1-10, 12-13~~, and R-8 in climate zones 1-2, 4~~11~~ and ~~14~~8-16. The standard design building is assumed to have the same number of stories as the proposed design for purposes of determining the duct efficiency.

Table 2-12: Summary of Standard Design Duct Location

Configuration of the Proposed Design	Standard Design	
	Standard Design Duct Location	Detailed Specifications
Attic over the dwelling unit	Ducts and air handler located in the attic	Ducts sealed (mandatory requirement) No credit for verified R-value, location or duct design
No attic but crawl space or basement	Ducts and air handler located in the crawl space or basement	
Multi-family buildings and buildings with no attic, crawl space or basement	Ducts and air handler located indoors	

This table is applicable only when the standard design system has air distribution ducts as determined in Table 2-10.

VERIFICATION AND REPORTING

Distribution type, location, R-value, and whether tested and sealed will be shown on the CF1R. If there are no ducts, this is shown as a special feature on the CF1R. Any duct location other than attic (e.g., crawl space) is shown as a special feature on the CF1R. Ducts in crawl space or basement shall include a special feature note if supply registers are located within 2 feet of the floor. Measures that require HERS verification will be shown in the HERS Verification section of the CF1R.

2.4.6.2 Duct Location

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

PROPOSED DESIGN

If any part of the supply or return duct system is located in an unconditioned attic, that entire duct system is modeled with an attic location. If no part of the supply or return duct system is located in the attic, but the duct system is not entirely in conditioned space, it is modeled in the unconditioned zone, which contains the largest fraction of its surface area. If the supply or return duct system is located entirely in conditioned space or the building type is multifamily, the duct system is modeled in conditioned space.

For ducted HVAC systems with some or all ducts in unconditioned space, the user specifies the R-value and surface area of supply and return ducts, and the duct location.

Duct location and areas other than the defaults shown in Table 2-13 may be used following the verification procedures in Reference ~~Appendices,~~ Residential Appendix RA3.1.4.1.

STANDARD DESIGN

The standard design duct location is determined from the building conditions (see Table 2-12).

VERIFICATION AND REPORTING

Duct location is reported on the CF1R. Ducts in conditioned space in other than multi-family buildings or low leakage ducts in conditioned space are reported in the HERS Required Verification listing on the CF1R.

Default duct locations are as shown in Table 2-13. The duct surface area for crawl space and basement applies only to buildings or zones with all ducts installed in the crawl space or basement. If the duct is installed in locations other than crawl space or basement, the default duct location is "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 2-13.

The surface area of ducts located in conditioned space is ignored in calculating conduction losses.

Table 2-13: Location of Default Duct Area

Supply duct location	Location of Default 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

2.4.6.3 Duct Surface Area

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

2.4.6.4 Default Return Duct Surface Area

Default return duct surface area is calculated using:

Equation 12 $$A_{r,out} = K_r \times A_{floor}$$

Where K_r (return duct surface area coefficient) is 0.05 for one-story buildings and 0.1 for two or more stories.

2.4.6.5 Default Supply Duct Surface Area

STANDARD DESIGN

The standard design and default proposed design supply duct surface area is calculated using Equation 13.

Equation 13 $$A_{S,out} = 0.27 \times A_{floor} \times K_S$$

Where K_s (supply duct surface area coefficient) is 1 for one-story buildings and 0.65 for two or more stories.

2.4.6.6 Supply Duct Surface Area for Less Than 12 feet of Duct In Unconditioned Space

PROPOSED DESIGN

For proposed design HVAC systems with air handlers located outside the conditioned space but with less than 12 linear feet of duct located outside the conditioned space including air handler and plenum, the supply duct surface area outside the conditioned space is calculated using Equation 14. The return duct area remains the default for this case.

Equation 14 $$A_{s,out} = 0.027 \times A_{floor}$$

2.4.6.7 Diagnostic Duct Surface Area

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

The surface area of each duct system segment ~~is~~ shall be calculated based on its inside dimensions and length. The total supply surface area in each unconditioned location (attic, attic with radiant barrier, crawl space, basement, other) is the sum of the area of all duct segments in that location. The surface area of ducts completely inside conditioned space need not be input in the 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.

2.4.6.8 Bypass Duct

§150.1(c)13 prohibits use of bypass ducts unless a bypass duct is otherwise specified on the Certificate of Compliance. A bypass duct may be needed for some single speed outdoor condensing unit systems. The software allows users to specify a bypass duct for the system. Selection of a bypass duct does not trigger changes in the ACM modeling defaults, but verification by a HERS Rater is required utilizing the procedure in Reference Residential Appendix Section RA3.1.4.6.

Note: specification of a single speed condensing unit for the system will trigger a default airflow rate value of 150 cfm/ton for the calculations which reduces the compliance margin as compared to systems that model 350 cfm/ton. Users may model airflow rates greater than 150 cfm/ton and receive credit in the calculations as described in section 2.4.5.2.

PROPOSED DESIGN

Software shall allow users to specify whether a bypass duct is or is not used for a zonally controlled forced air system.

STANDARD DESIGN

The standard design is based on a split system air conditioner meeting the requirements of §150.1(c) and Table 150.1-A. The system is not a zonally-controlled system.

VERIFICATION AND REPORTING

An HVAC system with zonal control, and whether the system is assumed to have a bypass duct or have no bypass duct, is reported in the *HERS Required Verification* listings on the CF1R.

2.4.6.9 Duct System Insulation

For the purposes of conduction calculations in both the standard and proposed designs, 85 percent of the supply and return duct surface is assumed to be duct material at its specified R-value and 15 percent is assumed to be air handler, plenum, connectors and other components at the mandatory minimum R-value.

The area weighted effective R-value is calculated by the compliance software using Equation 15 and including each segment of the duct system that has a different R-value.

Equation 15

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

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)

PROPOSED DESIGN

The software user inputs the R-value of the proposed duct insulation and details. The default duct thermal resistance is based on Table 150.1-A,Attic Option B, which is R-6 in climate zones 3 and 5-7, R-8 in zones 1-2, 4, and 8-16~~R-6.0~~.

Duct location, duct R-value, supply, and return duct areas are reported on the CF1R. Credit for systems with mixed insulation levels, non-standard supply and return duct surface areas, or ducts buried in the attic require the compliance and diagnostic procedures in Reference Residential Appendix RA3.1.4.1.

If a verified duct design is selected, non-standard values for the supply duct surface area and the return duct surface area may be input by the user. A verified duct design must be verified by a HERS Rater according to the procedures in Reference Residential Appendix RA3.1.4.1.1.

STANDARD DESIGN

Package A required duct insulation R-values for the attic option B, for applicable climate zone are used in the standard design.

VERIFICATION AND REPORTING

Duct location, duct R-value, ~~non-standard~~ supply, and return duct areas are reported on the CF1R. ~~Credit for systems with mixed insulation levels or ducts buried in the attic require the compliance and diagnostic procedures in Reference Appendices, Residential Appendix RA3.1.4.1.~~

2.4.6.10 Buried Attic Ducts

Ducts partly or completely buried in blown attic insulation in dwelling units meeting the requirements for verified quality insulation installation may take credit for increased effective duct insulation.

The duct design shall identify the segments of the duct that meet the requirements for being buried, and these are separately input into the computer software. Ducts to be buried shall have a minimum of R-6.0 duct insulation prior to being buried. The user shall calculate the correct R-value based on the modeled 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.

The portion 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 2-14. Credit is 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.

Duct segments deeply buried in lowered areas of ceiling and covered by at least 3.5 inches 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.

PROPOSED DESIGN

The software shall allow the user to specify the effective R-value of buried ducts. This feature must be combined with duct sealing and verified quality insulation installation. The default is no buried ducts.

STANDARD DESIGN

The standard design has no buried ducts

VERIFICATION AND REPORTING

Buried duct credit is reported in the HERS Required Verification listing on the CF1R.

Table 2-14: 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

2.4.6.11 Duct/Air Handler Leakage

Duct/air handler average leakage factors shown in Table 2-15 are used in simulating the duct system. The supply duct leakage for each case is the table value times 1.17. The return leakage is the table value times 0.83.

PROPOSED DESIGN

For each ducted system the software user specifies one of the duct/air handler leakage cases shown in Table 2-15.

STANDARD DESIGN

For ducted systems the standard design is sealed and tested duct systems in existing dwelling units or new duct systems.

VERIFICATION AND REPORTING

Sealed and tested duct systems are listed in the HERS verification section of the CF1R.

2.4.6.12 Low Leakage Air Handlers

PROPOSED DESIGN

Credit can be taken for installation of a factory sealed air handling unit tested by the manufacturer and certified to the Energy Commission to meet the requirements for a Low Leakage Air-Handler. Field verification of the air handler's model number is required.

STANDARD DESIGN

The standard design has a normal air handler.

VERIFICATION AND REPORTING

A Low Leakage Air Handler is reported on the compliance report and field verified in accordance with the procedures specified in Reference Appendices, Residential Appendix RA3.1.4.3.9.

2.4.6.13 Verified Low Leakage Ducts in Conditioned Space

PROPOSED DESIGN

For ducted systems the user may specify that all ducts are entirely in conditioned space and the software will model the duct system with no leakage and no conduction losses.

STANDARD DESIGN

The standard design has ducts in the default location.

VERIFICATION AND REPORTING

Systems that have all ducts entirely in conditioned space are reported on the compliance documents and this is verified by measurements showing duct leakage to outside conditions is equal to or less than 25 cfm when measured in accordance with Reference Appendices, Residential Appendix RA3.

Table 2-15: Duct/Air Handler Leakage Factors

Case	Average of Supply and Return
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~~0.965
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

2.4.7 Space Conditioning Fan Subsystems

Fan systems move air for air conditioning, heating and ventilation systems. The software allows the user to define fans to be used for space conditioning, indoor air quality and ventilation cooling. Indoor air quality and ventilation cooling are discussed in Sections 2.4.9 and 2.4.10.

PROPOSED DESIGN

For the space conditioning fan system, the user selects the type of equipment and enters basic information to model the energy use of the equipment. For ducted central air conditioning and heating systems the fan efficacy default is the mandatory minimum verified efficacy of 0.58 W/cfm (also assumed when there is no cooling system).

STANDARD DESIGN

The standard design fan shall meet the minimum §150.1(c) and Table 150.1-A requirements.

VERIFICATION AND REPORTING

Minimum verified fan efficacy is a mandatory requirement for all ducted cooling systems. Fan efficacy is reported in the HERS Required Verification listings on the CF1R.

2.4.8 Space Conditioning Systems

This section describes the general procedures for heating and cooling systems in low-rise residential buildings. The system includes the cooling system, the heating system, distribution system, and mechanical fans.

If multiple systems serve a building, each system and the conditioned space it serves may be modeled in detail separately or the systems may be aggregated together and modeled as one large system. If the systems are aggregated together they must be the same type and all meet the same minimum specifications.

2.4.8.1 Multiple System Types Within Dwelling

PROPOSED DESIGN

For proposed designs using more than one heating system type, equipment type or fuel type, and the types do not serve the same floor area, the user shall zone the building by system type.

STANDARD DESIGN

The standard design shall have the same zoning and heating system types as the proposed design.

VERIFICATION AND REPORTING

The heating system type of each zone is shown on the CF1R

2.4.8.2 Multiple Systems Servings Same Area

If a space or a zone is served by more than one heating system, compliance is 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 is deemed to be the most TDV energy-consuming system unless the supplemental heating meets the Exception to §150.1(c)6. See eligibility criteria in Residential Compliance Manual Section 4.2.2 for conditions under which the supplemental heat may be ignored.

For floor areas served by more than one cooling system, equipment, or fuel type, the system, equipment, and fuel type that satisfies the cooling load is modeled.

2.4.8.3 No Cooling

PROPOSED DESIGN

When the proposed design has no cooling system, the proposed design is required to model the standard design cooling system defined in §150.1(c) and Table 150.1-A. 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 the specified in §150.1(c) and Table 150.1-A for the applicable climate zone.~~same as the proposed design.~~

Verification and Reporting

No cooling is reported as a special feature on the CF1R.

2.4.8.4 Zonally Controlled Forced Air Cooling Systems

Zonally controlled central forced air cooling systems must be able to deliver, in every zonal control mode, an airflow to the dwelling of greater > 350 CFM per ton of nominal cooling capacity, and operating at an air-handling unit fan efficacy of < 0.58 W/CFM. This is a HERS verified measure, complying with Residential Appendix RA3.3.

An exception allows multispeed or variable speed compressor systems, or single speed compressor systems to meet the mandatory airflow (cfm/ton) and fan efficacy (Watt/cfm) requirements by operating the system at maximum compressor capacity and system fan speed with all zones calling for conditioning, rather than in every zonal control mode.

Proposed Design

The user selects zonally controlled as a~~n HVAC~~ cooling system input.

Standard Design

The standard design building does not have a zonally controlled cooling system.

Verification and Reporting

Zonally controlled forced air cooling systems are required to have the system bypass duct status verified by a HERS Rater according to the procedures in Reference Residential Appendix RA3.1.4.6, and the fan efficacy and airflow rate are required to be verified according to the procedures in RA3.3. ~~Zonal control is reported as a *Special Feature* on the CF1R.~~

2.4.9 Indoor Air Quality Ventilation

The standards require mechanical ventilation that complies with ASHRAE Standard 62.2 to provide acceptable indoor air quality for all newly constructed buildings and additions greater than 1,000 square feet. ASHRAE Standard 62.2 provides several ways to comply with the requirement for mechanical ventilation and these are described in the Residential 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 a supply or 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.

The minimum ventilation rate for continuous ventilation of each single family dwelling unit is given in Equation 16.

Equation 16 $$Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$$

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 less than one).

The minimum ventilation rate for continuous ventilation of each multi-family dwelling unit is given in Equation 17.

Equation 17 $$Q_{fan} = 0.03A_{floor} + 7.5(N_{br} + 1)$$

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 less than one).

PROPOSED DESIGN

The proposed design shall incorporate a mechanical ventilation system fan. This requirement is a mandatory measure. The compliance software allows the user to specify the IAQ ventilation type (see Table 2-16) and the cfm of outdoor ventilation air which must be equal to or greater than what is required by ASHRAE Standard 62.2. The default is a standalone exhaust system meeting standard 62.2.

STANDARD DESIGN

The mechanical ventilation system in the standard design is the same as the proposed design. The air flow rate is equal to the proposed design. The apparent heat or enthalpy recovery efficiency is the same as the proposed design. For standalone IAQ fan systems, the fan power ratio is equal to the proposed design value or 1.2 W/cfm, whichever is smaller. For central air handler fans, the fan power ratio is 0.58 W/cfm of central system airflow in ventilation mode.

VERIFICATION AND REPORTING

The required ventilation rate to comply with ASHRAE Standard 62.2 and the means to achieve compliance are indicated on the CF1R. The IAQ system characteristics are reported in the HERS Required Verification listing on the CF1R. The diagnostic testing procedures are in RA3.7.

Table 2-16: IAQ Fans

Type	Description	Inputs
Standalone IAQ Fan (exhaust, supply or balanced)	Dedicated fan system that provides indoor air quality ventilation to meet or exceed the requirements of ASHRAE Standard 62.2.	cfm, Watts/cfm, recovery effectiveness for balanced only
Central Fan Integrated (CFI) (variable or fixed speed)	Automatic operation of the normal furnace fan for IAQ ventilation purposes. Ventilation type uses a special damper to induce outdoor IAQ ventilation air and distribute it through the HVAC duct system. Mixing type distributes and mixes IAQ ventilation air supplied by a separate standalone IAQ fan system.	cfm, Watts/cfm

Table 2-17: CF1R Report – Indoor Air Quality

IAQ System Name	IAQ System Type	Whole Building IAQ Airflow Rate (cfm)	Standalone IAQ Fan Power Ratio (W/cfm)

2.4.10 Ventilation Cooling System

Ventilation cooling systems operate at the dwelling unit level using fans to bring in outside air to cool the house when this can reduce cooling loads and save cooling energy. Ventilation cooling systems such as whole house fans involve window operation and attic venting. Central fan ventilation cooling systems use the HVAC duct system to distribute ventilation air. Ventilation cooling systems operate according to the schedule and setpoints shown in Table 2-18. Ventilation cooling systems that exhaust air through the attic require a minimum of the larger of 1 ft^2 of free attic ventilation area per ~~375~~750 cfm of rated capacity for relief or the manufacturers' specifications (see §150.1(c)12 of the standards).

PROPOSED DESIGN

Software allows the user to specify whether a ventilation cooling system is included in conditioned and living zones (see Table 2-18). The user can specify the actual fan specifications or a default prescriptive whole house fan with a capacity of 1.5 CFM/ft2 of conditioned floor area. ~~The default is none.~~

STANDARD DESIGN

The standard design building for a newly constructed building or for an addition greater than 1,000 square feet has a whole house fan ~~with2 cfm/ft² conditioned floor area~~ in climate zones 8 through 14 and no ventilation cooling in other climate zones (see §150.1(c) and Table 150.1-A). The whole house fan has 1.5 CFM/ft2 of conditioned floor area with 1 square foot of attic vent free area for each 750 CFM of rated whole house fan air flow CFM.

VERIFICATION AND REPORTING

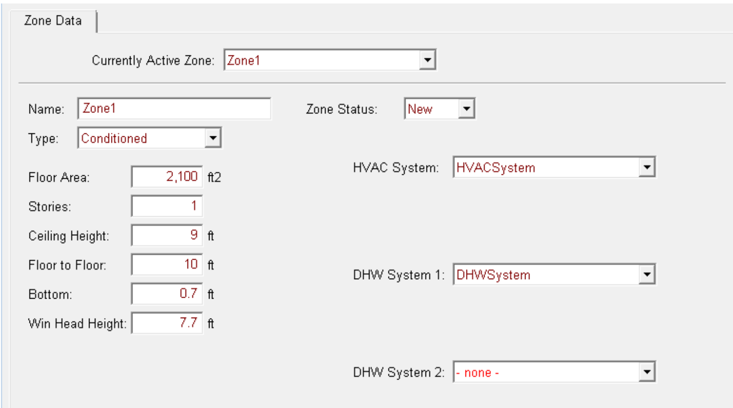
A ventilation cooling system is a *special feature* and the size and type is reported on the CF1R. A variable speed ventilation cooling system requires HERS verification of the make/model number and controls using the CF2R-MECH-30.

Table 2-18: Ventilation Cooling Fans

Measure	Description
Whole House Fan	Traditional whole house fan mounted in the ceiling to exhaust air from the house to the attic, inducing outside air in through open windows. Whole house fans are assumed to operate between dawn and 11 PM only at 25% of rated cfm to reflect manual operation of fan and windows by occupant. Fans must be listed in the California Energy Commission's Whole House Fan directory. If multiple fans are used, enter the total cfm.
Central Fan Ventilation Cooling Variable or fixed speed	Central fan ventilation cooling system. Ventilation type uses a special damper to induce outdoor air and distribute it through the HVAC duct system.

2.5 Conditioned Zones

Figure 2-6: Zone Data



The software requires the user to enter the characteristics of one or more conditioned zones. Subdividing dwelling units into conditioned zones for input convenience or increased accuracy is optional.

2.5.1 Zone Type

PROPOSED DESIGN

The zone is defined as conditioned, living or sleeping. Other zone types include garage, attic and crawl space.

STANDARD DESIGN

The standard design is conditioned.

VERIFICATION & REPORTING

When the zone type is living or sleeping, this is reported as a *Special Feature* on the CF1R.

2.5.1.1 Heating Zonal Control Credit

With the heating zonal control credit, the sleeping and living areas are modeled separately for heating, each with its own separate thermostat schedule and internal gain assumptions. Zonal control cannot be modeled with heat pump heating. The total non-closable opening area between zones cannot exceed 40 ft^2. Other eligibility criteria for this measure are presented in the Residential Compliance Manual, Chapter 4.

PROPOSED DESIGN

The user selects zonal control as a building level input with separate living and sleeping zones.

STANDARD DESIGN

The standard design building is not zoned for living and sleeping separately.

VERIFICATION AND REPORTING

Zonal control is reported as a *Special Feature* on the CF1R.

2.5.2 Conditioned Floor Area

The total conditioned floor area (CFA) is the raised floor as well as the slab-on-grade floor area of the conditioned spaces measured from the exterior surface of exterior walls. Stairwell floor area is included in conditioned floor area as the horizontal area of the stairs and landings between two floors of each story of the house.

PROPOSED DESIGN

The compliance software requires the user to enter the total conditioned floor area of each conditioned zone.

STANDARD DESIGN

The standard design building has the same conditioned floor area and same conditioned zones as the proposed design.

VERIFICATION AND REPORTING

The conditioned floor area of each conditioned zone is reported on the CF1R.

2.5.3 Number of Stories

2.5.3.1 Number of Stories of the Zone

PROPOSED DESIGN

The number of stories of the zone.

STANDARD DESIGN

The standard design is the same as the proposed design.

2.5.3.2 Ceiling Height

PROPOSED DESIGN

The average ceiling height of the proposed design is the conditioned volume of air enclosed by the building envelope. The volume is determined from the total conditioned floor area and the average ceiling height.

STANDARD DESIGN

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

VERIFICATION AND REPORTING

The conditioned volume of each zone is reported on the CF1R.

2.5.3.3 Free Ventilation Area

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

PROPOSED DESIGN

Free ventilation area for the proposed design is calculated as 5 percent of the fenestration area (rough opening), assuming all windows are operable.

STANDARD DESIGN

The standard design value for free ventilation area is the same as the proposed design.

VERIFICATION AND REPORTING

Free ventilation is not reported on the CF1R.

2.5.3.4 Ventilation Height Difference

Ventilation height difference is not a user input.

PROPOSED DESIGN

The default assumption for the proposed design is 2 feet for one-story buildings or one-story dwelling units and 8 feet for two or more stories (as derived from number of stories and other zone details).

STANDARD DESIGN

The standard design modeling assumption for the elevation difference between the inlet and the outlet is 2 feet for one-story dwelling unit and 8 feet for two or more stories.

2.5.3.5 Zone Elevations

The elevation of the top and bottom of each zone is required to set up the air flow network.

PROPOSED DESIGN

The user enters the height of the top surface the lowest floor of the zone relative to the ground outside as the "Bottom" of the zone. The user also enters the ceiling height (the floor to floor height (ceiling height plus the thickness of the intermediate floor structure) is calculated by the software).

Undergound zones are indicated with the number of feet below grade (for example -8).

STANDARD DESIGN

The standard design has the same vertical zone dimensions as the proposed design.

VERIFICATION AND REPORTING

Vertical zone dimensions are shown on the CF1R.

2.5.3.6 Mechanical Systems

PROPOSED DESIGN

The software requires the user to specify a previously defined HVAC system to provide heating and cooling for the zone and an indoor air quality (IAQ) ventilation system. The user may also specify a ventilation cooling system that applies to this and other conditioned zones.

STANDARD DESIGN

The software assigns standard design HVAC, IAQ ventilation, and ventilation cooling systems based on §150.1(c) and Table 150.1-A for the applicable climate zone.

2.5.3.7 Natural Ventilation

Natural ventilation (from windows) is available during cooling mode when needed and available as shown in Table 2-19. The amount of natural ventilation used by computer software for natural cooling is the lesser of the maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint. 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 is constrained by the compliance software to be greater than the heating setpoint temperature.

Table 2-19: Hourly Thermostat Set Points

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

Venting starts in the hour the sun comes up.

2.5.4 Conditioned Zone Assumptions

2.5.4.1 Internal Thermal mass

Internal mass objects are completely inside a zone so that they do not participate directly in heat flows to other zones or outside. They are connected to the zone radiantly and convectively and participate in the zone energy balance by passively storing and releasing heat as conditions change.

Table 2-19 shows the standard interior conditioned zone thermal mass objects and the calculation of the simulation inputs that represent them.

Table 2-20: Conditioned Zone Thermal Mass Objects

Item	Description	Simulation Object
Interior walls	The area of one side of the walls completely inside the conditioned zone is calculated as the conditioned floor area of the zone minus ½ of the area of interior walls adjacent to other conditioned zones. The interior wall is modeled as a construction with 25% 2x4 wood framing and sheetrock on both sides.	Wall exposed to the zone on both sides
Interior floors	The area of floors completely inside the conditioned zone is calculated as the difference between the CFA of the zone and the sum of the areas of zone exterior floors and interior floors over other zones. Interior floors are modeled as a surface inside the zone with a construction of carpet, wood decking, 2x12 framing at 16 in. o.c. with miscellaneous bridging, electrical and plumbing and a sheetrock ceiling below.	Floor/ceiling surface exposed to the zone on both sides
Furniture and heavy contents	Contents of the conditioned zone with significant heat storage capacity and delayed thermal response, for example heavy furniture, bottled drinks and canned goods, contents of dressers and enclosed cabinets. These are represented by a 2 in. thick slab of wood twice as large as the conditioned floor area, exposed to the room on both sides.	Horizontal wood slab exposed to the zone on both sides
Light and thin contents	Contents of the conditioned zone that have a large surface area compared to their weight, for example, clothing on hangers, curtains, pots and pans. These are assumed to be 2 BTU per square foot of conditioned floor area	Air heat capacity (C_{air}) = CFA * 2

PROPOSED DESIGN

The proposed design has standard conditioned zone thermal mass objects which are not user editable and are not a compliance variable. If the proposed design includes specific interior thermal mass elements that are significantly different from what is included in typical wood frame production housing, such as masonry partition walls, the user may include them. See also 2.5.6.4.

STANDARD DESIGN

The standard design has standard conditioned zone thermal mass objects.

VERIFICATION AND REPORTING

Any user input interior thermal mass elements are fully documented on the building plans and noted in the *Special Features* on the CF1R.

2.5.4.2 Thermostats and Schedules

Thermostat settings are shown in Table 2-19. The values for cooling, venting, and standard heating 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.

Systems with no setback required by §110.2(c) (gravity gas wall heaters, gravity floor heaters, gravity room heaters, non-central electric heaters, fireplaces or decorative gas appliances, wood stoves, room air conditioners, and room air-conditioner heat pumps) are assumed to have a constant heating set point of 68 degrees and the same value as in column 1 of Table 2-19 for the cooling set point in both the proposed design and standard design runs.

PROPOSED DESIGN

The proposed design assumes a mandatory setback thermostat meeting the requirements of §110.2(c). Systems exempt from the requirement for a setback thermostat are assumed to have no setback capabilities.

STANDARD DESIGN

The standard design has setback thermostat conditions based on the mandatory requirement for a setback thermostat. For equipment exempt from the setback thermostat requirement, the standard design has no setback thermostat capabilities.

VERIFICATION AND REPORTING

When the proposed equipment is exempt from setback thermostat requirements this is shown as a *Special Feature* on the CF1R.

2.5.4.3 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 2-19, the cooling setpoint is a constant 78°F and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode the heating setpoint is a constant 60°F, and the cooling and venting setpoints are set to the values in Table 2-19.

The 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). When this running average temperature is equal to or less than 60°F, the building is in a heating mode. When the running average is greater than 60°F, the building is in a cooling mode.

2.5.5 Internal Gains

Internal gains are consistent with the HERS Whole House specification:

> California Energy Commission, *HERS Technical Manual*, California Energy Commission, High Performance Buildings and Standards Development Office. CEC-400-2008-012.

except for modifications to include latent gains.

Seasonal Adjustments

Daily internal gain is modified each month according to the multipliers shown in Table 2-21. These multipliers are derived from the number of daylight hours for each month. Identical inputs are used for both the proposed design and the standard design.

Table 2-21: 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

2.5.6 Exterior Surfaces

The user enters exterior surfaces to define the envelope of the proposed design. The areas, construction assemblies, orientations, and tilts modeled are consistent with 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.

2.5.6.1 Ceilings below Attics

Ceilings below attics are horizontal surfaces between conditioned zones and attics. The area of the attic floor is determined by the total area of ceilings below attics defined in conditioned zones.

PROPOSED DESIGN

The software allows the user to define ceilings below attic, enter the area, and select a construction assembly for each.

STANDARD DESIGN ~~(HIGH PERFORMANCE ATTIC)~~

The standard design has the same ceiling below attic area as the proposed design. The standard design is a high performance attic with a ceiling is constructed with 2x4 framed trusses and insulated with the R-values specified in §150.1(c) and Table 150.1-A for the applicable climate zone assuming Option B with a tile roof with an air space.

Climate zones 1-3 and 5-7 have R-0 and climate zones 4 and 8-16 have R-13 insulation between the roofing rafters in contact with the roof deck. Climate zones 1, 2, 4, and 8-16 have R-38 insulation on the ceiling. Climate zones 3 and 5-7 have R-30 insulation on the ceiling. Climate zones 2, 3, 5-7 have a radiant barrier. Climate zones 1, 4, and 8-16 have no radiant barrier.

VERIFICATION AND REPORTING

Ceiling below attic area and ~~insulation~~constructions are reported on the CF1R. Metal frame or SIP assemblies are reported as a special feature on the CF1R.

2.5.6.2 Non-Attic (Cathedral) Ceiling and Roof

Non-Attic Ceilings, also known as cathedral ceilings, are surfaces with roofing on the outside and finished ceiling on the inside but without an attic space.

PROPOSED DESIGN

The software allows the user to define cathedral ceilings and enter the area and select a construction assembly for each. The user also enters the roof characteristics of the surface.

STANDARD DESIGN

The standard design has the same area as the proposed design cathedral ceiling modeled as ceiling below attic with the features of Option B from §150.1(c) and Table 150.1-A for the applicable climate zone.

The non-attic ceiling/roof areas of the standard design building has an area of ceiling below atticare 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). The standard design is modeled with the same construction assembly and characteristics as the proposed design but with Package A insulation R-value. The aged reflectance and emittance of the standard design are determined by §150.1(c) and Table 150.1-A for the applicable climate zone.

VERIFICATION AND REPORTING

Non-attic ceiling/roof area and constructions are reported on the CF1R. Metal frame or SIP assemblies are reported as a special feature on the CF1R.

2.5.6.3 Exterior Walls

PROPOSED DESIGN

The software allows the user to define walls, enter the gross area and select a construction assembly for each. The user also enters the plan orientation (front, left, back or right) or plan azimuth (value relative to the front, which is represented as 0 degrees) and tilt of the wall.

The wall areas modeled are consistent with the actual building design and the total wall area is equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. Underground mass walls are defined with inside and outside insulation and the number of feet below grade. Walls adjacent to unconditioned spaces with no solar gains (such as knee walls or garage walls) are entered as an interior wall with the zone on the other side specified as attic, or garage, or another zone and the compliance manager treats that wall as a demising wall. An attached The unconditioned space is modeled as an unconditioned zone.

STANDARD DESIGN (HIGH PERFORMANCE WALL)

The standard design building has high performance walls modeled with the same area of framed walls as is in the proposed design separating conditioned space and exterior or unconditioned space, with a U-factor equivalent to that ias specified in §150.1(c)1.B. and Table 150.1-A for the applicable climate zone. Walls have 2x6 wood framing with R-19 insulation between framing and R-5 continuous insulation in climate zones 1-5, 8-16 and 2x4 wood framing with R-15 insulation between framing and R-4 continuous insulation in climate zones 6-7.

The standard design building is modeled with the same area of above grade mass walls with interior and exterior insulation equivalent to the requirements in §150.1(c)1.B. and Table 150.1-A for the applicable climate zone.

The standard design building is modeled with the same area of below grade mass walls with interior insulation equivalent to the requirements in §150.1(c)1.B. and Table 150.1-A for the applicable climate zone.

The gross exterior wall area in the standard design is equal to the gross exterior wall area of the proposed design. If the proposed wall area is framed wall, the gross exterior wall area of framed walls in the standard design (excluding knee walls) contains wood framing and is equally divided between the four main compass points, north, east, south, and west.

Wall construction shall match wall construction and thermal characteristics of §150.1(c), Table 150.1-A. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. Walls adjacent to unconditioned space (garage walls) for all climate zones are wood framed, 2x4, 16-in. o.c., R-15 cavity insulation.

VERIFICATION AND REPORTING

Exterior wall area and construction details are reported on the CF1R. Metal frame or SIP assemblies are reported as a special feature on the CF1R.

2.5.6.4 Exterior Thermal Mass

Constructions for standard exterior mass is supported but not implemented beyond the assumptions for typical mass.

The performance approach assumes 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 (see Section 2.5.4.1).

-Mass such as concrete slab floors, masonry walls, double gypsum board and other special mass elements can be modeled. When the proposed design has more than the typical assumptions for mass in a building then each element of heavy mass is modeled in the proposed design, otherwise, the proposed design is modeled with the same thermal mass as the standard design.

PROPOSED DESIGN

The proposed design may be modeled with the default 20 percent exposed mass / 80 percent covered mass, or with actual mass areas modeled as separate covered and exposed mass surfaces. Exposed mass surfaces covered with flooring materials that is in direct contact with the slab can be considered as exposed mass. Examples of such materials are Tile, Stone, Vinyl, Linoleum, and Hard Wood.

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. Interior mass assumptions as described in Section 2.5.4.1 are also assumed. 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/ft3-°F; a conductivity of 0.98 Btu-in/hr-ft2-°F. The exposed portion shall have a surface conductance of 1.3 Btu/hr-ft2-°F (no thermal resistance on the surface) and the covered portion shall have a surface conductance of ~~2.0~~0.50 Btu/hr-ft2-°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/ft3-ºF; a conductivity of 0.98 Btu-in/hr-ft2-ºF; and a surface conductance of 1.3 Btu/hr-ft2-°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.

VERIFICATION AND REPORTING

Exposed mass greater than 20 percent exposed slab on grade and any other mass modeled by the user shall be reported as a special feature on the CF1R.

2.5.6.5 Doors

PROPOSED DESIGN

The compliance software shall allow users to enter doors specifying the U-factor, area, and orientation. Doors to the exterior or to unconditioned zones are modeled as part of the conditioned zone. For doors with less than 50 percent glass area, the U-factor shall come from JA4, Table 4.5.1 (default U-factor 0.50). 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), is modeled under the rules for fenestrations; the opaque area of the door is considered the total door area minus this calculated glass area. Doors with 50 percent or more glass area are modeled under the rules for fenestrations using the total area of the door.

When modeling a garage zone, large garage doors (metal roll-up or wood) are modeled with a 1.0 U-factor.

STANDARD DESIGN

The standard design has the same door area for each dwelling unit as the proposed design. The standard design door area is distributed equally between the four main compass points—north, east, south and west. All doors are assumed to have a U-factor of 0.50. The net opaque wall area is reduced by the door area in the standard design.

VERIFICATION AND REPORTING

Door area and construction are reported on the CF1R.

2.5.6.6 Fenestration

Fenestration is modeled with a U-factor and solar heat gain coefficient (SHGC). Acceptable sources of these values are National Fenestration Rating Council (NFRC), default tables from §110.6 of the standards, and Reference Appendix NA6.

In limited cases for certain site-built fenestration that is field fabricated the performance factors (U-factor, SHGC) may come from Nonresidential Reference Appendix NA6 as described in exception 4 to §150.1(c)3A.

There is no detailed model of chromogenic fenestration available at this time. As allowed by exception 3 to §150.1(c)3A , the lower rated labeled U-factor and SHGC may be used when installed with automatic controls when meeting criteria noted in the exception.

PROPOSED DESIGN

The compliance software allows users to enter individual fenestration or window types, the U-factor, SHGC, area, orientation, and tilt.

Performance data (U-factors and SHGC) ~~are either~~is from NFRC values or ~~are taken~~ from the Energy Commission default tables from §110.6 of the standards. In spaces other than sunspaces, solar gains from windows or skylights use the CSE default solar gain targeting.

Skylights are a fenestration with a slope of 60 degrees or more. Skylights are modeled as part of a roof.

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 §150.1(c) and Table 150.1-A (Package A). Where Package A has no requirement, the SHGC is set to ~~0.50~~match the proposed SHGC.

VERIFICATION AND REPORTING

Fenestration area, U-factor, SHGC, orientation, and tilt are reported on the CF1R.

Chromogenic (promised details from Nelson Pena on 10/29). Use . . . if auto controls, otherwise the proposed design is modeled with Package A values.

2.5.6.7 Overhangs and Sidefins

PROPOSED DESIGN

Software users enter a set of basic parameters for a description of an overhang and sidefin for each individual fenestration or window area entry. The basic parameters 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 may be modeled as sidefins.

Figure 2-7: Overhang Dimensions

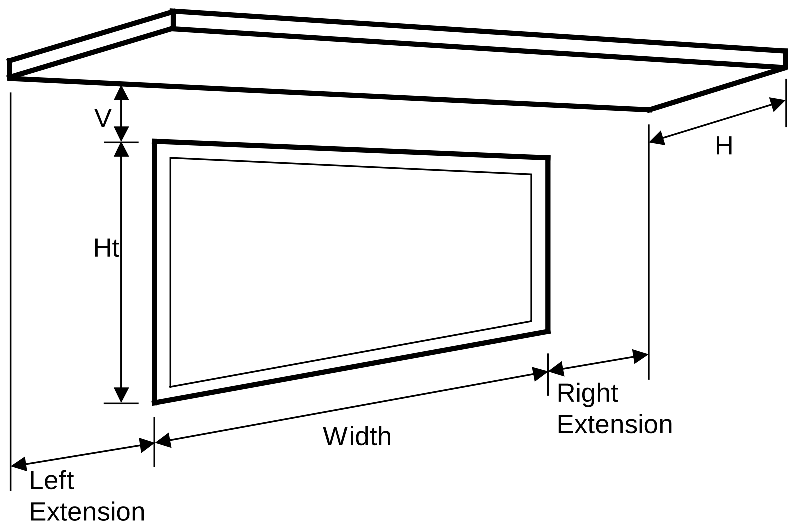
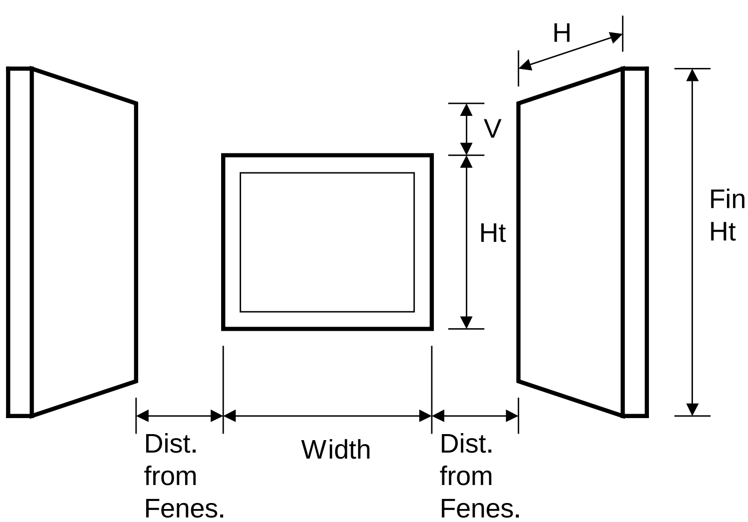


Figure 2-8: Side Fin Dimensions



STANDARD DESIGN

The standard design does not have overhangs or side fins.

VERIFICATION AND REPORTING

Overhang and fin dimensions are reported on the CF1R.

2.5.6.8 Interior Shading Devices

For both the proposed and standard design, all windows are assumed to have draperies and skylights are assumed to have no interior shading. Window medium drapes are closed at night and half open in the daytime hours. Interior shading is not a compliance variable and is not user editable.

2.5.6.9 Exterior Shading

For both the proposed and standard design, all windows are assumed to have bug screens and skylights are assumed to have no exterior shading. Exterior shading is modeled as an additional glazing system layer using the ASHWAT calculation.

PROPOSED DESIGN

The compliance software shall require the user to accept the default exterior shading devices, which are bug screens for windows and none for skylights. Credit for shading devices that are allowable for prescriptive compliance are not allowable in performance compliance.

STANDARD DESIGN

The standard design shall assume bug screens. The standard design does not have skylights.

~~2.5.6.10 Walls and Floors Between Zones~~

~~The user must model unconditioned attached zones such as garages, crawl spaces, and basements.~~

~~**PROPOSED DESIGN**~~

~~The user inputs the area and construction of walls and floors between zones.~~

~~**STANDARD DESIGN**~~

~~The standard design shall have the same wall and floor areas and the constructions meet §150.1(c) and Table 150.1-A.~~

~~**VERIFICATION AND REPORTING**~~

~~Areas and construction of interzone surfaces is reported on the CF1R.~~

~~2.5.6.11~~2.5.6.10 Slab on grade floors

PROPOSED DESIGN

The software allows users to enter areas and exterior perimeter of slabs that are heated or unheated, covered or exposed slab, and with or without with slab edge insulation. Perimeter is the length of wall between conditioned space and the exterior, but does not include edges that cannot be insulated, such as between the house and the garage. The default condition for the proposed design is that 80 percent of each slab area is carpeted or covered by walls and cabinets, and 20 percent is exposed. Inputs other than the default condition require that carpet and exposed slab conditions are documented on the construction plans.

When the proposed heating distribution is radiant floor heating (heated slab), the software user will identify that the slab is heated and model the proposed slab edge insulation. The mandatory minimum requirement is R-5 insulation in climate zones 1-15 and R-10 in climate zone 16 (§110.8(g), Table 110.8-A).

STANDARD DESIGN

The standard design perimeter lengths and slab on grade areas are the same as the proposed design. Eighty percent of standard design slab area is carpeted and 20 percent is exposed. For the standard design, an unheated slab edge has no insulation with the exception of climate zone 16, which assumes R-7 to a depth of 16 inches. The standard design for a heated slab is a heated slab with the mandatory slab edge insulation of R-5 in climate zones 1-15 and R-10 in climate zone 16.

VERIFICATION AND REPORTING

Slab areas, perimeter lengths and inputs of other than the default condition are reported on the CF1R.

~~2.5.6.12~~2.5.6.11 Raised Floors

PROPOSED DESIGN

The software allows the user to input floor areas and constructions for raised floors over a crawl space, over exterior (garage or unconditioned), over a controlled ventilation crawl space, and concrete raised floors. The proposed floor area and constructions are ~~is~~ consistent with the actual building design.

STANDARD DESIGN

The standard design ~~is~~has the same area and type of construction as the proposed design.~~,~~ ~~except~~ ~~t~~The thermal characteristics meet §150.1(c) and Table 150.1-A. For floor areas that are framed construction, the standard design floor has R-19 in 2x6 wood framing, 16" on center. For floor areas that are concrete raised floor, the standard design floor is 4 inches of lightweight concrete with R-8 continuous insulation in climate zones 1, 2, 11, 13, 14, 16, and R-4 in climate zoned 12 and 15, R-0 in climate zones 3-10.

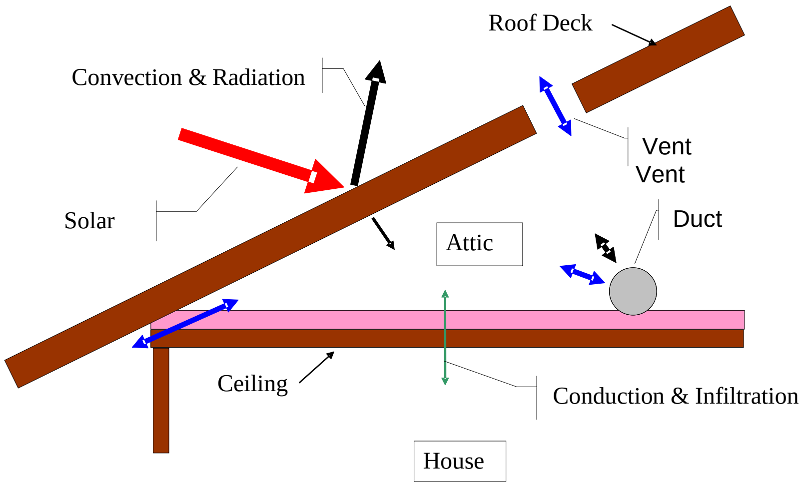
VERIFICATION AND REPORTING

Raised floor areas and constructions are reported on the CF1R.

2.6 Attics

The compliance software models attics as a separate thermal zone and includes 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 2-9.

Figure 2-9: Attic Model Components



2.6.1 Attic Components

2.6.1.1 Roof Rise

This is the ratio of rise to run (or pitch), and refers to the number of feet the roof rises vertically for every 12 feet horizontally. For roofs with multiple pitches the roof rise that makes up the largest roof area is used.

2.6.1.2 Vent Area

This value is the vent area as a fraction of attic floor area. This value is not a compliance variable and is assumed to be a value equal to attic floor area/300.

2.6.1.3 Fraction 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.

2.6.1.4 Roof Deck/Surface Construction

Typical roof construction types are concrete or clay tile, metal tile or wood shakes, or other high or low sloped roofing types.

2.6.1.5 Solar Reflectance

This input is a fraction that specifies the certified aged reflectance of the roofing material or 0.1 default value for uncertified materials. The installed value must be equal to or higher than the value specified here. Roof construction with a roof membrane mass of at least 25 lb/ft^3 or a roof area that has integrated solar collectors is assumed to meet the minimum solar reflectance.

2.6.1.6 Emittance

The certified aged emittance (or emissivity) of the roofing material, or a default value. The installed value must be equal to or greater than the value modeled here. Default value is 0.85 if certified aged thermal emittance value is not available from the Cool Roof Rating Council (www.coolroofs.org). 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.

PROPOSED DESIGN

The conditioning is either ventilated, unventilated, or conditioned. Each characteristic of the roof is modeled to reflect the proposed construction. Values for solar reflectance and emittance shall be default or from the Cool Roof Rating Council.

Roofs with ~~PV systems~~solar collectors or with thermal mass over the roof membrane with a weight of at least 25 lb/ft^2 may model the Package A values for solar reflectance and emittance.

STANDARD DESIGN

The standard design depends on the variables of the climate zone and roof slope. Low-sloped roofs (with a roof rise of 2 feet in 12 or less) in climate zones 13 and 15 will have a standard design aged solar reflectance of 0.63 and a thermal emittance of 0.85.

Steep-sloped roofs in climate zones 10 through 15 will have a standard design roof with an aged solar reflectance of 0.20 and a minimum thermal emittance of 0.85.

Roofs with ~~PV systems~~solar collectors or with thermal mass over the roof membrane with a weight of at least 25 lb/ft^2 are assumed to meet the standard design values for solar reflectance and thermal emittance.

VERIFICATION AND REPORTING

Each input of Section 2.3.2 Attics modeled for the proposed design is reported on the CF1R for verification. A reflectance of 0.20 or higher is reported as a cool roof, a value higher than the default but less than 0.20 is reported as a non-standard roof reflectance value.

2.6.2 Ceiling Below Attic

PROPOSED DESIGN

For each conditioned zone, the user enters the area and construction of each ceiling surface that is below an attic space. The compliance software shall allow a user to enter multiple ceiling constructions. Surfaces that tilt 60 degrees or more are treated as knee walls and are not included as ceilings. The sum of areas shall equal the overall ceiling area with conditioned space on the inside and unconditioned attic space on the other side.

The compliance software creates an attic zone whose floor area is equal to the sum of the areas of all of the user input ceilings below an attic in the building. The user specifies the framing and spacing, the materials of the frame path and the R-value of the insulation path for each ceiling construction.

The user inputs the proposed insulation R-value rounded to the nearest whole R. For simulation, all ceiling below attic insulation is assumed to have nominal properties of R-2.6 per ~~R/~~inch, a density of 0.5 lb/ft^3 and a specific heat of 0.2 Btu/lb.

STANDARD DESIGN

The standard design shall have the same area of ceiling below attic as the proposed design. The ceiling/framing construction is based on the Package A prescriptive requirement and standard framing is assumed to be 2x4 wood trusses at 24 inches on center.

VERIFICATION AND REPORTING

The area, insulation R-value, and layer of each construction is reported on the CF1R.

2.6.3 Attic Roof Surface and Pitch

PROPOSED DESIGN

The roof pitch is the ratio of ~~run to~~ rise to run, e.g., 4:12 or 5:12. If the proposed design has more than one roof pitch, the pitch of the largest area is used.

The compliance software creates an attic zone roof. The roof area is calculated as the ceiling below attic area divided by the cosine of the roof slope where the roof slope is angle in degrees from the horizontal. The roof 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.

If the user specifies a roof with a pitch less than 2:12, the compliance software creates an attic with a flat roof that is 30 in~~.~~ches above the ceiling.

STANDARD DESIGN

The standard design shall have the same roof pitch, roof surface area and orientations as the proposed design.

VERIFICATION AND REPORTING

The roof pitch is reported on the CF1R.

2.6.4 Attic Conditioning

Attics may be ventilated (typical) or unventilated. Insulation in a ventilated attic is usually at the ceiling level but could also be located at the roof deck. and for an uUnventilated attics usually have insulation located at the roof deck may be and at the ceiling or roof level (§150.0(a)).

In an unventilated (conditioned) attic, the roof system becomes part of the insulated building enclosure. Local building jurisdictions may impose additional requirements.

PROPOSED DESIGN

When spray foam insulation is applied to a roof that will not be vented, it is modeled as a "conditioned" attic and the volume of the attic is included in the conditioned space. A conventional attic is assumed to be "ventilated."

STANDARD DESIGN

Attic ventilation is not a compliance variable and is the same for both proposed and standard design.

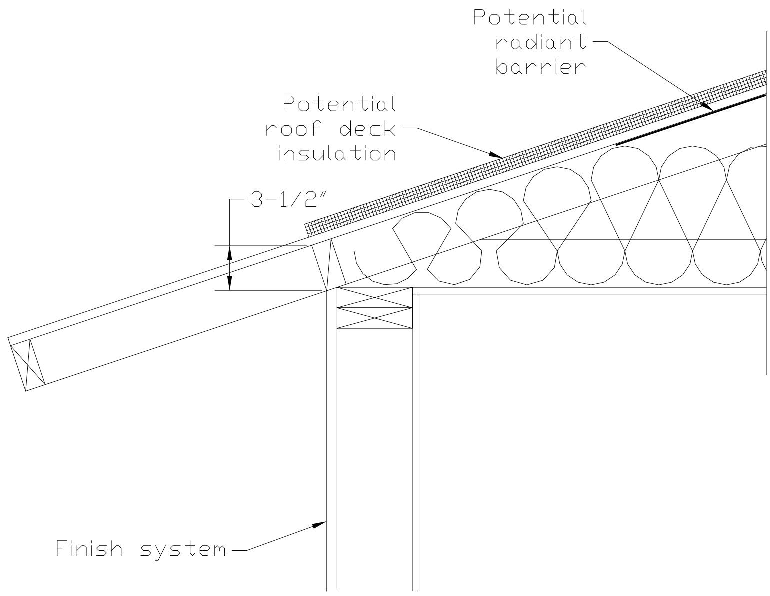
VERIFICATION AND REPORTING

The attic conditioning (ventilated, unventilated, or conditioned) is reported on the CF1R.

2.6.5 Attic Edge

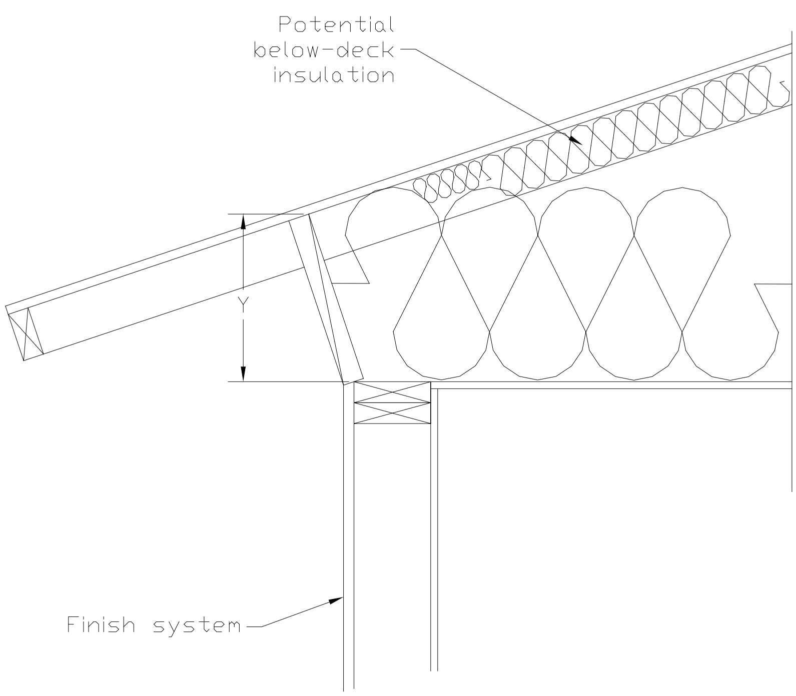
With a standard roof truss (Figure 2-10), the depth of the ceiling insulation is restricted to the space left between the roof deck and the wall top plate for the insulation path and the space between the bottom and top chord of the truss in the framing path. If the modeled insulation completely fills this space, there is no attic air space at the edge of the roof. Heat flow through the ceiling in this attic edge area is directly to the outside both horizontally and vertically, instead of to the attic space. Measures that depend on an attic air space, such as radiant barriers or ventilation, do not affect the heat flows in the attic edge area.

Figure 2-10: Section at Attic Edge with Standard Truss



A raised heel truss (Figure 2-11) provides additional height at the attic edge that, depending on the height Y and the ceiling insulation R, can either reduce or eliminate the attic edge area and its thermal impact.

Figure 2-11: Section at Attic Edge with a Raised Heel Truss



For cases where the depth of insulation (including below deck insulation depth) is greater than the available height at the attic edge, the compliance software automatically creates cathedral ceiling surfaces to represent the attic edge area and adjusts the dimensions of the attic air space using the algorithms contained in the document *2016 Residential Alternative Calculation Method Algorithms*. If above deck insulation is modeled, it is included in the attic edge cathedral ceiling constructions, but radiant barriers below the roof deck are not.

PROPOSED DESIGN

The compliance software shall allow the user to specify that a raised heel truss will be used (as supported by construction drawings), with the default being a standard truss as shown in Figure 2-10. If the user selects a raised heel truss, the compliance software will require the user to specify the vertical distance between the wall top plate and the bottom of the roof deck (Y in Figure 2-11).

STANDARD DESIGN

The standard design shall have a standard truss with the default vertical distance of 3.5 in. between wall top plate and roof deck as shown in Figure 2-10.

VERIFICATION AND REPORTING

A raised heel truss is a special feature and its vertical height above the top plate will be included on the CF1R.

2.6.6 The 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 2-12, which shows a detailed section through the roof deck.

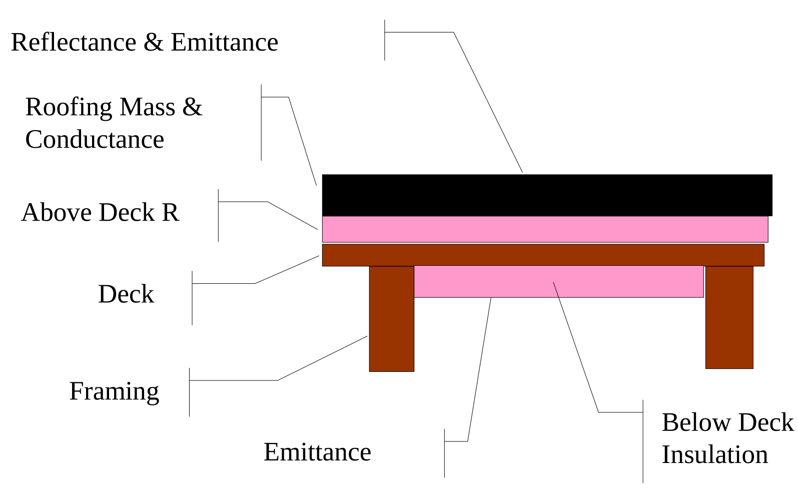


Figure 2-12: Components of the Attic through Roof Deck

2.6.6.1 Radiant Barrier

Radiant barriers are used to reduce heat flow at the bottom of the roof deck in the attic. A 0.05 emittance is modeled at the bottom surface of the roof deck if radiant barriers are used. If no radiant barrier is used, the value modeled is 0.9. If radiant barrier is installed over existing skip sheathing in a reroofing application, 0.5 is modeled.

PROPOSED DESIGN

The user shall specify whether or not the proposed design has a:

- Continuous Radiant Barrier
- Radiant Barrier over Discontinuous Sheathing
- No Radiant Barrier

STANDARD DESIGN

The standard design shall have a radiant barrier if required by the prescriptive standards (§150.1(c) and Table 150.1-A) for the applicable climate zone.

VERIFICATION AND REPORTING

Radiant barriers are reported as a *Special Feature* on the CF1R.

2.6.6.2 Below Deck Insulation

Below deck insulation is insulation that will be installed below the roof deck between the roof trusses or rafters.

PROPOSED DESIGN

The compliance software shall allow the user to specify the R-value of insulation that will be installed below the roof deck between the roof trusses or rafters. The default is no below deck roof insulation.

STANDARD DESIGN

The standard design has below deck insulation.

VERIFICATION AND REPORTING

The R-value of any below deck insulation is reported as a *Special Feature* on the CF1R.

2.6.6.3 Roof Deck and Framing

The roof deck is the structural surface which supports the roofing. The compliance software assumes a standard wood deck and this is not a compliance variable. The size, spacing and material of the roof deck framing are compliance variables.

PROPOSED DESIGN

The roof deck is wood siding/sheathing/decking. The compliance software shall default the roof deck framing to 2x4 trusses at 24 in. o. c. The compliance software shall allow the user to specify alternative framing size, material and framing spacing.

STANDARD DESIGN

The standard design is 2x4 trusses at 24 in. o. c.

VERIFICATION AND REPORTING

Non-standard roof deck framing or spacing is reported as a *Special Feature* on the CF1R.

2.6.6.4 Above Deck Insulation

Above deck insulation represents the insulation value of the air gap in “concrete or clay tile” or “metal tile or wood shakes.” The R-value of any user modeled insulation layers between the roof deck and the roofing is added to the air gap value.

PROPOSED DESIGN

This input defaults to R=0.85 for “concrete or clay tile” or for “metal tile or wood shakes” to represent the benefit of the air gap, but no additional insulation. The compliance software shall allow the user to specify the R-value of additional above deck insulation in any roof deck construction assembly.

STANDARD DESIGN

The standard design accounts for the air gap based on roofing type, but has no additional above deck insulation.

VERIFICATION AND REPORTING

Above deck insulation R-value is reported as a *Special Feature* on the CF1R.

2.6.6.5 Roofing Type and Mass

PROPOSED DESIGN

The choice of roofing type determines the air gap characteristics between the roofing material and the deck, and establishes whether other inputs are needed, as described below. The choices for roof type are shown below.

- **Concrete or clay tile.** These have significant thermal mass and an air gap between the deck and the tiles.
- **Metal tile or wood shakes.** These are lightweight, but have an air gap between the tiles or shakes and the deck. Note that tapered cedar shingles do not qualify and are treated as a conventional roof surface.
- **Other high slope roofing types.** This includes asphalt and composite shingles and tapered cedar shingles. These products have 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 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

STANDARD DESIGN

The roof type and slope shall match the proposed design.

VERIFICATION AND REPORTING

The roof type is reported on the CF1R.

2.6.6.6 Solar Reflectance and Thermal Emittance

PROPOSED DESIGN

The compliance software shall allow the user to default the solar reflectance and thermal emittance of the roofing. The solar reflectance default is 0.10 for all roof types. The thermal emittance default is 0.85.

The compliance software shall allow the user to input aged solar reflectance and thermal emittance of roofing material that are rated by the Cool Roof Rating Council (CRRC). The installed value must be equal to or higher than the value specified here. Roof construction with a roof membrane mass of at least 25 lb/ft³ or roof area incorporated integrated solar collectors are assumed to meet the minimal solar reflectance.

STANDARD DESIGN

The solar reflectance and thermal emittance of the standard design roofing are as specified in the prescriptive Standards.

VERIFICATION AND REPORTING

Thermal emittance and solar reflectance shall be reported on the CF1R. A reflectance of 0.20 or higher is reported as a cool roof, a value higher than the default but less than 0.20 is reported as a non-standard roof reflectance value.

2.7 Crawl Spaces

The crawl space type is either a (1) normal vented crawl space (has a conditioned space above with raised floor insulation), (2) insulated with reduced ventilation [as used in the Building Code], or (3) sealed and mechanically ventilated crawl space (also called a controlled ventilation crawl space or CVC).

PROPOSED DESIGN

The software user will model the crawl space as a separate unconditioned zone, selecting the appropriate crawl space type, with the perimeter of the crawlspace (in linear feet) and the height of the crawl space.

STANDARD DESIGN

The standard design has a typical vented crawlspace when a crawl space is shown. Otherwise the raised floor is assumed to be over exterior or unconditioned space.

VERIFICATION AND REPORTING

The crawl space zone type and characteristics shall be reported on the CF1R. A controlled ventilation crawl space shall be reported as a special feature on the CF1R.

~~2.8 Basements~~

~~2.9~~2.8 Garage/Storage

An attached unconditioned space is modeled as a separate unconditioned zone. While the features of this space have no effect on compliance directly, it is modeled to accurately represent the building. The modeling of the garage will shade the walls adjacent to conditioned space and will also have a lower air temperature (than the outside) adjacent to those walls. The walls and door that separate the conditioned zone from the garage are modeled as part of the conditioned zone.

PROPOSED DESIGN

The software user will model the area and type for the floor, exterior walls (ignore windows), large metal roll-up or wood doors (assume a 1.0 U-factor), and roof/ceiling (typically an attic or the same as the conditioned zone).

STANDARD DESIGN

The standard design building has the same features as the proposed design.

VERIFICATION AND REPORTING

The presence of an attached garage or unconditioned space is reported as general information on the CF1R. The general characteristics of the unconditioned zone are reported on the CF1R.

~~2.10~~2.9 Domestic Hot Water (DHW)

Water heating energy use is based on the number of dwelling units, fuel type, distribution system, water heater type, and conditioned floor area (up to 2500 ft^2).

PROPOSED DESIGN

The water heating system is defined by the tank type, heater element type, distribution type, multi-family central water heating distribution, efficiency (either energy factor or recovery efficiency with the standby loss), tank volume, exterior insulation R-value (only for indirect) and rated input.

Tank types include:

- Small storage: <= 75,000 Btuh gas/propane, <=105,000 Btuh/hr oil, <= 12 kW electric, or <= 24 amps heat pump.
- Small tankless: gas or propane with an input of 200,000 Btu per hour or less, oil with an input of 210,000 Btu per hour or less, or electric with an input of 12 kW or less. Tankless water heater is a water heater with an input rating of >= 4,000 Btu per hour per gallon of stored water. Rated with an energy factor.

- Large storage: > 75,000 Btu gas/propane, >105,000 Btu/hr oil, or > 12 kW electric. Rated with thermal efficiency and standby loss.
- Large tankless: gas or propane with an input of >200,000 Btu per hour, oil with an input of >210,000 Btu per hour, or electric with an input of >12 kW. Tankless water heater is a water heater with an input rating of >= 4,000 Btu per hour per gallon of stored water. Rated with thermal efficiency.
- Mini tank: a temperature buffering electric heater ~~sometimes~~ used ~~with gas tankless~~ to mitigate fluctuations between draws (units not listed in the appliance database use a standby loss (in Watts) of 100). Must be modeled in combination with a tankless gas water heater.
- Indirect: a tank with no heating element or combustion device used in combination with a boiler or other device serving as the heating element.
- Boiler: a water boiler that supplies hot water. Rated with Thermal Efficiency or AFUE.

Heater element type includes:

- Electric resistance
- Natural gas/oil
- Propane, or
- Heat pump.

Distribution system types for systems serving an individual dwelling unit include:

- Standard (the full length of the line from the water heater to the kitchen fixtures and all piping of nominal ¾" or larger diameter insulated with 1 inch of insulation
- Pipe Insulation, All Lines
- Insulated and Protected Pipe Below Grade
- Parallel Piping
- Recirculation, Non-Demand Control
- Recirculation, Demand Control Push Button
- Recirculation, Demand Control Occupancy/Motion
- HERS Required Pipe Insulation, All Lines
- HERS Required Insulated and Protected Pipe Below Grade
- HERS Required Parallel Piping
- HERS Required Recirculation, Demand Control Push Button
- HERS Required Recirculation, Demand Control Occupancy/Motion
- HERS Required Point of Use
- HERS Required Compact Distribution System

Distribution types for multi-family central hot water heating include:

- No Control
- Recirculating Demand Control
- Recirculating Temperature Modulation Control
- Recirculating Temperature Modulation and Monitoring (standard design for new construction)
- Dual loop design for buildings with 8 or more dwelling units w/HERS Verification (can be combined with any of the recirculating conditions)
- Increased pipe insulation w/HERS verification (can be combined with any of the recirculating conditions).

Some distribution systems have an option to increase the amount of credit received if the option for HERS verification is selected. See Appendix E for the amount of credit and Reference Appendices, Residential Appendix Table RA2-1 for a summary of inspection requirements.

STANDARD DESIGN

The standard design is based on §150.1(c)8.

2.9.1 Individual dwelling units

~~: The standard design is based on §150.1(c)8.~~ For systems serving individual ~~single-family dwellings or~~ dwelling units the standard design building has ~~served by a dedicated water heating system, each dwelling unit has~~ single gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank, and that meets the mandatory certification and installation requirements of Sections 110.1 and 110.3.

What about electric and HP

~~one small storage (< 75000 Btu), 50-gallon gas storage water heater, meeting minimum federal Energy Factor standard (0.575 in 2014, 0.60 in 2015). If natural gas is not available, the fuel type is the same as the proposed fuel type, meeting the minimum federal Energy Factor standard for propane (0.575 in 2014, 0.60 in 2015) or electric (0.904 in 2014, 0.945 in 2015). When the proposed fuel type is electric resistance, a solar water heating system with a minimum solar savings fraction of 0.50 is included. The distribution type for gas or propane is either standard or, if a recirculating system is shown in the proposed design, a recirculating system with manual controls. The distribution type for electric resistance is no recirculating system.~~

Table 2-22: Standard Design for Systems Serving Multiple Dwelling Units

<table>
<tr>
<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 propane water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is electric.

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.

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.

The EF of each 100 gallon water heater shall be based on the compliance year as:

~~2014 Gas-fired EF = 0.67 – (0.0019*Vol)~~
~~Electric EF = 0.97 – (0.00132*Vol)~~

2015 Gas-fired > 20 - < 55 gal EF = 0.675 – (0.0015*Vol)
> 55 - ≤ 100 gal EF = 0.8012 – (0.00078*Vol)
Electric > 20 - < 55 gal EF = 0.960 – (0.0003*Vol)
> 55 - ≤ 100 gal EF = 2.057 – (0.00113*Vol)

See specification of distribution system below.</td>
</tr>
<tr>
<td>No</td>
<td>Standard design is composed of the same number of large storage gas or propane 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 electric.

The thermal efficiency is 0.80 and stand-by losses are as specified in the Appliance Efficiency Regulations

See specification of distribution system below.</td>
</tr>
<tr>
<td>No</td>
<td colspan="3">Standard design is the same number of natural gas or propane 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 electric.

Efficiency of the instantaneous water heaters shall be:

~~2014 Input ≤ 200000 < 2 gal EF = 0.62 – (0.0019*Vol)~~
2015 Input ≤ 200000 < 2 gal EF = 0.82 – (0.0019*Vol)
Any Input > 200000 80% Thermal Efficiency

See specification of distribution system below.</td>
</tr>
</table>

2.9.2 Multiple dwelling units

Water heating device.: If When the proposed design is a central water heating system, the standard design is the same type of water heating equipment (natural gas, if available or electric meeting minimum appliance efficiency standard) as the proposed design meeting the minimum appliance efficiency requirements. Natural gas, if available, otherwise propane fuel type.

Recirculating system. The system standard design includes a recirculation system with controls that regulate pump operation based on measurement of hot water demand and hot water return temperature, is capable of turning off the system (§110.3(c)2). The system, has at least two recirculation loops (if serving more than eight dwelling units) loops that meet the requirements of § 110.3(c)5), includingwith efficiency based on Nonresidential Appendix NA6, and incorporates provisions of §110.3(c)5:

1) Air release valve or vertical pump installation,
2) Recirculation loop backflow prevention,
3) Equipment for pump priming,
4) Pump isolation valves,
5) Cold water supply and recirculation loop connection to hot water storage tank, and
6) Cold water supply backflow prevention.

Solar. The standard design has Aa solar water heating system meeting the installation criteria specified in Reference Residential Appendix RA4 and with central water heating system standard design also includes a minimum solar savings fraction of 0.20 in climate zones 1 through 9, or and 0.35 in climate zones 10 through 16.

Verification and Reporting

All modeled features and the number of devices modeled for the water heating system are reported on the CF1R. Where distribution systems specify HERS verification, those features are listed in the HERS Required Verification listings on the CF1R.

2.10.12.9.3 Solar Thermal Water Heating Credit

When a water heating system has a solar thermal system to provide part of the water heating, the Solar Fraction (SF) is determined using an F-chart program, OG-100 or OG-300 calculation method (see www.gosolarcalifornia.org). The calculation method requires that the user specify the climate zone and conditioned floor area, in addition to published data for the solar thermal water heating system.

[NOT IN CBECC-Res ALPHA VERSION]

~~2.11~~2.10Additions/Alterations

Addition and alteration compliance is based on standards §150.2. Alterations must model the entire dwelling unit. ~~Additionally, if~~ When there is no addition, Section 150.2(b)2 requires ~~the standards require~~ at least two components of the residence ~~are~~ must be altered ~~(see 150.2(b)2)~~. Additions may be modeled as an entirely new building (whole building), addition alone, or as "existing+addition+alteration".

~~2.11.1~~2.10.1Whole Building

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. This is a difficult standard to meet as the existing building usually does not meet current standards and must be ~~substantively~~ upgraded.

~~2.11.2~~2.10.2Addition Alone Approach

The proposed addition alone is modeled the same as a newly constructed building except that the internal gains are prorated ~~to~~ based on the size of the dwelling and any surfaces such as walls or ceilings that are between the existing building and the addition are ~~modeled~~ not included in the calculations. 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. Modifications to any surfaces between the existing building and the addition are part of the addition and are not considered alterations.

PROPOSED DESIGN

The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. Any surfaces that are between the existing building and the addition are either not modeled or are treated as adiabatic surfaces. All other features of the addition shall be modeled the same 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 (or Package A, see Sections 2.4.1 and 2.4.5). When a dual-glazed greenhouse or garden window is installed in an addition or alteration, the proposed design U-factor can be assumed to be 0.32.

STANDARD DESIGN

The addition alone is modeled the same as a newly constructed building~~.~~, with the following exceptions:

A. When roofing requirements are included in Table 150.1-A, they are included in the standard design if the added conditioned floor area is greater than 300 ft².

A.B. When ventilation cooling (whole house fan) is required by Table 150.1-A, it is included in the standard design when the added conditioned floor area is greater than 1,000 ft².

2.11.32.10.3 Existing + Addition + Alteration Approach

Standards §150.2(a)2 and (b)2 contain the provisions for additions and alterations to be modeled by including the existing building in the calculations. This is called the "Existing + Addition + Alteration" (or "E+A+A") performance approach.

The proposed design is modeled by identifying each energy feature as part of the existing building, the addition, or an alteration. The compliance software uses this information to create an E+A+A standard design in accordance withusing the rules in the standards that take into account whether altered components meet or exceed the threshold at which point they receive a compliance credit and whether any measures are triggered by altering a given component. For example, when replacing or adding an air handler, outdoor condensing unit of a split system, or cooling or heating coil, the prescriptive requirements include duct leakage testing to 15%.

For building surfaces and systems designated below, all compliance software must provide an input field with labels for the proposed design which define how the standard design requirements are established, based on the option selected by the software user:

- **Existing:** remains unchanged within the proposed design.
- **Altered:** the surface or system is being altered in the proposed design. No verification of existing conditions is performedassumed.
- **Verified and Altered**: the surface or system is being altered in the proposed design and the original condition is verified by a HERS rater (an optional selection).
- **New:** a new surface or system is added in the proposed design (typically part of the addition, but may be in the existing building or an addition).

Features being removed are not included in the proposed design.

When the standard design requirements for existing, altered and new are identical for a particular input, this section uses the term "all".

The compliance software user shall indicate that an existing + addition + alteration is being modeled and select the correct tag for each surface or system. Features to be altered must be paired with an existing feature. The compliance documentation shall clearly indicate each tag.

The user chooses whether the project is runan altered feature includes "Without" or "With Third Party Verification" of an existing condition (see §150.2, Table 150.2-B):

- ~~**Without**~~ **Altered** with no third party verification of existing conditions (the default selection). This compliance path does not require an on-site inspection of existing conditions prior to the start of construction. The attributes of the existing condition is undefined, with the standard design for altered components based on Table 150.2-B and the climate zone. ~~software ignores the specific attributes of the existing condition, and automatically sets the standard design based solely on the type of surface or system being altered and the climate zone.~~ Energy compliance credit is a function of the difference between the value for that specific feature allowed in Table 150.2-B and the modeled/installed efficiency of the feature. ~~This path is the default user selection.~~

  ~~The existing condition for altered features may be left undefined since the software uses Table 150.1-B to set the standard design.~~

  ~~Example: an existing 2x4 wood frame exterior wall with no insulation is upgraded to include R-15 cavity insulation. The standard design is based on R-13 cavity insulation (U=0.102), the mandatory minimum insulation requirement, and the proposed R-15 in the walls receives an energy credit for the difference between R-13 and R-15.~~

- **Verified Altered** ~~With Third Party Verification of~~ existing conditions. This compliance path requires that a HERS Rater perform an on-site inspection of pre-alteration conditions prior to construction ~~registration of the performance Certificate of Compliance by the HERS Provider Data Registry~~. If an altered component or system meets or exceeds the prescriptive alteration requirements, the compliance software uses the user-defined existing condition as the standard design value. ~~Energy compliance credit is then based on the difference between the verified existing condition for that altered feature and the modeled/installed efficiency of the proposed design.~~

  The HERS Rater verifies only ~~those existing~~ features that are flagged by the user to be ~~being~~ altered ~~for compliance credit and used to set the standard design~~. A summary of the existing measures to be verified are listed on a Certificate of Verification ~~a special Verification of Existing Conditions~~ form ~~(CF3R-20-H) which can be downloaded by the HERS Rater from the HERS Provider website~~.

  ~~In this approach, the existing condition for altered features must be defined by the user since that is used to set the standard design.~~

  ~~Using the same example as above, the standard design is the existing uninsulated wall, and the energy compliance credit is based on the difference between the R-0 wall and the proposed R-15 wall.~~

- ~~Details on the verification of existing conditions are contained in the Residential Compliance Manual, Appendix G.~~

~~This subsection presents a summary of standard design modeling assumptions based on proposed design inputs, including whether a proposed feature is new, altered or existing to remain unchanged.~~

~~2.11.3.1~~2.10.3.1 Roof/Ceilings

STANDARD DESIGN

The standard design roof/ceiling construction assembly is based on the proposed design assembly type as shown in Table 2-23. The standard design for unaltered ceilings and roofs is the existing condition.

Table 2-23: *Standard Design for Roofs/Ceilings*

~~Proposed Design Roof/Ceiling Types~~	~~Standard Design Based on Proposed Roof/Ceiling Status (Tag)~~			
	~~ADDITION~~ ~~Addition or New Construction~~	~~ALTERED~~ ~~Without 3rd Party Verification~~	~~VERIFIED ALTERED~~ ~~With 3rd Party Verification~~	~~EXISTING~~
~~Ceilings Below Attics~~	~~CZ1 & 11-16: R-38 between 2x wood framing, 24" o.c.~~ ~~CZ2-10: R-30 between 2x wood framing, 24" o.c.~~	~~R-30 between 2x wood framing, 24" o.c.~~	~~If Proposed is U-factor <= Altered, standard design = Existing roof/ ceiling.~~ ~~If proposed U-factor is > Altered, standard design = Altered~~	~~Existing Roof/Ceiling~~
~~Non-Attic (Cathedral) Ceilings and Roofs~~	~~CZ1 & 11-16: R-38 between 2x wood framing, 24" o.c.~~ ~~CZ2-10: R-30 between 2x wood framing, 24" o.c.~~	~~R-30 between 2x wood framing, 24" o.c. R-19 if proposed is R-19~~	~~If proposed is U-factor <= Altered, standard design = Existing Roof/Ceiling or 0.054 (whichever is higher).~~ ~~If proposed U-factor is > 0.54, standard design = 0.54~~	~~Existing Roof/Ceiling~~
~~Radiant Barrier~~	~~CZ2-15: Radiant Barrier~~ ~~CZ1&16: No Radiant Barrier~~	~~Existing radiant barrier condition~~	~~Existing radiant barrier condition (Y/N)~~	~~Existing Radiant Barrier condition (Y/N)~~
~~Roofing Surface (Cool Roof)~~	~~Low Sloped (< 2:12),~~ ~~CZ13&15: Reflectance=0.63 & Emittance=0.85 or SRI=75~~ ~~Steep Sloped (> 2:12),~~ ~~CZ10-15: Reflectance=0.20 & Emittance=0.85; or SRI=16~~	~~Same as Addition.~~	~~Existing roof surface.~~	~~Existing Roof Surface~~

Proposed Design Roof/Ceiling Types	Standard Design Based on Proposed Roof/Ceiling Status				
	Add ≤ 300 ft^2	Add > 300 ft^2 and ≤ 700 ft	Addition > 700 ft^2	Altered	Verified Altered
Ceilings Below Attics	R-22 / U-0.043	R-22 / U-0.043	CZ 4, 8-16=R-18 above deck + R-38 CZ 1, 2 = R-38 CZ 3, 4-7 = R-30	R-22 / U-0.043	Existing
Non-Attic (Cathedral) Ceilings and Roofs	R-19 / U-0.054	R-19 / U-0.054	Same as above	R-19.U-0.054	Existing
Radiant Barrier	NR	NR	CZ 2, 3, 5-7 REQ CZ 1, 4, 8-16 NR	NR	Existing
Roofing Surface (Cool Roof) Steep Slope	NR	CZ 10-15 >0.20 Reflectance, >0.75 emittance	CZ 10-15 >0.20 Reflectance, >0.75 emittance	CZ 10-15 >0.20 Reflectance, >0.75 emittance	Existing
Roofing Surface (Cool Roof) Low Slope	NR	CZ 13, 15 > 0.63	CZ 13, 15 > 0.63 Reflectance, >0.75 Emittance	CZ 13, 15 > 0.63 Reflectance, >0.75	Existing

		Reflectance, >0.75 Emittance		Emittance	

~~2.11.3.2~~2.10.3.2 Exterior Walls

PROPOSED DESIGN

Existing structures being converted to conditioned space using an E+A+A approach are allowed to show compliance using R-11 wall insulation, without having to upgrade to R-13 mandatory insulation requirements. The walls are modeled as an assembly with R-11 insulation.

STANDARD DESIGN

The areas, orientation and tilt of existing, new and altered net exterior wall areas (with windows and doors subtracted) are the same in the existing and addition portions of standard design as the proposed design.

If the proposed wall area is framed, the gross exterior wall area (excluding knee walls) is equally divided between the four building orientations: front, left, back and right. The gross exterior wall area of any unframed walls is also equally divided between the four orientations in the standard design.

The standard design exterior wall construction assembly is based on the proposed design assembly type as shown in Table *2-24*. Framed walls are modeled as 16-inch on center wood framing. The standard design for unaltered walls is the existing condition.

Table 2-24: Standard Design for Exterior Walls

Proposed Design Exterior Wall Assembly Type	**Standard Design Values Based on Proposed Wall Status (Tag)**			
	ADDITION Addition or New Construction	ALTERED Without 3rd Party Verification	VERIFIED ALTERED With 3rd Party Verification	EXISTING
Above Grade, Any Framed Wall	R-15 cavity insulation in 2x4 16" o.c. wood frame + R-4 exterior continuous insulation	R-13 cavity insulation in 2x4 16" o.c. wood frame	If proposed U-factor is <= Altered, standard design = existing wall. If proposed U-factor is > Altered, standard design = Altered	Existing Wall
Above & Below Grade, Mass Wall, Interior Insulation	CZ1-15: R-13 cavity insulation in 2x4 16" o.c. wood frame inside 8" CMU heavy weight solid grout CZ16: R-13 cavity insulation in 2x4 16" o.c. wood frame + R-4 continuous insulation inside 8" CMU heavy weight solid grout	If proposed U-factor is <= Addition, standard design = existing wall. If proposed U-factor is > Addition, standard design = Addition	Pre-alteration Existing Wall	Existing Wall
Above Grade, Mass Wall, Exterior Insulation	CZ1-15: R-8 continuous insulation outside of 8" CMU heavy weight solid grout CZ16: R-13 cavity insulation in 2x4 16" o.c. wood frame outside of 8" CMU heavy weight solid grout	If proposed U-factor is <= Addition, standard design = existing wall. If proposed U-factor is > Addition, standard design = Addition	Pre-alteration Existing Wall	Existing Wall
Below Grade, Mass Wall, Exterior Insulation	CZ1-13: R-5 continuous insulation outside of 8" CMU heavy weight solid grout CZ14-15: R-10 continuous insulation outside of 8" CMU heavy weight solid grout CZ16: R-19 cavity insulation in 2x6 16"o.c. frame outside of 8" CMU heavy weight solid grout	If proposed U-factor is <= Addition, standard design = existing wall. If proposed U-factor is > Addition, standard design = Addition	Pre-alteration Existing Wall	Existing Wall
Framed Wall Adjacent to Unconditioned (Garage Wall)	R-15 cavity insulation in 2x4 16" o.c. wood frame	R-13 cavity insulation in 2x4 16"o.c. wood frame	Pre-alteration Existing Wall	Existing Wall

Proposed Design Exterior Wall Assembly Type	Standard Design Values Based on Proposed Wall Status			
	Addition ≤ 700 ft²	Addition > 700 ft²	Altered	Verified Altered
Above Grade, Framed Walls	R-15 in 2x4 R-19 in 2x6	CZ 1-5, 8-16 = R-19 in 2x6 + R-5 continuous CZ 6-7 = R-15 in 2x4 + R-4 continuous	R-15 in 2x4 R-19 in 2x6	Existing
Framed Wall Adjacent to Unconditioned (Garage Wall)	R-15 in 2x4 R-19 in 2x6	R-15 in 2x4 wood framing R-19 in 2x6 wood framing	R-15 in 2x4 R-19 in 2x6	Existing
Mass Interior Insulation	CZ 1-15 = R-13 CZ 16 = R-17	CZ 1-15 = R-13 CZ 16 = R-17	CZ 1-15 = R-13 CZ 16 = R-17	Existing
Mass Exterior Insulation	CZ 1-15 = R-8 CZ 16 = R-13	CZ 1-15 = R-8 CZ 16 = R-13	CZ 1-15 = R-8 CZ 16 = R-13	Existing
Below Grade Mass Interior Insulation	CZ 1-15 = R-13 CZ 16 = R-15	CZ 1-15 = R-13 CZ 16 = R-15	CZ 1-15 = R-13 CZ 16 = R-15	Existing

~~2.11.3.3~~2.10.3.3 Fenestration

Table 2-25: Standard Design for Fenestration (in Walls and Roofs)

~~Proposed Design Fenestration Type~~	~~Standard Design Based on Proposed Fenestration Status (Tag)~~			
	~~ADDITION~~ ~~Addition or New Construction~~	~~ALTERED~~ ~~Without 3rd Party Verification~~	~~VERIFIED ALTERED~~ ~~With 3rd Party Verification~~	~~EXISTING~~
~~Vertical Glazing: Area and Orientation~~	~~See full description below.~~	~~See full description below..~~	~~See full description below.~~	~~Existing vertical glazing areas and orientations~~
~~Vertical Glazing: U-Factor~~	~~U=0.32~~	~~U=0.40~~	~~If proposed U-factor is <= Altered, standard design = existing U-factor. If proposed U-factor > Altered, standard design = Altered~~	~~Existing vertical glazing U-factor~~
~~Vertical Glazing: SHGC~~	~~CZ2, 4, 6 -16: SHGC=0.25~~ ~~CZ1,3 & 5: SHGC=0.66~~	~~CZ2, 4 & 6-16: SHGC = 0.35~~ ~~CZ1,3 & 5: SHGC = 0.66~~	~~If proposed SHGC is <= Altered, standard design = existing SHGC. If proposed SHGC > Altered, standard design = Altered~~	~~Existing vertical glazing SHGC~~
~~Skylight: Area and Orientation~~	~~No skylight area in the standard design~~	~~See full description below, "*E+A+A standard design Fenestration Areas and Orientation*".~~	~~Same respective areas and orientations as in Altered.~~	~~Existing skylight areas and orientations~~
~~Skylight: U-Factor~~	~~U=0.32~~	~~U=0.55~~	~~If proposed U-factor is <= Altered, standard design = existing U-factor. If proposed U-factor > Altered, standard design = Altered~~	~~Existing skylight U-factor~~
~~Skylight: SHGC~~	~~CZ2, 4, 6 -16: SHGC=0.25~~ ~~CZ1,3 & 5: SHGC=0.66~~	~~SHGC=0.30~~	~~If proposed SHGC is <= Altered, standard design = existing SHGC. If proposed SHGC > Altered, standard design = Altered~~	~~Existing skylight SHGC~~

Proposed Design Fenestration Type	Standard Design Based on Proposed Fenestration Status				
	Add ≤ 400 ft^2	Add > 400 and ≤ 700 ft^2	Add > 700 ft^2	Altered	Verified Altered
Vertical Glazing: Area and Orientation	75 ft^2 or 30 %	120 ft^2 or 25%	175 ft^2 or 20%	See full description below.	Existing
West Facing Maximum Allowed	CZ2, 4, 6 -16=60 ft^2	CZ2, 4, 6 -16=60 ft^2	CZ2, 4, 6 -16=70 ft^2 or 5%		
Vertical Glazing: U-Factor	0.32	0.32	0.32	0.40	See below
Vertical Glazing: SHGC	CZ2, 4, 6 -16= 0.25 CZ1,3 & 5= 0.50	CZ2, 4, 6 -16= 0.25 CZ1,3 & 5= 0.50	CZ2, 4, 6 -16= 0.25 CZ1,3 & 5= 0.50	CZ2, 4 & 6-16= 0.35 CZ1,3 & 5= 0.50	Existing
Skylight: Area and Orientation	No skylight area in the standard design	No skylight area in the standard design	No skylight area in the standard design		Existing
Skylight: U-Factor	0.32	0.32	0.32	0.55	Existing
Skylight: SHGC	CZ2, 4, 6 -16=0.25 CZ1,3 & 5=0.50	0.30	0.30	0.30	Existing

PROPOSED DESIGN

Fenestration areas are modeled in the addition as new. In the existing building they may be existing, altered or new. Altered (replacement) fenestration is defined in §150.2(b)1.B as "*existing fenestration area in an existing wall or roof [which is] replaced with a new manufactured fenestration product...Up to the total fenestration area removed in the existing wall or roof....*" Added fenestration area in an existing wall or roof is modeled as new.

Example: ~~A 5′-0″ x 6′-8″ (33.33 ft^2) single pane metal frame sliding door is replaced with a 6′-0″ x 6′-8″ (40.0 ft^2) dual vinyl low-e sliding door. Since the new glass sliding door replaces the full area of the existing glass sliding door, an altered glass door is modeled with an area of 33.33 ft^2, and a new glass door is modeled with an area of (40.0 - 33.33) = 16.67 ft^2.~~

STANDARD DESIGN

Standard design fenestration U-factor and SHGC are based on the proposed design fenestration as shown in Table 2-25. Vertical glazing includes all fenestration in exterior walls such as windows, clerestories and glazed doors. Skylights include all glazed openings in roofs and ceilings.

New fenestration in an alteration is modeled with the same U-factor and SHGC as required for an addition.

West-facing limitations are combined with maximum fenestration allowed and are not an additional allowance.

The standard design is set for fenestration areas and orientations as shown in Table *2-25*:

1. ***Proposed design ≤ ~~20~~allowed % total fenestration area:***

In the existing building, the standard design uses the same area and orientation of each existing or altered fenestration area (in its respective existing or altered wall or roof.)

In the addition, new fenestration is divided equally between the four project compass points similar to new gross wall areas in the addition described above.

2. ***Proposed design > ~~20~~allowed % total fenestration area:***

The standard design first calculates the allowed total fenestration area as ~~follows~~the total existing and altered fenestration area in existing or altered walls and roofs + 20% of the addition conditioned floor area.

Example: ~~An existing 2,000 sf house is undergoing alterations and a 400 ft^2 addition. The existing portion of the house has a total of 560 ft^2 (28%) of windows, glazed doors and skylights that are existing (unchanged) or altered (replaced) within the exterior walls and roofs to remain. Therefore:~~

~~Standard design = 560 + (0.20 x 400) = 560 + 80 = 640 ft^2~~

~~The standard design is based on 640 ft² of glazing divided among the 4 building surfaces.~~

~~2.11.3.4~~2.10.3.4 Overhangs, Sidefins and Other Exterior Shading

STANDARD DESIGN

The standard design for a proposed building with overhangs, sidefins and/or other exterior shades is shown in Table 2-26. Treated differently than fixed overhangs and sidefins, exterior shading includes such features as exterior woven or louvered sunscreen, or roll-down awnings or slats as explained in Section 2.5.6.9.

Table 2-26: Standard Design for Overhangs, Sidefins and Other Exterior Shading

~~Proposed Design Shading Type~~	~~Standard Design Based on Proposed Shading Status (Tag)~~			
	~~ADDITION~~ ~~Addition or New Construction~~	~~ALTERED~~ ~~Without 3rd Party Verification~~	~~VERIFIED ALTERED~~ ~~With 3rd Party Verification~~	~~EXISTING~~
~~Overhangs and Sidefins~~	~~No overhangs or sidefins on new fenestration in the standard design.~~	~~Standard design uses whatever overhangs and sidefins are defined with the altered fenestration.~~	~~Same as Altered.~~	~~Existing overhangs and sidefins~~
~~Exterior Shading~~	~~No exterior shading except default (standard) bug screens.~~	~~Standard design uses whatever exterior shading is defined as part of the altered fenestration.~~	~~Existing exterior shading~~	
~~Window Film~~	~~No exterior shading except default (standard) bug screens.~~	~~Standard design uses whatever exterior shading is defined as part of the altered fenestration.~~	~~Existing exterior shading~~	

Proposed Design Shading Type	Standard Design Based on Proposed Shading Status		
	Addition	Altered	Verified Altered
Overhangs and Sidefins	No overhangs or sidefins	Proposed altered condition	Same as Altered.
Exterior Shading	Standard (bug screens on fenestration, none on skylights)	Proposed altered condition	Existing exterior shading
Window Film	No window film	Proposed altered condition	Existing exterior shading

~~2.11.3.5~~2.10.3.5 Window Film

PROPOSED DESIGN

A window film is treated as a window replacement for the SHGC value. To determine the SHGC value, use Table 2-27 to calculate the adjusted SHGC value for the program input. If a window film does not have a 10-year warranty, multiply column 3 by column 4 (ignore column 5) and enter the adjusted SHGC value into the software for the window's altered SHGC value. If a window film has a 10-year warranty, the multiplier in Column 4 is used with the NFRC value in column 5 (ignore column 3) and enter the adjusted SHGC value into the software for the window's altered SHGC value. It shall be treated as a window replacement.

Table 2-27: Window Film Calculated SHGC

1	2	3		4		5		6
Operator Type	Default Glazing Reference	Default SHGC Value Table 110.6-B		SHGC Ratio		NFRC Window Film SHGC		New Adjusted Total Value
Fixed	3 mm (1/8in.) clear (Single Pane)	0.83		1.1528	x		=	
Fixed	3 mm (1/8in.) clear (Double Pane - Clear)	0.73		1.1406	x		=	
Window Wall	6 mm (1/4in.) clear (Single Pane - Clear)	0.83		1.1370	x		=	
Window Wall	6 mm (1/4in.) grey (Single Pane - Tinted)	0.68		1.3077	x		=	
Window Wall	6 mm (1/4in.) clear (Double Pane - Clear)	0.73		1.1587	x		=	
Window Wall	6 mm (1/4in.) grey 6 mm (1/4in.) clear (Double Pane - Tinted)	0.60		1.4634	x		=	

~~2.11.3.6~~2.10.3.6 Floors

STANDARD DESIGN

Table 150.2-C requires that the standard design is based on the mandatory requirements from Section 150.0(d). The standard design for floors is shown in Table 2-28.

Table 2-28: Standard Design for Raised Floor, Slab-on-Grade and Raised Slab

Proposed Design Floor Type	**Standard Design Based on Proposed Floor Status (Tag)**		
	Addition	Altered (mandatory)	Verified Altered
Raised Floor Over Crawl Space or Over Exterior	R-19 in 2x6 16" o.c. wood framing	R-19 in 2x6 16" o.c. wood framing	If proposed ≤ 0.037, standard design = existing raised; if proposed > 0.037, standard design = Altered
Slab-on-Grade: Unheated	CZ1-15: R-0 CZ16: R-7 16" vertical	Proposed design	Existing unheated slab-on-grade
Slab-on-Grade: Heated	CZ1-15: R-5 16" vertical CZ 16: R-10 16" vertical	Proposed design	Existing heated slab-on-grade
Raised Concrete Slab	CZ1,2,11,13,14,16: R-8 CZ3-10: R-0 CZ12,15: R-4	Proposed design	Existing raised concrete slab

~~2.11.3.7~~2.10.3.7 Thermal Mass

STANDARD DESIGN

The standard design for thermal mass in existing plus addition plus alteration calculations is the same as for all newly constructed buildings as explained in Section 2.5.4.1.

~~2.11.3.8~~2.10.3.8 Air Leakage and Infiltration

STANDARD DESIGN AIR LEAKAGE AND INFILTRATION

The standard design for space conditioning systems is shown in Table 2-29.

Table 2-29: Standard Design for Air Leakage and Infiltration

Proposed Air Leakage and Infiltration	Standard Design Air Leakage Based on Building Type		
	Addition	Altered	Verified Altered
Single Family Buildings	5 ACH50	5 ACH50	Diagnostic testing of existing ACH50 value by HERS Rater or 7.0 ACH50, whichever is less
Multi-Family Buildings	7 ACH50	7 ACH50	7 ACH50

~~2.11.3.9~~2.10.3.9 Space Conditioning System

STANDARD DESIGN

The standard design for space conditioning systems is shown in Table 2-30.

Table 2-30: Standard Design for Space Conditioning Systems

~~Proposed Design Space Conditioning System Type~~	~~Standard Design Based on Proposed Space Conditioning Status~~			
	~~ADDITION~~ ~~Addition or New Construction~~	~~ALTERED~~ ~~Without 3rd Party Verification~~	~~VERIFIED ALTERED~~ ~~With 3rd Party Verification~~	~~EXISTING~~
~~Heating System: Compliance 2014~~	~~See Section 2.4 based on fuel source and equipment type.~~	~~Same as Addition.~~	~~Existing heating fuel type, equipment type/efficiency.~~	
~~Heating System: Compliance 2015~~	~~See Section 2.4 and 2015 Federal Appliance Stds based on fuel source and equipment type.~~	~~Same as Addition.~~	~~Existing heating fuel type and equipment type/efficiency.~~	
~~Cooling System: Compliance 2014~~	~~See Section 2.4based on equipment type.~~ ~~CZ2 & CZ8-15: Refrigerant Charge Verification~~	~~Same as Addition.~~	~~Existing cooling equipment type/efficiency.~~	
~~Cooling System: Compliance 2015~~	~~See Section 2.4and 2015 Federal Appliance Stds based on equipment type.~~ ~~CZ2 & CZ8-15: Refrigerant Charge Verification~~	~~Same as Addition.~~	~~Existing cooling equipment type/efficiency.~~	
~~Whole House Fan (WHF) applies only if addition > 1,000 ft²~~	~~CZ8-14: Whole House Fan in New Single Family only; 2.0 cfm/sf~~	~~Same as Addition.~~	~~Existing condition. To count as Existing the WHF must be >= 2.0 cfm/sf and be CEC-rated~~	

Proposed Design Space Conditioning System Type	Standard Design Based on Proposed Space Conditioning Status		
	Added	Altered	Verified Altered
Heating System:	See Section 2.4 and 2015 Federal Appliance Stds based on fuel source and equipment type.	Same as Addition.	Existing heating fuel type and equipment type/efficiency.
Cooling System:	See Section 2.4 and 2015 Federal Appliance Stds based on fuel source and equipment type.	Same as Addition.	Existing cooling equipment type/efficiency.
Refrigerant Charge	CZ2, 8-15:Yes CZ1, 3-7: No	Same as Addition.	Existing
Whole House Fan (WHF) applies only if addition > 1,000 ft^2	CZ8-14; 1.5 cfm/sf		Existing condition. To count as Existing the WHF must be >= 1.5 cfm/sf and be CEC-rated

~~2.11.3.10~~2.10.3.10Duct System

STANDARD DESIGN

Table 2-31: Standard Design for Duct Systems

~~Proposed Design Duct System Type~~	~~Standard Design Based on Proposed Duct System Status~~			
	~~ADDITION~~ ~~Addition or New Construction~~	~~ALTERED~~ ~~Without 3rd Party Verification~~	~~VERIFIED ALTERED~~ ~~With 3rd Party Verification~~	~~EXISTING~~
~~All~~	~~CZ 1-10, 12: Duct insulation R-6 and duct sealing <= 6%~~ ~~CZ 11, 14-16: Duct insulation R-8 and duct sealing <= 6%~~	~~Proposed duct R-value and duct leakage of 15%.~~	~~Existing duct R-value and duct leakage of 15%.~~	

Proposed Design Duct System Type	Standard Design Based on Proposed Duct System Status	
	Altered	Verified Altered
All	CZ 1-10, 12-13: Duct insulation R-6 and duct sealing <= 15% CZ 11, 14-16: Duct insulation R-8 and duct sealing <= 15%	Existing duct R-value and duct leakage of 15%.

Note 1: Refer to section 150.2(b)1Diia for definition of an "**Entirely New or Complete Replacement Duct System**".

~~2.11.3.11~~2.10.3.11Water Heating System

STANDARD DESIGN

Table 2-32: Standard Design for Water Heater Systems

Proposed Design Water Heating System Type	Standard Design Based on Proposed Water Heating Status			
	ADDITION Addition or New Construction	ALTERED Without 3rd Party Verification	VERIFIED ALTERED With 3rd Party Verification	EXISTING
Single Family	Package A water heating system (see Section 2.10).	Same as Addition.	Existing water heater type(s), efficiency, distribution system.	
Multi-family: Individual Water Heater for Each Dwelling Unit	Package A water heating system for each dwelling unit (see Section 2.10).	Same as Addition.	Existing water heater type(s), efficiency, distribution system	
Multi-family: Central Water Heating System	Central water heating system per Section 2.10.	Same as Addition.	Existing water heater type(s), efficiency, distribution system	

Proposed Design Water Heating System Type	Standard Design Based on Proposed Water Heating Status		
	Addition	Altered	Verified Altered
Single Family	Existing fuel type, minimum efficiency, standard distribution.	Mandatory and Prescriptive requirements (excluding any solar).	Existing water heater type(s), efficiency, distribution system.
Multi-family: Individual Water Heater for Each Dwelling Unit	Package A water heating system for each dwelling unit (see Section 2.9).	Mandatory and Prescriptive requirements (excluding any solar).	Existing water heater type(s), efficiency, distribution system
Multi-family: Central Water Heating System	Central water heating system per Section 2.9.	Mandatory and Prescriptive requirements (excluding any solar).	Existing water heater type(s), efficiency, distribution system

2.12 2.11 Documentation

The software shall be capable of displaying and printing an output of the energy use summary and a text file of the building's features. These are the same features as shown on the CF1R when generated using the Report Manager.

See CBECC User Manual or vendor software guide for detailed modeling guidelines.

APPENDIX A – SPECIAL FEATURES

Measure	*CF1R Documentation Requirement*
GENERAL	
Multiple orientation compliance	Special feature
Controlled-Ventilation Crawlspace (CVC)	Special feature
Photovoltaic (PV) system credit	Special feature
Living and sleeping zones	Special feature
Zonal control	Special feature
ENVELOPE	
Above deck insulation	Special feature
Below deck insulation	Special feature
Building air leakage / reduced infiltration	HERS verification of reported ACH50 value
Cool roof	Special feature
Dynamic glazing	Special feature
Exterior shading device (anything other than standard)	Special feature
Exposed slab area greater than 20%	Special feature
High quality insulation installation (QII) or Improved construction quality	HERS verification
Metal-framed assembly	Special feature
Non-default spray foam insulation R-values	HERS verification
Non-standard construction assembly	Special feature
Non-standard roof deck framing	Special feature
Non-standard wall framing	Special feature
Overhangs and sidefins	Special feature
Radiant barrier	Special feature
Raised heel truss (height above top plate)	Special feature
Spray foam insulation, closed cell >R-5.8/inch	HERS verification

Spray foam insulation, open cell >R-3.6/inch	HERS verification
Structurally insulated panel (SIP) assembly	Special feature
Thermal mass	Special feature
MECHANICAL	
Air filter device design	HERS verification
Air handling unit fan efficacy	HERS verification
Airflow or System Airflow (cfm)	HERS verification
Continuous whole-building mechanical ventilation airflow	HERS verification
Combined hydronic heating system	Special feature
Energy Efficiency Ratio (EER)	HERS verification
Evaporatively-cooled condenser (not yet implemented)	HERS verification
Evaporative cooling, indirect, indirect/direct	Not yet implemented.
Fan efficacy	HERS verification
High Seasonal Energy Efficiency Ratio (SEER)	HERS verification
Hydronic heating	Special feature
Indoor air quality ventilation	HERS verification
No cooling	Special feature
Refrigerant charge or charge indicator display (CID)	HERS verification
Setback thermostat exemption	Special feature
Ventilation cooling system—whole house fan	Special feature
Ventilation cooling system, central fan	HERS verification
Whole-building mechanical ventilation airflow	HERS verification
Whole house fan	Special feature
DUCTS	
Buried duct	HERS verification
Bypass duct conditions in a zonal system	HERS verification
Deeply buried duct	HERS verification

Duct leakage testing	HERS verification
Ducts in conditioned space	HERS verification
Ducts in crawl space	Special feature
High R-value ducts	Special feature
Low leakage air handler	HERS verification
Low leakage ducts in conditioned space	HERS verification
Non-ducted system	Special feature
Non-standard duct leakage target	HERS verification
Non-standard duct location (any location other than attic)	Special feature
Return duct design	HERS verification
Supply duct location, surface area, R-value	HERS verification
WATER HEATING	
Below grade pipe insulated and protected (HERS verified)	HERS verification
Below grade pipe insulated and protected	Special feature
Compact distribution system (HERS verified)	HERS verification
High efficiency water heating	Special feature
Multi-family: Central water heating recirculating loop	Special feature
Multi-family: Central water heating recirculating loop (HERS verified)	HERS verification
Multi-family: Demand recirculating	Special feature
Multi-family: Pipe insulation, central water heating (HERS verified)	HERS verification
Multi-family: Pipe insulation, central water heating	Special feature
Multi-family: Recirculating with continuous monitoring	Special feature
Multi-family: Recirculating with temperature modulation	Special feature
Multi-family: Solar water heating credit	Special feature and additional documentation
Parallel piping	Special feature

Parallel piping (HERS verified)	HERS verification
Parallel piping, central water heating	Special feature
Pipe insulation, all lines	Special feature
Pipe insulation, all lines (HERS verified)	HERS verification
Point of use	Special feature
Point of use (HERS verified)	HERS verification
Recirculation with demand control, occupancy/ motion sensor	Special feature
Recirculation with demand control, occupancy/ motion sensor (HERS verified)	HERS verification
Recirculation with demand control, push button	Special feature
Recirculation with demand control, push button (HERS verified)	HERS verification
Recirculation with non-demand control	Special feature
Recirculation with non-demand control (HERS verified)	HERS verification
Solar water heating credit, single family building	Special feature and additional documentation
ADDITIONS/ALTERATIONS	
Verified existing conditions	HERS verification

APPENDIX B – WATER HEATING CALCULATION METHOD

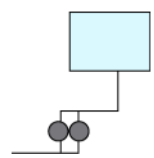
B1. Purpose and Scope

ACM Reference Manual Appendix B documents the methods and assumptions used for calculating the hourly energy use for residential water heating systems for both the proposed design and the standard design. The hourly fuel and electricity energy use for water heating will be combined with hourly space heating and cooling energy use to come up with the hourly total fuel and electricity energy use to be factored by the hourly TDV energy multiplier. The calculation procedure applies to low-rise single family, low-rise multi-family, and high-rise residential.

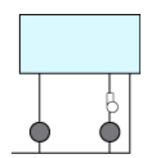
When buildings have multiple water heaters, the hourly total water heating energy use is the hourly water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

The following diagrams illustrate the domestic hot water (DHW) system types that shall be recognized by the compliance software.

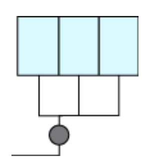
1 One distribution system with one or multiple water heaters serving a single dwelling unit. The system might include recirculation loops within the dwelling unit.



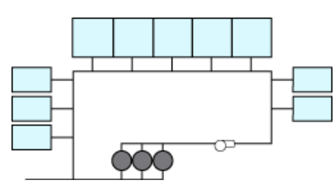
2 Two water heaters with independent distribution systems serving a single dwelling unit. One or more of the distribution systems may include a recirculation loop within the dwelling unit.



3 One distribution system without recirculation loop and with one or multiple water heaters serving multiple dwelling units.



4 One distribution system with one or multiple recirculation loops and with one or multiple water heaters serving multiple units.



B2. Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one water heating appliance. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.

i Used to describe an individual dwelling unit. For instance CFAi would be the conditioned floor area of the i^{th} dwelling unit. N is the total number of dwelling units.

j Used to refer to the number of water heaters in a system. M is the total number of water heaters.

k Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.

l Used to refer to the l^{th} unfired- or indirectly-fired storage tank in the k^{th} system. L is the total number of unfired- or indirectly-fired storage tanks in the k^{th} system. Temperature buffering tanks with electric heating shall not to be treated as unfired or indirectly-fired storage tanks.

B3. Hourly Adjusted Recovery Load

The hourly adjusted recovery load (HARL) can be calculated by Equation 1 through Equation 6.

Equation 1 $$HARL_k = HSEU_k \times DLM_k - HSEU_k \times SSF_k + HRDL_k + \sum_l HJL$$

Where,

$HARL_k$ = Hourly adjusted recovery load (Btu).

$HSEU_k$ = Hourly standard end use at all use points (Btu). See Equation 2

DLM_k = Distribution loss multiplier (unitless). See Equation 4

SSF_k = Solar savings fraction (unitless) for the k^{th} water heating system, which is the fraction of the total water heating load that is provided by solar hot water heating. Annual average value for SSF_k is provided from the results generated by the CEC approved calculations approaches for the OG-100 and OG-300 test procedure. A CEC approved method shall be used to convert the annual average value for SSF_k to hourly values to be used in Equation 1. For hours when $SSF_k > DLM_k$, set $SSF_k = DLM_k$.

$HRDL_k$ = Hourly recirculation distribution loss (Btu) See Equation 10.

HJL_l = The tank surface losses of the l^{th} unfired tank of the k^{th} system (Btu) See Equation 41.

Equation 1 calculates the hourly adjusted recovery load (HARL) which is the heat content of the water delivered at the fixture. HRDL only occurs for multi-family central water heating systems and is zero for single family dwellings.

Equation 2 $$HSEU_k = 8.345 \times GPH_k \times \Delta T$$

Where,

$HSEU_k$ = Hourly standard end use (Btu).

GPH_k = Hourly hot water consumption (gallons)

ΔT = Temperature difference (ºF) See Equation 3

Equation 2 calculates the hourly standard end use (HSEU). The heat content of the water delivered at the fixture is the draw volume in gallons (GPH) times the temperature rise ΔT (difference between the cold water inlet temperature and the hot water supply temperature) times the heat required to elevate a gallon of water 1ºF (the 8.345 constant).

Equation 3 $$\Delta T = T_s - T_{inlet}$$

Where,

ΔT = Temperature difference between the cold water inlet and the hot water supply (ºF)

T_s = Hot water supply temperature of (ºF). For DHW system type 1, 2, and 3, use 124 ºF. For DHW system type 4, use 130 ºF.

T_{inlet} = The cold water inlet temperature (ºF) is defined in Section E3.3.

Equation 3 calculates the temperature difference (ºF) between cold water inlet temperature T_{inlet} and the hot water supply temperature T_s.

Equation 4 $$DLM_k = 1 + \left(SDLM_k - 1\right) \times DSM_k$$

Where,

DLM_k = Distribution loss multiplier (unitless)

$SDLM_k$ = Standard distribution loss multiplier (unitless). See Equation 5

DSM_k = Distribution system multiplier (unitless) Equation 4 calculates the distribution loss multiplier (DLM) which combines two terms: the standard distribution loss multiplier (SDLM), which depends on the floor area of the dwelling unit and the distribution system multiplier (DSM) listed in Table B-2.

Equation 5 $$SDLM_k = 1.004 + 0.000202 \times CFA_k - 0.0000000231 \times CFA_k \times CFA_k$$

Where,

$SDLM_k$ = Standard distribution loss multiplier (unitless).

CFA_k = Conditioned floor area (ft^2) capped at 2500 ft^2 for all single and multi-family units.

Equation 5 calculates the standard distribution loss multiplier (SDLM) for all dwelling units with three stories or less. For situations with one or more water heaters serving a single dwelling unit (System Types 1 or 2), CFA_k is calculated as the total dwelling unit CFA divided by the number of water heaters. For multi-family configurations where multiple dwelling units are served by a central water heating system, either with or without recirculation distribution loops (System Types 3 or 4), CFA_k is defined as the average CFA for all dwelling units covered by the system k. For all residential building types, CFA_k is capped at 2500 ft2 in Equation 5. When a water heating system has more than one water heater, the total system load is assumed to be shared equally by each water heater. The HARL for the j[th] water heater is shown in Equation 6.

Equation 6
$$HARL_j = \frac{HARL_k + \sum_{l=1}^{L} HJL_l}{NmbrWH_k}$$

Where,

$HARL_j$ = Hourly adjusted recovery load for the j^{th} water heater of the k^{th} system (Btu).

$HARL_k$ = Hourly adjusted total recovery load for the k^{th} system (Btu)

HJL_l = The tank surface losses of the l^{th} unfired tank of the k^{th} system (Btu)

L = The total number of unfired tanks in the k^{th} system

$NmbrWH_k$ = The number of water heaters in the k^{th} system.

3.1 Hourly Hot Water Consumption (GPH)

The average daily hot water consumed (not including hot water waste) at use points GPD for a dwelling unit is equal to 21.4 gallons/day plus an additional 6.79 gallons per day for each 1000 ft^2 of conditioned floor area. Consumption is equal to 26.2 gallons/day for a 700 ft^2 apartment and 38.4 gallons/day for a 2500 ft^2 dwelling unit. The equation for daily hot water consumption can be expressed as follows:

Equation 7
$$GPD_I = 21.4 + 0.00679 \times CFA_I$$

Where,

GPD_i = Average daily hot water consumption (gallons) of the i^{th} dwelling unit.

CFA_i = Conditioned floor area (ft^2) of the i^{th} dwelling unit. When actual conditioned floor area is greater than 2500 ft^2, 2500 should be used in Equation 7.

The hourly water consumption GPH of the k^{th} system is calculated using the average daily hot water consumption and the hourly water consumption schedule for all dwelling units served by the system.

Equation 8
$$GPH_k = \left(\sum_i GPD_i\right) \times WF_m \times SCH_m$$

Where,

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

WF_m = Hot Water Waste Factor. For system type 1, 2, and 3, WF_m = 1.0 for non-recirculating systems, 0.90 for recirculating systems. For system type 4, WF_m = 1.0.

SCH_m = Fractional daily load for hour m from Table B-1.

m = Hour of the day.

There are significant variations between hot water usage on weekdays and weekends, and separate schedules are used. The hourly schedules shown in Table B-1 shall be used for calculating the hourly hot water consumption. These data are used for dwelling units of all types.

Table B-1. Hourly Water Heating Schedules

Hour	Weekday	Weekend
1	0.014	0.018
2	0.008	0.010
3	0.009	0.009
4	0.011	0.008
5	0.020	0.015
6	0.044	0.023
7	0.089	0.026
8	0.107	0.047
9	0.089	0.077
10	0.066	0.083
11	0.052	0.074
12	0.038	0.061
13	0.036	0.051
14	0.033	0.043
15	0.032	0.039
16	0.026	0.039
17	0.042	0.052
18	0.048	0.058
19	0.052	0.056
20	0.047	0.052
21	0.042	0.047
22	0.039	0.044
23	0.036	0.040
24	0.022	0.028
Sum	1.000	1.000

3.2 Distribution System Multiplier (DSM) within the Dwelling Unit

The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems within the dwelling unit. A value of 1.00 for "standard" distribution systems, defined as a non-recirculating system with the following mandatory requirements:

The full length of the line from the water heater to the kitchen fixtures insulated to a nominal R-4.

All piping of nominal ¾" or larger diameter insulated to a nominal R-4.

For all four system types, values for alternative distribution systems are given in Table B-2. Improved DSM values are available for cases where voluntary HERS inspections are completed, as per the eligibility criteria shown in Reference Residential Appendix RA4.4. Detailed descriptions of all of the distribution system measures is found in Residential Appendix RA 4.4.

Table B-2. Distribution System Multipliers within a Dwelling Unit with One or More Water Heaters

Distribution System Types	Assigned Distribution System Multiplier	System Type 1and 2	System Type 3 and 4
No HERS Inspection Required			
Trunk and Branch -Standard (STD)	1.0	Yes	Yes
Pipe Insulation (PIC)	0.9	Yes	Yes
Parallel Piping (PP)	1.05	Yes	
Insulated and Protected Pipe Below Grade (IPBC)	1.4	Yes	
Recirculation: Non-Demand Control Options (R-ND)	7.0*	Yes	
Recirculation with Manual Demand Control (R-DRmc)	1.15*	Yes	
Recirculation with Motion Sensor Demand Control (R-DRsc)	1.3*	Yes	
Optional Cases: HERS Inspection Required		Yes	
Pipe Insulation (PIC-H)	0.8	Yes	Yes
Parallel Piping with 5′ maximum length (PP-H)	0.95	Yes	
Compact Design (CHWDS-H)	0.7	Yes	
Point of Use (POU-H)	0.3	Yes	
Recirculation with Manual Demand Control (R-DRmc-H)	1.05*	Yes	
Recirculation with Motion Sensor Demand Control (RDRsc-H)	1.2*	Yes	
Non-Compliant Installation Distribution Multiplier	1.2	Yes	Yes
*Recirculation DSMs reflect impact of reduced hot water consumption associated with recirculation systems.			

3.3 Cold Water Inlet Temperature

The water heater inlet temperature is assumed to vary on a daily basis with the following relationship defined by the data included in the climate zone weather files. For each day of the year, T_{inlet} will be calculated as follows:

Equation 9 $$T_{inlet} = T_{ground} * 0.65 + T_{avg31} * 0.35$$

Where,

T_{avg31} is the dry-bulb temperature averaged over the previous 31 days (note for January days, weather data from December will be used), and

T_{ground} is calculated by the following:

For each ~~hour~~ day (THETA = 1 TO ~~8760~~365)

T_{ground}(THETA) = TyrAve - 0.5×(TyrMax-TyrMin) ×COS(2×pi×(THETA/PB)-PO-PHI) ×GM

Where,

TyrAve = average annual temperature, degrees F

TyrMin is the lowest average monthly temperature, degrees F

TyrMax is the highest average monthly temperature, degrees F

pi	=	3.1416
PB	=	~~8760~~365
PO	=	0.6
DIF	=	~~0.0435~~0.025
BETA	=	SQR(PI/(DIF*PB))*10
XB	=	EXP(-BETA)
CB	=	COS(BETA)
SB	=	SIN(BETA)
GM	=	SQR((XB*XB - 2.*XB*CB + 1)/(2.*BETA*BETA))
PHI	=	ATN((1.-XB*(CB+SB)) / (1.-XB*(CB-SB)))

B4. Hourly Recirculation Distribution Loss for Central Water Heating Systems

This section is applicable to the DHW system type 3 and 4, as defined in B1 Purpose and Scope. The distribution losses accounted for in the distribution loss multiplier (DLM), Equation 4, reflect distribution heat loss within each individual dwelling unit. Additional distribution losses occur outside dwelling units and they include losses from recirculation loop pipes and branch piping feeding individual dwelling units. The hourly values of these losses, HRDL, shall be calculated according to Equation 10. Compliance software shall provide input for specifying recirculation system designs and controls according to the following algorithms.

Equation 10 $HRDL_k = NLoop_k \times HRLL_k + HRBL_k$

Where,

$HRDL_k$= Hourly recirculation loop and branch pipe distribution loss for k^{th} system (Btu).

$HRLL_k$= Hourly recirculation loop pipe heat loss (Btu). This component is only applicable to system type 4. See Equation 11

$HRBL_k$= Hourly recirculation branch pipe heat loss (Btu). See Equation 19

$NLoop_k$= Number of recirculation loops in water heating system k.
This component is only applicable to system type 4. See section 4.3

A recirculation loop usually includes multiple pipe sections with different pipe diameters, which are exposed to different ambient conditions. The compliance software shall provide input entries for up to six pipe sections with three sections for supply piping and three sections for return piping for users to describe the configurations of the recirculation loop. For each of the six pipe sections, input entries shall include pipe diameter (inch), pipe length (ft), and ambient conditions. Ambient condition input shall include three options: outside air, underground, conditioned or semi-conditioned air. Modeling rules for dealing with recirculation loop designs are provided in Section 4.3.

Outside air includes crawl spaces, unconditioned garages, unconditioned equipment rooms, as well as actual outside air. Solar radiation gains are not included in the calculation because the impact of radiation gains is relatively minimal compared to other effects. Additionally, the differences in solar gains for the various conditions (e.g., extra insulation vs. minimum insulation) are relatively even less significant.

The ground condition includes any portion of the distribution piping that is underground, including that in or under a slab. Insulation in contact with the ground must meet all the requirements of Section 150.0(j), Part 6, of Title 24.

The losses to conditioned or semi-conditioned air include losses from any distribution system piping that is in an attic space, within walls (interior, exterior or between conditioned and unconditioned spaces), within chases on the interior of the building, or within horizontal spaces between or above conditioned spaces. It does not include the pipes within the residence. The distribution piping stops at the point where it first meets the boundaries of the dwelling unit.

4.1 Hourly Recirculation Loop Pipe Heat Loss Calculation

Hourly recirculation loop pipe heat loss ($HRLL_k$) is the hourly heat loss from all six pipe sections. There are two pipe heat loss modes, pipe heat loss with non-zero water flow (PLWF) and pipe heat loss without hot water flow (PLCD). The latter happens when the recirculation pump is turned off by a control system and there is no hot water draw flows, such as in recirculation return pipes. Pipe heat loss modes are determined by recirculation control schedules and hot water draw schedules. For each pipe section, hourly pipe heat loss is the sum of heat loss from the two heat loss modes. Hourly heat loss for the whole recirculation loop ($HRLL_k$) is the heat loss from all six pipe sections, according to the following equation:

Equation 11 $HRLL_k = \sum_n [PLWF_n \cdot (1-f_{noflow,n}) + PLCD_n \cdot f_{noflow,n}]$

Where,

$PLWF_n$= Hourly pipe heat loss with non-zero water flow (Btu/hr). See Equation 12

$PLCD_n$= Hourly pipe heat loss without water flow (Btu/hr). See ~~Equation 16~~Equation 17

$f_{noflow,n}$ = Fraction of the hour for pipe section n to have zero water flow. See Equation 13

n= Recirculation pipe section index, 1-6.

Equation 12 $PLWF_n = (Flow_{Draw,n} + Flow_{Recirc}) \cdot \rho \cdot C_p \cdot (T_{IN,n} - T_{OUT,n})$

Where,

$Flow_{Draw,n}$ = Average hourly hot water draw flow (gallon). For supply sections, n=1, 2, or 3, $Flow_{Draw,n} = GPH_k/NLoop$. For return pipes, n=4, 5,and 6, $Flow_{Draw,n} = 0$.

$Flow_{Recirc}$ = Hourly recirculation flow (gallon). It is assumed to be 360 gallons based on the assumption that the recirculation flow rate is 6 GPM.

ρ = Density of water, 8.3 (lb/gallon).

C_p = Heat Capacity of water, 1 (Btu/lb/°F).

$T_{IN,n}$ = Input temperature of section n (°F). For the first section (n=1), $T_{IN,1}$ shall be determined based on ~~Table B-4~~Table B-3. The control schedule of the proposed design shall be based on user input. The standard design is demand control. For other sections, input temperature is the same as the output temperature the proceeding pipe section, $T_{IN,n} = T_{OUT,n-1}$. A proposed design may not provide input for all pipe sections, the compliance software shall treat all sections with input as connected in sequence.

$T_{OUT,n}$ = Output temperature of section n (°F). See Equation 14

Equation 13 $f_{noflow,n} = (1-SCH_{k,m}) \cdot NoDraw_n$

Where,

$NoDraw_n$ = Fraction of the hour for pipe section n to have no hot water draw flows. $NoDraw_1$ = 20%, $NoDraw_2$ = 40%, $NoDraw_3$ = 60%, $NoDraw_4 = NoDraw_5 = NoDraw_6$ = 100%.

$SCH_{k,m}$ = Recirculation pump operation schedule, representing the fraction of the hour that the recirculation pump is turned off, see Table B-3. $SCH_{k,m}$ for the proposed design shall be based on proposed recirculation system controls. Recirculation system control for the standard design is demand control.

Equation 14

$$T_{OUT,n} = T_{Amb,n} + (T_{IN,n} - T_{Amb,n}) \cdot e^{-\frac{UA_n}{\rho \cdot C_p \cdot Flow_n}}$$

Where,

$T_{Amb,n}$ = Ambient temperature of section n (°F), which can be outside air, underground, conditioned or semi-conditioned air. Outside air temperatures shall be the dry-bulb temperature from the weather file. Underground temperatures shall be obtained from ~~Table B-3~~Equation 9. Hourly conditioned air temperatures shall be the same as conditioned space temperature. For the proposed design, $T_{Amb,n}$ options shall be based on user input. The standard design assumes all pipes are in conditioned air.

UA_n = Heat loss rate of section n (Btu/hr-°F). See Equation 15 and Equation 16

Equation 15 is for standard design with extra 0.5 inch of insulation and Equation 16 is for minimum pipe insulation.

Equation 15 $$UA_n = \frac{2\pi \cdot Len_n \cdot cond}{12 \cdot ln\left(\frac{Dia_n + 2\cdot(Thick+0.5)}{Dia_n}\right)} \cdot f_{UA} \cdot f_{Area}$$

Equation 16 $$UA_n = \frac{2\pi \cdot Len_n \cdot cond}{12 \cdot ln\left(\frac{Dia_n + 2\cdot Thick}{Dia_n}\right)} \cdot f_{UA} \cdot f_{Area}$$

Where,

π = 3.1416

Dia_n = Section n pipe diameter (inch). It is divided by 12 in the above equation to convert the unit from inch to foot. For the proposed design, use user input; for the standard design, see Equation 27.

Len_n = Section n pipe length (foot). For the proposed design, use user input; for the standard design, see Equation 26.

Thick = Pipe insulation minimum thickness (inch) as defined in the Title 24 Section 120.3, TABLE 120.3-A for service hot water system.

cond = Insulation conductivity shall be assumed 0.26 (Btu inch/h·sf·F)

f_{UA} = Correction factor to reflect imperfect insulation, insulation material degradation over time, and additional heat transfer through connected branch pipes that is not reflected in branch loss calculation. It is assumed to be 2.0.

f_{area} = The multiplier to adjust proposed design based on pipe surface area validation. See Equation 28.

Pipe heat loss without water flow shall be calculated according to the following equations:

Equation 17 $$PLCD_n = Vol_n \cdot \rho \cdot C_p \cdot (T_{Start,n} - T_{End,n})$$

Where,

Vol_n = Volume of section n (gallons). It is calculated as $\mathbf{7.48 \cdot \pi \cdot \left(\frac{Dia_s + 0.125}{24}\right)^2 \cdot Len_n}$, where 0.125 inch is added to reflect thermal mass of the pipe and 7.48 is the volumetric unit conversion factor from cubic feet to gallons.

$T_{Start,n}$ = Average pipe temperature (°F) of pipe section n at the beginning of the hour. It is the average of $T_{IN,n}$ and $T_{Out,n,}$ calculated according to Equation 14.

$T_{End,n}$ = Average pipe temperature (°F) of pipe section n at the end of pipe cool down . See Equation 18.

Equation 18

$$T_{End,n} = T_{Amb,n} + \left(T_{Start,n} - T_{Amb,n}\right) \cdot e^{-\frac{UA_n}{Vol_n \cdot \rho \cdot C_p \cdot f_{UA}}}$$

Equation 18 calculates average pipe temperature after one hour of cooling down, so the pipe heat loss calculated by Equation 17 is for pipe with zero flow for one hour. Recirculation pumps are usually turned off for less than an hour and there could hot water draw flows in the pipe. As a result, recirculation pipes usually cool down for less than an hour. The factor $f_{noflow,n}$ calculated according Equation 13 is used to reflect this effect, when it is used in Equation 11.

Compliance software shall provide four options of recirculation system controls listed in Table B-3. A proposed design shall select a control type from one of the four options. Standard design shall use demand control.

~~E~~4.2 Hourly Recirculation Branch Pipe Heat Loss Calculation

The proposed design and standard design shall use the same branch pipe heat loss assumptions. Branch pipe heat loss is made up of two components. First, pipe heat losses occur when hot water is in use (HBUL). Second, there could be losses associated with hot water waste (HBWL) when hot water was used to displace cold water in branch pipes and hot water is left in pipe to cool down after hot water draws. and must be dumped down the drain. The Total Hourly Branch Losses ($HRBL_k$) shall include both components and be calculated as:

Equation 19 $HRBL_k = Nbranch_k \times (HBUL + HBWL)$

Where,

HBUL =	Hourly pipe loss for one branch when water is in use (Btu/hr).	See Equation 20
HBWL =	Hourly pipe loss for one branch due to hot water waste (Btu/hr).	See Equation 23
$Nbranch_k$ =	Number of branches in water heating system k.	See Equation 30

The hourly branch pipe loss while water is calculated in the same way as recirculation pipe heat loss with non-zero water flow (PLWF) using the following equations:

Equation 20

$$HBUL = \left(\frac{GPH_k}{Nbranch_k}\right) \cdot \rho \cdot C_p \cdot \left(T_{IN,b} - T_{OUT,b}\right)$$

Where,

$T_{IN,b}$ = Average branch input temperature (°F). It is assumed to be equal to the output temperature of the first recirculation loop section, $T_{OUT,1}$.

TOUT,b = Average branch output temperature (oF). See Equation 21

Equation 21 $$T_{OUT,b} = T_{Amb,b} + \left(T_{IN,b} - T_{Amb,b}\right) \times e^{-\frac{UA_b}{\rho \cdot C_p \cdot Flow_b}}$$

Where,

$T_{Amb,b}$ = Branch pipe ambient temperature (°F) Branch pipes are assumed to be located in the conditioned or semi-conditioned air.

UA_b = Branch pipe heat loss rate (Btu/hr-°F). See Equation 22.

$Flow_b$ = Average branch hot water flow rate (Gal/hr). It is assumed to be 2 GPM or 120 Gal/hr.

Table B-3. Recirculation Loop Supply Temperature and Pump Operation Schedule

Hour	No Control		Demand Control		Temperature Modulation		Temperature Modulation with Continuous Monitoring	
	$T_{IN,1}$ (°F)	$SCH_{k,m}$	$T_{IN,1}$ (°F)	$SCH_{k,m}$	$T_{IN,1}$ (°F)	$SCH_{k,m}$	$T_{IN,1}$ (°F)	$SCH_{k,m}$
1	130	1	130	0.2	120	1	115	1
2	130	1	130	0.2	120	1	115	1
3	130	1	130	0.2	120	1	115	1
4	130	1	130	0.2	120	1	115	1
5	130	1	130	0.2	120	1	115	1
6	130	1	130	0.2	125	1	120	1
7	130	1	130	0.2	130	1	125	1
8	130	1	130	0.2	130	1	125	1
9	130	1	130	0.2	130	1	125	1
10	130	1	130	0.2	130	1	125	1
11	130	1	130	0.2	130	1	125	1
12	130	1	130	0.2	130	1	125	1
13	130	1	130	0.2	130	1	125	1
14	130	1	130	0.2	130	1	125	1
15	130	1	130	0.2	130	1	125	1
16	130	1	130	0.2	130	1	125	1
17	130	1	130	0.2	130	1	125	1
18	130	1	130	0.2	130	1	125	1
19	130	1	130	0.2	130	1	125	1
20	130	1	130	0.2	130	1	125	1
21	130	1	130	0.2	130	1	125	1
22	130	1	130	0.2	130	1	125	1
23	130	1	130	0.2	130	1	125	1
24	130	1	130	0.2	125	1	120	1

Equation 22~~2~~

$$UA_b = \frac{2\pi \cdot Len_b \cdot cond}{12 \cdot ln\left(\frac{Dia_b + 2 \cdot Thick_b}{Dia_b}\right)}$$

Where,

π = 3.1416

Dia_b = Branch pipe diameter (inch). It is divided by 12 in the above equation to convert the unit from inch to foot. See Equation 31.

Len_b = Branch pipe length (foot). See Equation 32.

$Thick_b$ = Branch pipe insulation thickness (inch). Since not all branch piping is required to be insulated, it shall be assumed to be 0.5 inch.

Cond = Insulation conductivity, (assumed 0.26 Btu inch/h·sf·F)

$$HBWL = (N_{waste} \cdot SCH_{waste,m}) \cdot \left(f_{vol} \cdot 7.48 \cdot \pi \cdot \left(\frac{Dia_b}{24}\right)^2 \cdot Len_b\right) \cdot \rho \cdot C_p \cdot (T_{IN,b} - T_{Inlet})$$

Equation 23

Where

N_{waste} = Number of times in a day for which water is dumped before use. It depends on the number of dwelling units served by a branch. Statistically, the less times of water waste is inversely proportional to the number of units a branch serves. See Equation 24.

$SCH_{waste,m}$ = Hourly schedule of water waste. See ~~Table B-5~~Table B-4 Branch Water Waste Schedule.

f_{vol} = The volume of hot water waste is more than just the volume of branch pipes, due to branch pipe heating, imperfect mixing, and user behaviors. This multiplier is applied to include these effects and is assumed to be 1.4.

$T_{IN,b}$ = Average branch input temperature (°F). It is assumed to equal to the output temperature of the first recirculation loop section, $T_{OUT,1}$.

T_{inlet} = The cold water inlet temperature (ºF) according to Section 3.3 Cold Water Inlet Temperature.

$$N_{waste} = 19.84 \cdot e^{(-0.544 \cdot N_{unit,b})}$$

Equation 24

Where,

$N_{unit,b}$= Number of dwelling units served by the branch. See Equation 29.

~~Hourly water waste in gallons (HBWW) for water heating system k can be calculated as:~~

$$HBWW_k = Nbranch_k \cdot \left(f_{vol} \cdot \pi \cdot \left(\frac{Dia_b}{24}\right)^2 \cdot Len_b\right)$$

~~*Equation 25*~~

Table B-4. Branch Water Waste Schedule

Hour	$SCH_{waste,m}$
1	0.01
2	0.02
3	0.05
4	0.22
5	0.25
6	0.22
7	0.06
8	0.01
9	0.01
10	0.01
11	0.01
12	0.01
13	0.01
14	0.01
15	0.01
16	0.01
17	0.01
18	0.01
19	0.01
20	0.01
21	0.01
22	0.01
23	0.01
24	0.01

4.3 Recirculation System Plumbing Designs

A recirculation system can have one or multiple recirculation loops. Each recirculation loop consists of many pipe sections, which are connected in sequence to form a loop. Each pipe section could have different pipe diameter, length, and location. The compliance software shall use six pipe sections, with three supply pipe sections and three return pipe sections, to represent a recirculation loop. When multiple recirculation loops exist, all recirculation loops are assumed to be identical. The compliance software shall provide default and standard recirculation system designs based on building geometry according to the procedures described in the following sections. The default design reflects typical recirculation loop design practices. The standards design represents an improved design with two recirculation loops and is used to set recirculation loop heat loss budget.

Compliance software shall provide users with the option either to provide a user-input recirculation system design or to use the default design as the proposed design. The option of using the default design as the proposed design helps users to reduce compliance documentation efforts. However, this option leads to a higher recirculation pipe heat loss than the standard design, since the default design is less efficient than the standard design. User-input recirculation designs shall be validated according the process described in Equation 28.

The first step of establishing recirculation system designs is to determine the number of recirculation loops, Nloop, in water heating system k. The default design has one recirculation loop, Nloop =1, while the standard design has two recirculation loops, Nloop =2. Proposed designs are allowed to specify more than one loops only if the recirculation loop designs are verified by a HERS rater. Otherwise, the proposed design can only be specified to have one recirculation loop.

The standard and default recirculation loop designs are based on characteristics of the proposed building. There could be many possibilities of building shapes and dwelling unit configurations, which would determine recirculation loop pipe routings. Without requiring users to provide detailed dwelling unit configuration information, the compliance software shall assume the proposed buildings to have same dwelling units on each floor and each floor to have a corridor with dwelling units on both sides. Recirculation loops start from the mechanical room (located on the top floor), go vertically down to the middle floor, loop horizontally in the corridor ceiling to reach the dwelling units on both ends of the building, then go vertically up back to the mechanical room. At each dwelling unit on the middle floor, a vertical branch pipe, connected to the recirculation loop supply pipe, is used to provide hot water connection to dwelling units on other floors. For the default design, the mechanical room is assumed to be located at one end of the top floor, so that the recirculation pipes on the middle floor loop around the whole floor in one loop. For the standard design, the mechanical room is assumed to be located in the middle of the top floor, so that the supply pipe splits into two to form two loops, with each serving half of the building.

Both the standard and default recirculation loop designs are assumed to have equal length of supply sections and return sections. The first section is from the mechanical room to the middle floor. The second section serves first half branches connected to the loop and the third section serves the rest branches. The first and second sections have the same pipe diameter. Pipe size for the third section is reduced since less dwelling units are served. Return sections match with the corresponding supply pipes in pipe length and location. All return sections have the same diameter. For both the standard and default designs, mechanical room is optimally located so that only vertical piping is needed between the mechanical room and the recirculation pipes located on the middle floor. Pipe sizes are determined based on the number of dwelling units served by the loop, following the 2009 Uniform Plumbing Code (UPC) pipe sizing guidelines. The detailed recirculation loop configurations are calculated as following.

Pipe Length in the mechanical room (foot): $L_{mech} = 8$
Height of each floor (foot): $H_{floor} = 10$
Length of each dwelling unit (foot): $L_{unit} = \sqrt{CFA_i}$

Length of recirculation pipe sections (foot):

Equation 25 Default Design

$$Len_1 = L_{mech} + H_{floor} \cdot \frac{Nfloor}{2}$$

$$Len_2 = L_{unit} \cdot \frac{Nunit}{4 \cdot Nk \cdot Nfloor}$$

$$Len_3 = Len_2$$

$$Len_4 = Len_3$$

$$Len_5 = Len_2$$

$$Len_6 = Len_1$$

Equation 26 Standard Design

$$Len_1 = L_{mech} + H_{floor} \cdot \frac{Nfloor}{2}$$

$$Len_2 = L_{unit} \cdot \frac{Nunit}{8 \cdot Nk \cdot Nfloor}$$

$$Len_3 = Len_2$$

$$Len_4 = Len_3$$

$$Len_5 = Len_2$$

$$Len_6 = Len_1$$

Pipe diameters (inch) for supply sections depends on the number of dwelling units being served. They shall be calculated using Equation 27, which is based on 2009 UPC pipe sizing specifications.

Equation 27

$$Dia_1 = INT((-7.525 \cdot 10^{-9} \cdot N_{unit,1}\text{^}4 + 2.82 \cdot 10^{-6} \cdot N_{unit,1}\text{^}3 - 4.207 \cdot 10^{-4} \cdot N_{unit,1}\text{^}2 + 0.04378 \cdot N_{unit,1} + 1.232)/0.5 + 1) \cdot 0.5$$

$$Dia_2 = Dia_1$$

$$Dia_3 = INT((-7.525 \cdot 10^{-9} \cdot N_{unit,3}\text{^}4 + 2.82 \cdot 10^{-6} \cdot N_{unit,3}\text{^}3 - 4.207 \cdot 10^{-4} \cdot N_{unit,3}\text{^}2 + 0.04378 \cdot N_{unit,3} + 1.232)/0.5 + 1) \cdot 0.5$$

$Dia_4 = Dia_5 = Dia_6 = 0.75$ for low-rise multi-family building and hotel/motel less than four stories

$Dia_4 = Dia_5 = Dia_6$ = for high-rise multi-family and hotel/motel more than three stories

where

Nunit = Number of dwelling unit in the building.

Nfloor = Number of floors of the building.

Nk = Number of water heating system in the building.

$N_{unit,1}$= Number of dwelling unit served by the section 1. $N_{unit,1} = \frac{Nunit}{Nk \cdot Nfloor \cdot Nloop}$

$N_{unit,3}$= number of dwelling unit served by the section 3, $N_{unit,3} = \frac{N_{unit,1}}{2}$

The compliance software shall validate the proposed recirculation system design to generate a validation correction factor, f_{area}, based on comparison of total recirculation loop pipe surface area, according to Equation 28. When the proposed design has more than one loop and is HERS verified, the correction factor, f_{area}, is set to be one, since the proposed design meets the prescriptive requirement.

Equation 28

$$f_{area} = 1\left(for\ \frac{SF_{Default}}{SF_{Proposed}} < 1.0\right)\ or\ \frac{SF_{Default}}{SF_{Proposed}}\left(for\ \frac{SF_{Default}}{SF_{Proposed}} \geq 1.0\right)$$

Where,

$SF_{Proposed}$ = Proposed design recirculation loop surface area (sqft), $(\sum_s \pi \cdot Dia_s \cdot \frac{Len_s}{12}) \cdot Nloop$ based on proposed design inputs.

$SF_{Default}$ = Default design recirculation loop surface area (sqft), $(\sum_s \pi \cdot Dia_s \cdot \frac{Len_s}{12})$ based on default design loop configurations.

Branch design parameters include number of branches, branch length, and branch diameter. The standard design assumes that the dwelling units are evenly distributed on each floor and one branch is needed for each dwelling unit on a floor. Therefore, the number of branches in water heating system k is calculated as:

Equation 29

$$N_{unit,b} = Nfloor$$

Equation 30

$$Nbranch_k = INT\left(\frac{Nunit}{N_{unit,b} \cdot NK} + 0.5\right)$$

Where,

$N_{unit,b}$= Number of dwelling unit served by each branch

$Nbranch_k$= Number of branch in water heating system k

The branch pipe diameter shall be calculated using ~~the look up table of Equation 6 [“table of RE-6”]~~ Table B-5 according to the number of dwelling unit served by the branch, or using the formula below. Both methods are based on 2009 UPC pipe sizing specifications.

$$Dia_b = INT((-0.0139 \cdot N_{unit,b}^3 + 0.1845 \cdot N_{unit,b}^2 - 0.5873 \cdot N_{unit,b} + 1.45) * 2 + 0.25)/2$$

Equation 31

The branch length includes the vertical rise based on the number of floors in the building plus four feet of pipe to connect the branch to the recirculation loop.

$$Len_b = 4 + H_{floor} \cdot (Nfloor - 1)$$

Equation 32

Proposed designs shall use the same branch configurations as those in the standard design. Therefore, compliance software does not need to collect branch design information.

Table B-5. Pipe Sizing Schedule

Number of Dwelling Units	Pipe Diameter (inch)
<8	1.5
8 – 20	2
21 – 42	2.5
43 – 67	3
68 – 100	3.5
101 – 144	4

B5. High Rise Residential Buildings, Hotels and Motels

Simulations for high rise residential buildings, hotels and motels shall follow all the rules for central or individual water heating with the following exceptions.

For central systems which do not use recirculation but use electric trace heaters the program shall assume equivalency between the recirculation system and the electric trace heaters.

For individual water heater systems which use electric trace heating instead of gas, the program shall assume equivalency.

B6. Energy Use of Individual Water Heaters

Once the hourly adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below.

6.1 Small[1] Gas, Oil, or Electric Storage[2] and Heat Pump Water Heaters

The hourly energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

Equation 33

$$WHEU_j = \left[\frac{HARL_j \times HPAF_j}{LDEF_j} \right]$$

where

$WHEU_j$ = Hourly energy use of the water heater (Btu for fuel or kWh for electric), adjusted for tank insulation. The above equation provides a value in unit of Btu. For electric water heaters, the calculation result needs to be converted to the unit of kWh by dividing 3413 Btu/kWh.

$HARL_j$ = Hourly adjusted recovery load (Btu).

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

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1 "Small water heater" means a water heater that is a gas storage water heater with an input of 75,000 Btu per hour or less, an oil storage water heater with an input of 105,000 Btu per hour or less, an electric storage water heater with an input of 12 kW or less, or a heat pump water heater rated at 24 amps or less.

2 "Small storage water heater" means a water heater that is a gas storage water heater with an input of 75,000 Btu per hour or less, an oil storage water heater with an input of 105,000 Btu per hour or less, or an electric storage water heater with an input of 12 kW. A small water heater includes a heat pump water heater rated at 24 amps or less.

Table B- 6. Heat Pump Adjustment Factors

Climate Zone	Heat Pump Adjustment Factor	Climate Zone	Heat Pump Adjustment Factor
1	1.040	9	0.920
2	0.990	10	0.920
3	0.990	11	0.920
4	1.070	12	1.070
5	1.070	13	0.920
6	0.920	14	1.040
7	0.920	15	0.920
8	0.920	16	1.500

$LDEF_j$ = The hourly load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the nominal EF rating for storage water heaters for different load conditions.

Equation 34

$$LDEF_j = e \times \left(\ln\left(\frac{HARL_j \times 24}{1000} \right) (a \times EF_j + b) + (c \times EF_j + d) \right)$$

where

a,b,c,d,e = Coefficients from the table below based on the water heater type.

Table B-7. LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
a	-0.098311	-0.91263	0.44189
b	0.240182	0.94278	-0.28361
c	1.356491	4.31687	-0.71673
d	-0.872446	-3.42732	1.13480
e	0.946	0.976	0.947
~~Note 1: EF for storage gas water heaters under 20 gallons must be assumed to be 0.58 unless the manufacturer has voluntarily reported an actual EF to the California Energy Commission. As of April 2003, manufacturers of this equipment are no longer required to do so.~~			

EFj = Energy factor of the water heater (unitless). This is based on the DOE test procedure. <u>EF for storage gas water heaters under 20 gallons must be assumed to be 0.58 unless the manufacturer has voluntarily reported an actual EF to the California Energy Commission.</u>

6.2 Small Gas or Oil Instantaneous[3]

The hourly energy use for instantaneous gas or oil water heaters is given by Equation 35, where the nominal rating is factor by 0.92 to reflect the impacts of heat exchanger cycling under real world load patterns.

Equation 35

$$WHEU_j = \left(\frac{HARL_j}{EF_j * 0.92} \right)$$

Where,

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu).

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers' literature or from the CEC Appliance Database.

0.92 = Efficiency adjustment factor

6.3 Small Electric Instantaneous

The hourly energy use for instantaneous electric water heaters is given by the following equation.

Equation 36

$$WHEU_{j,electric} = \frac{HARL_j}{EF_j \cdot 0.92 \cdot 3413}$$

Where,

$WHEU_{j, elec}$ = Hourly electric energy use of the water heater (kWh).

$HARL_j$ = Hourly adjusted recovery load (Btu).

EF_j = Energy factor from DOE test procedure (unitless).

0.92 = Adjustment factor to adjust for overall performance.

3413 = Unit conversion factor (Btu/kWh).

6.4 Mini-Tank Electric Water Heaters

(Note: Not used in the current calculation)

[3] "Instantaneous water heater" means a water heater that has an input rating of at least 4,000 Btu per hour per gallon of stored water. Small instantaneous water heaters include: gas instantaneous water heaters with an input of 200,000 Btu per hour or less, oil instantaneous water heaters with an input of 210,000 Btu per hour or less, and electric instantaneous water heaters with an input of 12 kW or less.

Mini-tank electric heaters are occasionally used with gas tankless water heaters to mitigate hot water delivery problems related to temperature fluctuations that may occur between draws. If mini-tank electric heaters are installed, the installed units must be listed in the CEC Appliance Database and their reported standby loss (in Watts) will be modeled to occur each hour of the year. (If the unit is not listed in the CEC Appliance Database, a standby power consumption of 100 W should be assumed.)

Equation 37 $$MTEU = \left(\sum_j MTSBL_j\right)/1000$$

Where,

MTEU = Hourly standby energy use of mini-tank electric water heaters (Watts)

MTSBLj = Mini-tank standby Watts for tank j (if not listed in CEC Appliance directory, assume 100 W)

~~E~~6.5 Large[4] Gas or Oil Storage

Energy use for large storage gas is determined by the following equations. Note: large storage gas water heaters are defined as any gas storage water heater with a minimum input rate of 75,000 Btu/h.

Equation 38 $$WHEU_j = \left[\frac{HARL_j}{EFF_j} + SBL\right]$$

Where,

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation.

$HARL_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute $HARL_j$ from Section E3.

SBL = Total Standby Loss (Btu/hr). Obtain from CEC Appliance Database or from AHRI certification database. This value includes tank losses and pilot energy. If standby rating is not available from either of the two databases, it shall be calculated as per Table F-3 of the 2012 Appliance Efficiency Regulations, as follows:

SBL = Q/800 + 110 $(V)^{1/2}$, where Q is the input rating in Btu/hour, and V is the tank volume in gallons..

EFF_j = Efficiency (fraction, not %). Obtained from CEC Appliance Database or from manufacturer's literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

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4 "Large water heater" means a water heater that is not a small water heater.

6.6 Large Instantaneous, Indirect Gas and Hot Water Supply Boilers[5]

Energy use for these types of water heaters is given by the following equation.

Equation 39 $$WHEU_j = \left[\frac{HARL_j}{EFF_j \times 0.92} + PILOT_j\right]$$

Where,

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation.

$HARL_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute $HARL_j$ from Section B3.

~~HJL_j = Hourly jacket loss (Btu/h) for tank rated with the water heater. To account for independent hot water storage tanks substitute $HARL_j$ (from Section E6.8 Jacket Loss) for $HARL_j$ storage tanks~~

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

~~EAF_j = Efficiency adjustment factor (unitless).~~

$PILOT_j$ = Pilot light energy (Btu/h) for large instantaneous. For large instantaneous water heaters, and hot water supply boilers with efficiency less than 89 percent assume the default is 750 Btu/hr if no information is provided in manufacturer's literature or CEC Appliance Database.

0.92 = Adjustment factor used when system is not supplying a storage system.

6.7 Large Electric Storage

Energy use for large storage electric water heaters is given by the following equation.

Equation 40 $$WHEU_{j,elec} = \left[\frac{HARL_j}{3413 \cdot EFF_j}\right] + SBL$$

Where,

$WHEU_{j,\,elec}$ = Hourly electric energy use of the water heater (kWh).

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

[5] "Hot water supply boiler" means an appliance for supplying hot water for purposes other than space heating or pool heating.

$HARL_j$ = Hourly adjusted recovery load (Btu).

SBL = Total Standby Loss (kWh). Obtain from CEC Appliance Database or from AHRI certification database. If the standby loss is reported in unit of Btu/hr, it needs to be converted to kWh by dividing by 3413 Btu/kWh. If standby loss is reported as a percent, SBL shall be determined based on the definition in Title 20 2012 Appliance Efficiency Regulations, Table F-2, as follows:
SBL = (standby loss percent x 8.25 Btu/gallon-°F x measured water heater tank volume (gallons) x 70°F) / 3413 (Btu per kWh).

6.8 Jacket Loss

The hourly jacket loss for the l^th unfired tank or indirectly fired storage tank in the k^th system is calculated as

Equation 41
$$HJL_l = \frac{TSA_l \times \Delta TS}{RTI_l + REI_l} + FTL_l$$

Where,

HJL_l = The tank surface losses of the l^th unfired tank of the k^th system

TSA_l = Tank surface area (ft^2).

ΔTS = Temperature difference between ambient surrounding water heater and hot water supply temperature (ºF). Hot water supply temperature shall be 124ºF. For water heaters located inside conditioned space use 75ºF for the ambient temperature. For water heaters located in outside conditions use hourly dry bulb temperature ambient.

FTL_l = Fitting losses. This is a constant 61.4 Btu/h.

REI_l = R-value of exterior insulating wrap. No less than R-12 is required.

RTI_l = R-value of insulation internal to water heater. Assume 0 without documentation.

6.9 Tank Surface Area

Tank surface area (TSA) is used to calculate the hourly jacket loss (HJL) for large storage gas, indirect gas water heaters, and large storage electric water heaters. TSA is given in the following equation as a function of the tank volume.

Equation 42
$$TSA_j = e \times \left(f \times VOL_j^{0.33} + g\right)^2$$

Where,

VOLj = Tank capacity (gallons).

e, f, g = Coefficients given in Table B-8.

Table B-8. Coefficients for Calculating Tank Surface Areas

Coefficient	Storage Gas	Large Storage Gas and Indirect Gas	Storage Electric and Heat Pumps
E	0.00793	0.01130	0.01010
F	15.67	11.8	11.8
G	1.9	5.0	5.0

6.10 Electricity Use for Circulation Pumping

For single-family recirculation systems, hourly pumping energy is fixed as shown in Table B-9.

Table B-9. Single Family Recirculation Energy Use (kWh) by Hour of Day

Hour	Non-Demand Controlled Recirculation	Demand Recirculation
1	0.040	0.0010
2	0.040	0.0005
3	0.040	0.0006
4	0.040	0.0006
5	0.040	0.0012
6	0.040	0.0024
7	0.040	0.0045
8	0.040	0.0057
9	0.040	0.0054
10	0.040	0.0045
11	0.040	0.0037
12	0.040	0.0028
13	0.040	0.0025
14	0.040	0.0023
15	0.040	0.0021
16	0.040	0.0019
17	0.040	0.0028
18	0.040	0.0032
19	0.040	0.0033
20	0.040	0.0031
21	0.040	0.0027
22	0.040	0.0025
23	0.040	0.0023
24	0.040	0.0015
Annual Total	350	23

Multi-family recirculation systems typically have larger pump sizes, and therefore electrical energy use is calculated based on the installed pump size. The hourly recirculation pump electricity use (HEUP)is calculated by the hourly pumping schedule and the power of the pump motor as in the following equation.

Equation 43 $$HEUP_k = \frac{0.746 \times PUMP_k \times SCH_{k,m,}}{\eta_k}$$

Where,

$HEUP_k$ = Hourly electricity use for the circulation pump (kWh).

$PUMP_k$ = Pump brake horsepower (bhp).

η_k = Pump motor efficiency.

$SCH_{k,m}$ = Operating schedule of the circulation pump, see Table B-4Table B-3. The operating schedule for the proposed design shall be based on user input. The standard design operation schedule is demand control.

6.10 Prorating Energy Use in Multi-Family Buildings

For central water heating systems, the energy use is calculated at the system level, not at the dwelling unit level. When it is necessary to allocate energy use to individual dwelling units for home energy ratings or other purposes, the procedure in this section may be used.

The fraction of the energy that is allocated to an individual dwelling unit is the ratio of the gallons-per-day load for that dwelling unit to the gallons-per-day estimate for the whole building. This fraction is shown in Equation 44.

Equation 44

$$Fraction_I = \frac{GPD_I}{\left(\sum_{I}^{NmbrDU} GPD_i\right)}$$

Where,

$Fraction_i$ = Fraction of water heating energy allocated to the i^{th} dwelling unit.

GPD_i = Gallons per day of consumption for the i^{th} dwelling unit. See Equation 8.