RESIDENTIAL ALTERNATIVE CALCULATION METHOD (ACM) APPROVAL METHOD

CALIFORNIA ENERGY COMMISSION

2008 BUILDING ENERGY EFFICIENCY STANDARDS

EXPRESS TERMS – 45 DAY LANGUAGE

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NOTICE

This version of the Residential Alternative Calculation Method (ACM) Approval Manual for the 2008 Building Energy Efficiency Standards is a marked version; that is, it contains underlined or struck-out text showing changes from the 2005 version. For more information, visit www.energy.ca.gov/title24, call the Title 24 Energy Efficiency hotline at 800/772-3300 (toll-free from within California) or 916/654-5106, or send email to title24@energy.state.ca.us.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Overview

This Manual explains the requirements for approval of residential Alternative Calculation Methods (ACMs or compliance software). Residential ACMscompliance software are is used to demonstrate compliance with the performance approach to the California Energy Efficiency Standards for Low-Rise Residential Buildings.

The approval procedure is one of self-testing and self-certification by the ACMcompliance software vendor. The vendor conducts the specified tests, evaluates the results and certifies in writing that the ACMcompliance software passes the tests. The California Energy Commission (Commission) will perform spot checks and may require additional tests to verify that the proposed ACMcompliance software is suitable for compliance purposes. The vendor is required to develop a compliance supplement (program user manual) explaining how to use the program for showing compliance with the standards. The compliance supplement will also be checked by the Commission for accuracy and ease of use.

When energy analysis techniques are compared, there are two basic sources of discrepancies: differences in user interpretation when entering the building specifications, and differences in the ACMcompliance software's algorithms for estimating energy use. The approval tests in this manual are designed to minimize differences in interpretation by providing explicit detailed descriptions of the test buildings that shall be analyzed.

This chapter presents the general requirements for residential ACMscompliance software. Appropriate inputs for all modeling capabilities are discussed in Chapter 2 addresses standard reports. Chapter 3 has the rules for defining the Standard Design. Chapter 4 has and algorithms and modeling assumptions used in the reference method. Chapters 5 4 and 6 5 have accuracy tests. Chapter 7 has requirements for field verification and diagnostic testing. Chapter 6 s 8 and 9 have has requirements for ACMcompliance software vendors.

1.1 Minimum Modeling Capabilities

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

- Conduction gains and losses through opaque and fenestration surfaces
- Slab edge gains and losses
- Infiltration gains and losses
- Solar gains through glazing including the effects of internal shading devices, external shading devices and fixed overhangs.
- Natural ventilation cooling and natural ventilation for Indoor Air Quality (IAQ).
- Mechanical Ventilation for Indoor Air Quality (IAQ).
- Thermal mass effects to dampen temperature swings.
- Space conditioning equipment efficiency and distribution systems.
- Water heating equipment efficiency and distribution systems
- Building additions
- Unconditioned ZoneAttic Modeling (UZM)
- Attic Model
- Crawl Space
- Radiant Barrier

Cool Roof

• Radiant Barriers

• Cool Roofs

- Maximum Cooling Capacity

1.2 Optional Modeling Capabilities

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

- Raised floors with automatically operated crawl space vents.
- Zonal control or multi-zone modeling of the sleeping and living areas of the house.
- Attached sunspaces for collection and possible storage of heat for transfer to the main house.
- Exterior mass walls.
- Overhangs and Side Fin Shading.
- Combined hydronic space and water heating.
- Building additionsalterations.
- Solar water heating.

• Form 3 report generator.

- Gas fired and- Absorption Cooling
- Evaporatively cooled condensing units
- Ice storage air conditioner
- Evaporative coolers

Many of the optional modeling capabilities have been previously approved by the Commission through the exceptional methods process. The approval tests for optional modeling capabilities are included in Chapter 6.

1.3 Application Checklist

The following is a checklist of all the items that shall be included in an application package for ACMscompliance software. Some materials are required only for general purpose ACMscompliance software and are so indicated.

- ACMCompliance software Vendor Certification Statement. A statement from the ACMcompliance software vendor certifying the ACMcompliance software, and, its reliability and accuracy when used for compliance purposes (see Residential ACM Manual Appendix RA-2008).
- Computer Run Summary Sheets. Hard copy summary sheets of all the required computer runs (see Residential ACM Manual Appendix RA-2008).
- Computer Runs. Copies of the computer runs specified in Chapters 5 and 6 of this Manual, including complete input and output files, on diskettes or in computer readable form acceptable to the Commission to enable spot checks.
- Compliance Supplement. A copy of the Compliance Supplement discussed in Chapter 8. The Compliance Supplement and the ACMCompliance software User's Manual may be combined into the same document.

- Copy of the ~~ACM~~compliance software. A ~~magnetic media~~computer readable copy of the ~~ACM~~compliance software (in a format agreed to by the Commission staff) for verification of analyses and random verification of compliance analyses. Weather data shall be included.
- Application Fee. An application fee of $1,000.00 (one thousand dollars) is required to cover costs of evaluating the application.

1.4 Types of Approval

This Manual addresses three types of ~~ACM~~compliance software approval: full approval, streamlined approval of new program features, and amendments to full approvals.

1.4.1 Full Approval

Full approval is required when a candidate ~~ACM~~compliance software has never been previously approved by the Commission, and/or when the ~~ACM~~compliance software vendor makes changes to the executable program code or algorithms, or any other change that in any way affects the results. The Commission may also require that all ~~ACMs~~compliance software be approved again when the standards are updated on the three-year cycle or whenever substantial revisions are made to the approval process, for instance, if new analysis capabilities come into widespread use, and the Commission declares them to be minimum capabilities for all ~~ACMs~~compliance software.

When re-approval is necessary, the Commission will notify all ~~ACM~~compliance software vendors of the timetable for renewal. There will also be a revised ~~ACM~~compliance software Approval Manual published, with complete instructions for re-approval.

Full approval is required for all ~~ACM~~compliance software changes, unless they qualify for the streamlined approval process or for an addendum, as discussed below.

1.4.2 Streamlined Approval

Certain types of changes may be made to approved residential ~~ACMs~~compliance software through a streamlined procedure. Examples of changes that qualify for streamlined approval are modifications to the user interface or implementation on a different operating system as long as there are no changes to the executable program code that would in anyway affect the results.

If an ~~ACM~~compliance software modification qualifies for streamlined approval, then the following procedure is followed:

- The ~~ACM~~compliance software vendor prepares an addendum to the compliance supplement, when appropriate, describing the change to the ~~ACM~~compliance software.
- The ~~ACM~~compliance software vendor notifies the Commission by letter of the change. The letter shall describe in detail the nature of the change and why it is being made. The notification letter shall be included in the Compliance Supplement.
- Provide the Commission with an updated copy of the ~~ACM~~compliance software and include any new reports created by the ~~ACM~~compliance software (or modifications in the standard reports).
- The Commission responds in 45 days. The Commission response may take several forms. The Commission may request additional information, refuse to approve the change or require that the ~~ACM~~compliance software vendor make specific changes to either the Compliance Supplement addendum or the ~~ACM~~compliance software.
- With Commission approval, the vendor may issue new copies of the ~~ACM~~compliance software with the Compliance Supplement addendum and notify ~~ACM~~compliance software users and building officials.

1.4.3 Amendments

~~ACMc~~Compliance software approval shall be amended when optional modeling capabilities are added. The vendor shall provide the additional computer runs required for the optional modeling capability. It is not necessary to include computer runs previously submitted.

An amendment to ~~an~~ approved ~~ACM~~compliance software shall be accompanied by a cover letter explaining the type of amendment requested, and copies of other documents as necessary. All items on the application checklist should be submitted, when applicable. The timetable for approval of amendments is the same as for full approval.

1.4.4 When Approval Is Not Required

Changes that do not affect compliance with the Energy Efficiency Standards for Residential Buildings do not require full or streamlined approval. However, the ~~ACM~~compliance software vendor shall notify the Commission and provide the Commission with an updated copy of the program and user manual. Re-approval is required for any ~~ACM~~compliance software program change that affects the energy use calculations for compliance, the modeling capabilities for compliance, the format and/or content of compliance forms, or any other change which would affect a building's compliance with the Standards. Any questions regarding applicable approval procedures should be directed to the Commission.

1.5 Challenges

Building officials, program users, program vendors or other interested parties may challenge any residential ~~ACM~~compliance software approval. If any interested party believes that a compliance program, an algorithm, or method of calculation used in a compliance program, a particular capability or other aspect of a program provides inaccurate results, the party may challenge the program.

1.6 Decertification of ~~ACMs~~Compliance Software

The Commission may decertify (rescind approval of) an alternative calculation method through various means:

- All ~~ACMs~~compliance software are decertified when the standards undergo substantial changes, which usually occurs every three years.
- Any ~~ACM~~compliance software can be decertified by a letter from the ~~ACM~~compliance software vendor requesting that a particular version (or versions) of the ~~ACM~~compliance software be decertified. The decertification request shall briefly describe the nature of the program errors or "bugs" which justify the need for decertification.
- Any "initiating party" may commence a procedure to decertify a~~n~~ ~~ACM~~compliance software according to the steps outlined below. The intent is to include a means whereby serious program errors, flawed numeric results, improper forms and/or incorrect program documentation not discovered in the certification process can be verified, and use of the particular ~~ACM~~compliance software version discontinued. In this process, there is ample opportunity for the Commission, the ~~ACM~~compliance software vendor and all interested parties to evaluate any alleged errors in the ~~ACM~~compliance software program.

Process. Following is a description of the process for challenging ~~an~~ ~~ACM~~compliance software or initiating a decertification procedure:

1. Any party may initiate a review of ~~an~~ ~~ACM~~compliance software's approval by sending a written communication to the Commission's Executive Director. (The Commission may be the initiating party for this type of review by noticing the availability of the same information listed here.)

The initiating party shall:

(a) State the name of the ~~ACM~~compliance software and the program version number(s) which contain the alleged errors;

(b) Identify concisely the nature of the alleged errors in the ~~ACM~~compliance software which require review;

(c) Explain why the alleged errors are serious enough in their effect on analyzing buildings for compliance to justify a decertification procedure; and,

(d) Include appropriate data electronically (in a format agreed to by the Commission staff) and/or information sufficient to evaluate the alleged errors.

2. The Executive Director shall make a copy or copies of the initial written communication available to the ~~ACM~~compliance software vendor and interested parties within 30 days. Comments from interested parties must be received within 60 days of the acceptance of the original application.
3. Within 75 days of receipt of the written communication, the Executive Director may request any additional information needed to evaluate the alleged ~~ACM~~compliance software errors from the party who initiated the decertification review process. If the additional information is incomplete, this procedure will be delayed until the initiating party submits complete information.
4. Within 75 days of receipt of the initial written communication, the Executive Director may convene a workshop to gather additional information from the initiating party, the ~~ACM~~compliance software vendor and interested parties. All parties will have 15 days after the workshop to submit additional information regarding the alleged program errors.
5. Within 90 days after the Executive Director receives the application or within 30 days after receipt of complete additional information requested of the initiating party, whichever is later, the Executive Director shall either:

   (a) Determine that the ~~ACM~~compliance software need not be decertified; or,

   (b) Submit to the Commission a written recommendation that the ~~ACM~~compliance software be decertified.
6. The initial written communication, all other relevant written materials and the Executive Director's recommendation shall be placed on the consent calendar and considered at the next business meeting after submission of the recommendation. The matter may be removed from the consent calendar at the request of any person.
7. If the Commission approves the ~~ACM~~compliance software decertification, it shall take effect 60 days later. During the first 30 days of the 60 day period, the Executive Director shall send out a Notice to Building Officials and Interested Parties announcing the decertification.

All initiating parties have the burden of proof to establish that the review of alleged ~~ACM~~compliance software errors should be granted. The decertification process may be terminated at any time by mutual written consent of the initiating party and the Executive Director.

As a practical matter, the ~~ACM~~compliance software vendor may use the 180 to 210-day period outlined here to update the ~~ACM~~compliance software program, get it re-approved by the Commission, and release a revised version that does not contain the bugs initially brought to the attention of the Commission. Sometimes the ~~ACM~~compliance software vendor may wish to be the initiating party to ensure that a faulty program version is taken off the market.

1.7 ~~Alternative ACM~~Compliance Software Tests

This Manual provides tests to verify that ~~ACMs~~compliance software are accurate. These tests are provided in Chapters 5 and 6 of the Manual. ~~An~~The ~~ACM~~compliance software vendor may propose alternate tests when the vendor believes that one or more of the standard tests are not appropriate for the ~~ACM~~compliance software. Alternate tests will be evaluated by the Commission and will be accepted if they are considered reasonable. If accepted, the alternate test(s) will be added to this manual as an addendum and the alternate test(s) will be available for use by all ~~ACMs~~compliance software. The alternate test will coexist with the standard test presented in this Manual until the Manual is revised. When a new version of this Manual is produced, the alternative test may be substituted for the current test or may continue to coexist with the original test.

1.8 Approval of New Exceptional Methods

The Commission may approve new exceptional methods. Exceptional methods are special modeling capabilities or calculation methods necessary to recognize building features that cannot be adequately modeled with existing ACMscompliance software. When an Exceptional Method is approved, a new optional capabilities test may be approved as part of the process. Exceptional Methods do not necessarily produce optional capabilities for ACMscompliance software. For instance, radiant heating systems are recognized by an adjusted equipment efficiency that may be used directly in ACMscompliance software or other compliance methods. To be approved for the new optional capability, vendors shall amend their ACMcompliance software approval.

Even if anthe ACMcompliance software already incorporates the Exceptional Method, the vendor shall receive approval to use the Exceptional Method in the compliance process. The ACMcompliance software vendor shall demonstrate that the ACMcompliance software automatically uses the correct fixed and restricted inputs for the Exceptional Method and that the standard reports identify the building feature(s) recognized by the Exceptional Method. Additionally, the ACM compliance supplement shall be updated, referencing the use of the new Exceptional Method.

To receive a copy of the Exceptional Method contact the Residential Office at (916) 654-4064.

2. Standard Reports

2.1 General

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

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

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

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

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

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

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

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

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

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

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

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

2.2.1 Report Headings

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

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

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

2.2.2 Building Features

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

2.2.3 Energy Use Summary

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

2.2.4 Building Features

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

2.2.5 Special Features Inspection Checklist

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

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

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

This house uses multiple conditioned zones. The non-closable area between zones cannot exceed 40 ft^2 and each zone must be controlled with a separate thermostat. In addition the air flow requirements and fan watt draw requirements in Residential Appendix RA-6 must be met.This house has Zonal control with multiple zones, interzone surfaces, and interzone ventilation.		
This building uses metal-framed walls that shall meet mandatory insulation requirements. In many cases sheathing insulation is used in addition to cavity insulation. Metal-framed walls shall be built according to the details in Joint Appendix 4 for <*construction type*>.This building uses metal-framed walls that shall meet mandatory insulation requirements. In many cases sheathing insulation is used in addition to cavity insulation.		
A non-NAECA large storage gas water heater is specified. System specifications are shown in the SPECIAL WATER HEATER/BOILER DETAILS table of compliance form CF-1R.This house uses a non-NAECA large storage gas water heater. Check the SPECIAL WATER HEATER/BOILER DETAILS listing for specifications.		
This house has an attached sunspace with interzone surfaces, custom solar heat gain distribution and sunspace thermal mass elements.		
This house is modeled with reduced infiltration and/or mechanical ventilation. Consequently the homeowner's manual provided by the builder to the homeowner shall include operating instructions for the homeowner on how to use operable windows and/or mechanical ventilation to achieve adequate ventilation. Testing for reduced infiltration shall be performed as specified in ASTM E 779-03. This listings shall also report the target $CFM50_H$ required for the blower door test to achieve the modeled SLA and the minimum $CFM50_H$ (corresponding to an SLA of 1.5) allowed to avoid backdraft problems.		

2.2.6 HERS Required Verification

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

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

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

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

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

2.2.7 Compliance Statement and Signatures

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

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

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

2. Standard Reports

2.1 General

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

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

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

The structure and organization of the Standard Reports described in the subsequent sections should be followed as closely as possible. The reports are divided into tabular listings that have a title, column headings and data entries. The data entries shown in the listings that appear in this manual are typical values and are included only to illustrate the report format; they are not default values and cannot be assumed to be in compliance with the standards. The specification of the category or type of data expected in each field is provided in the list of definitions associated with each column heading. The type of data entries will be one of the following:

- Text: A variable-length text field input by the user.
- Recommended Descriptor: An abbreviation or short name from lists or tables of permissible types provided within this manual (e.g., LgStoGas). Only types found in these lists or tables may be used. Different descriptors may be used by the ACM as long as they are reasonable descriptors for the list entry item and are not misleading. In some cases where the descriptor is a short complete word, the descriptors are prescribed and shall be used. Even for prescribed descriptors some discretion is allowed. For example, for tables with long rows Y may be used for the prescribed descriptor Yes. User-defined descriptors may NOT be used but rather shall be automatically assigned by the ACM based upon user input. For example, UWALL01 may be assigned by the ACM to the first user-defined wall type.
- Filename.ext: The name of the input or output file
- Dimensions or units of measure, such as "hr-ft^2-ºF /Btu", ft^2, etc.
- Num: A cardinal or ordinal number.

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

Some of the tables in the standard reports are not applicable for all buildings. When a table is not applicable for a particular building, it should be omitted. When one of the standard tables is included, all the columns should be included (although column width may be reduced), even if some of the information in the columns is not applicable to the proposed design.

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

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

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

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

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

2.2.1 Report Headings

The following heading shall appear on the first page.

CERTIFICATE OF COMPLIANCE: Page 1 of 4
RESIDENTIAL COMPUTER METHOD

Project Title Filename:	Date:
Project Address Run Title:	<runcode>
Documentation Author	<initiation time>
Telephone	Building Permit #
Compliance Method	Plan Check / Date
Location/Climate Zone	Field Check/ Date

The Filename, Run Title, Runcode, and Initiation Time need not appear in the header as shown above but shall appear as part of the header information for all pages of the Certificate of Compliance.

The following heading shall appear on subsequent pages.

CERTIFICATE OF COMPLIANCE: Page 2 of 4
RESIDENTIAL COMPUTER PERFORMANCE

Project Title Filename:		Date:
	Run Title:	<runcode/initiation time>

□*Project Title, Date, Project Address, Documentation Author and Telephone, and Climate Zone (text):* Display user inputs for these fields.

□*Filename (filename.ext):* The filename of the input file used to generate the compliance form.

□*Compliance Method (text):* The Alternative Calculation Method program name and version number.

□*<Runcode/Initiation Time> (alphanumeric text):* A unique runcode designation generated automatically by the ACM to identify the specific run. This number and the initiation time changes with each run initiated by the user even though the filename and Run Title may remain the same. The initiation time is the time (including the hour and minute) that the compliance run was initiated by the user.

□*Run Title (text):* Optional user input item. Use for commentary or description of unique characteristics of a particular run.

2.2.2 Energy Use Summary

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

TDV ENERGY USE SUMMARY (kBtu/ft^2-yr)

	Standard Design Energy Budget	Proposed Design Energy Use
Space Heating	23.45	21.23
Space Cooling	10.34	8.23
Water Heating	15.90	14.67
Total	49.69	44.13

Additional rows may be added to the table when necessary to accommodate energy uses that are to be included in the analysis but cannot be easily assigned to one of the three principal categories. Examples of possible additional rows might include separating fan energy (typically included with cooling) or recirculating pump energy.

2.2.3 General Information

This listing in the Certificate of Compliance follows the first page heading and provides basic information about the building. A description of these data elements is given later in this chapter.

GENERAL INFORMATION

HERS Field Verification/Diagnostic Testing Required for Compliance	Yes
Conditioned Floor Area:	1384 ft^2
Average Ceiling Height	10.2 ft.
Building Type:	Single Family
Building Front Orientation:	15 deg (North)
Glazing Area as % of Floor Area	14.4%
Average Fenestration U-factor	0.52
Average Fenestration SHGC	0.60
Number of Dwelling Units:	1
Number of Stories:	2
Floor Construction Type:	Slab on grade
Number of Conditioned Zones:	2
Total Conditioned Volume:	11072 cf
Conditioned Slab Floor Area:	1384 ft^2
Total Conditioned Floor Area:	1384 ft^2

- *HERS Field Verification/Diagnostic Testing Required For Compliance (yes or no).* At the very beginning of the Certificate of Compliance, this provides a prominent notification when compliance with the performance standards requires HERS Rater field verification or diagnostic testing.

- *Conditioned Floor Area.* The conditioned floor area of all building zones modeled in the computer run.

- *Building Type.* The type of building. Possible types are single-family and multi-family.

- *Construction Type.* The type of construction. Possible types are new, existing, addition alone and existing plus addition plus alteration.

- *Building Front Orientation.* The azimuth of the front of the building. This will generally be the side of the building where the front door is located. A typical reported value would be "290° (west)". This would indicate that the front of the building faces north 70° west in surveyors terms. The closest orientation on 45° compass points should be verbally reported in parenthesis, e.g. north, northeast, east, southeast, south, southwest, west or northwest. When compliance is shown for multiple orientations, "all orientations" may be reported. When "all orientations" is reported it shall be included in the *Special Features and Modeling Assumptions* listing.

- *Number of Dwelling Units.* The total number of dwelling units in the building. This number may be a fraction for cases of addition alone.

- *Number of Stories*. The number of building stories as defined by the *California Building Code*.

- *Floor Construction Type.* The ground floor construction type is one of the factors considered when determining the amount of thermal mass in the *Standard Design*.

- *Number of Conditioned Zones.* The number of conditioned zones modeled in the computer run.

- *Total Conditioned Volume.* The total volume of conditioned space within the building.

- *Conditioned Slab Floor Area.* The total area of slab floor (on grade or raised) with conditioned space above and the ground or unconditioned space below. This is used to determine the standard design mass requirement for buildings and the default values of the thermal mass requirements for the proposed design.

- *Total Conditioned Floor Area.* The total floor area of conditioned space in the building to be permitted. This area shall be no less than the *Conditioned Slab Floor Area* specified above. The conditioned nonslab floor area is the difference between the *Total Conditioned Floor Area* and the *Conditioned Slab Floor Area* and is used to determine the thermal mass for the Standard Design, the default value of thermal mass for the Standard Design, and the threshold thermal mass requirement for thermal mass credit in the Proposed Design. The conditioned nonslab floor area includes any nonslab floors, raised or not, and raised slab floors with conditioned space above and below the floor.

2.2.4 Building Zone Information

For most compliance documentation, only one row will be reported in this table. Additional rows are reported when a proposed building is modeled as two zones or when attached, unconditioned spaces are modeled, such as crawl spaces or sunspaces.

BUILDING ZONE INFORMATION

Zone Name	Floor Area ft^2)	Volume (ft^3)	# of Units	Zone Type	Tstat Type	Vent Height (ft)	Vent Area (ft^2)
House	1384	11072	1	Conditioned	Setback	2.0	32

Zone Name. Each zone is given a name that is used to categorize information in the following tables.

Floor Area (ft^2). The floor area of the zone measured to outside wall. The sum of the floor area of all conditioned zones shall equal the conditioned floor area reported under "General Information".

Volume (ft^3). The volume of the zone. The sum of the volume of all conditioned zones shall equal the total volume reported under "General Information".

# of Units. The number of dwelling units in the zone. This number may be a fraction for cases of addition alone or a building in which there are more zones than dwellings.

Zone Type. This description controls some modeling restrictions, such as infiltration, internal and solar gains, etc. Possible conditioned zone entries are Conditioned, Living and Sleeping. Possible unconditioned zone entries include Unconditioned, CVCrawl and Sunspace.

Thermostat Type. Possible conditioned zone entries are Setback, NoSetback, LivingStat, SleepingStat. Additional thermostat types may be allowed for optional modeling capabilities.

Vent Height (ft). The height difference between the "inlet" ventilation area and the "outlet" ventilation area. The default ventilation height is determined by the number of stories: one story - 2 feet, two or more stories - 8 feet. Different vent heights may be modeled but a non-default vent height is considered a special feature or special modeling assumption that shall be reported in the *Special Features and Modeling Assumptions* listing for special verification. The ventilation height for other windows is the average height difference between the centers of the lower operable window openings and the centers of the upper operable window openings.

Vent Area (ft^2). This entry is either the default vent area which is assumed by the ACM based on entries in the Fenestration Surfaces table or some other value entered by the user. A Vent Area value greater than 10% of the total rough-out opening area (all windows treated as opening type: “slider”) of all fenestration shall be reported in the *Special Features and Modeling Assumptions* listing for special verification.

2.2.5 Opaque Surfaces

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

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

OPAQUE SURFACES

Surface Type	Area (ft²)	U-factor	Cavity Insul R-value	Sheath. Insul. R-value	True Azimuth	Tilt	Solar Gains	Appendix IV Reference	Location/ Comments
Zone=Living									
Wall	105.4	0.088	R-13	na	0	90	Yes	IV1-A3	Typical
Wall	145.4	0.068	R-11	R-4	180	90	Yes	IV1-A3	Typical
Base WallA	100	0.124	na	R-6	0	90	No	IV5-E5	0-2 ft below grade
Base Wall B	160	0.124	na	R-6	0	90	No	IV5-E5	2-6 ft. below grade
Wall	176.8	0.088	R-13	na	270	90	Yes	IV1-A3	Typical
Roof	692	0.031	R-30	na	0	0	Yes	IV4-A8	Typical
Zone=Sleep									
Wall	145.4	0.088	R-13	na	0	90	Yes	IV1-A3	Typical
Wall	176.8	0.068	R-11	R-4	90	90	Yes	IV1-A3	Typical
Wall	145.4	0.088	R-13	na	180	90	Yes	IV1-A3	Typical
Roof	692	0.031	R-30	na	0	0	Yes	IV4-A8	Typical
Zone=SunSpc									
Wall	72	0.088	R-13	na	90	90	Yes	IV1-A3	Sunspace Wall
Wall	90	0.088	R-13	na	180	90	Yes	IV1-A3	Sunspace Wall
Wall	72	0.088	R-13	na	270	90	Yes	IV1-A3	Sunspace Wall
Roof	135	0.031	R-30	na	0	0	Yes	IV4-A8	Sunspace Roof

- *Surface Type.* Valid types are Wall, BaseWallA (0-1.99 ft below grade), BaseWallB (2.0-5.99 ft below grade), BaseWallC (more than 6 ft below grade), Roof/Ceiling, and Floor. If floor is over a crawl space (FlrCrawl), then the U-factors used in the custom budget run are based on having a crawl space. Otherwise, they are not. Floor types and areas are also used to determine the default thermal mass for the Proposed Design and the thermal mass for the Standard Design.

- *Area (ft²).* The area of the surface.

- *Assembly U-factor.* The overall U-factor of the construction assembly selected from ACM Joint Appendix IV. Note that the U-factors reported in this table are the same whether or not construction quality procedures are followed. There is a credit for construction quality, but it is embedded in the software and not reported as adjustment to the U-factor.

- *Cavity Insul R-val.* The rated R-value of the installed insulation in the cavity between framing members. This does not include framing effects or the R-value of drywall, air films, etc. When insulating sheathing is installed over a framed wall, the "Cavity Insul R-val" should report the insulation in the cavity only. This value is not entered by the user, but is determined when the user selects a standard construction from ACM Joint Appendix IV.

- *Sheath Insul R-val.* The sum total rated R-value of all installed layers of insulating sheathing shall be reported. The sum of the R-values is reported for multiple sheathing layers. This value is not entered by the user, but is determined when the user selects a standard construction from ACM Joint Appendix IV.

- *True Azimuth.* The actual azimuth of the surface after adjustments for building rotation. There are various ways of describing the orientation or azimuth of surfaces. For ACMs approved by the CEC, a standard convention shall be used. The azimuth is zero degrees for surfaces that face exactly north. From this reference the azimuth is measured in a clockwise direction. East is 90 degrees, south 180 degrees and west 270 degrees.

- *Tilt.* The tilt of the surface. Vertical walls are 90°; flat roofs are 0°; floors are 180°.

- *Solar Gains.* A yes/no response is given to indicate if a surface receives solar gains. Surfaces that do not receive solar gains may include floors over crawl spaces and walls adjacent to garages. Only a yes/no response is required since the surface absorptance is a fixed input.

□*ACM Joint Appendix IV Reference.* A reference to the construction assembly selected from ACM Joint Appendix IV. This name may also be referenced from the thermal mass table to indicate an exterior mass wall.

□*Location/Comments.* User provided text describing where the surface is located or other relevant information.

2.2.6 Perimeter Losses

This table provides details about components of the building envelope that are modeled as perimeter losses. Typical perimeter losses are slab edge losses, retaining wall losses, and losses from the base of controlled ventilation crawl spaces. A row is provided in the table for each unique perimeter element. Note that a single F-factor is reported for slab edge losses for slab floor interiors that are carpeted or exposed based on a fixed assumption of 20% of the edge adjacent to exposed slab. This assumption shall be used and separate F-factor values for different interior covering conditions may not be reported or modeled by an approved ACM.

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

PERIMETER LOSSES

Perimeter Type	Length (ft)	F-Factor	Insul R-val	Insul Depth (in)	Location/Comments
Zone=Living					
SlabEdge	76	0.70	R-5	24	Exposed edge
Zone=Sleep					
SlabEdge	76	0.70	R-5	24	Exposed edge
Zone=SunSpc					
SlabEdge	65	0.73	R-0	na	Exposed edge

□*Perimeter Type.* The perimeter type. Possible types are slab edge, crawl space perimeter, etc. Names may be abbreviated.

□*Length (ft).* The perimeter length in feet.

□*F-Factor.* The perimeter heat loss factor (see Section 3.2.6).

□*Insul R-Val.* The R-value of the installed insulation. "R-0" or "None" should be reported when no insulation is installed.

□*Insul Depth (in).* The depth that the insulation extends below the top surface of the slab in inches.

□*Location/Comments.* User provided information on the location of the perimeter element or other relevant information.

2.2.7 Fenestration and Doors

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

This listing shall include information about each fenestration surface in the proposed building. Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. One row is included in the listing for each unique fenestration condition. ACMs shall restrict users to select from a limited list of exterior shading devices and their associated solar heat gain coefficients (SHGCs), namely, those devices and SHGCs listed in for exterior shading devices. ACMs shall not allow users to enter custom shading devices nor account for differences in alternative color, density, or light transmission characteristics. ACMs are required to calculate, but not report, $SHGC_{open}$ and $SHGC_{closed}$ using 2001 Standards calculation procedures and assumptions.

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

FENESTRATION AND DOORS

Fenestration #/Type/Orien	Area (ft^2)	U-factor	Fenes.SHGC	True Az	Tilt	Exterior Shade Type /SHGC	Location / Comments
Zone=Living							
1 Wdw Front(N)	70.4	0.65	0.88	0	90		
2 Wdw Left(E)	70.4	0.65	0.88	90	90	WveScrn/ 0.39	
3 Front Door	20						
4.Garage Door	20						
Zone=Sleeping							
4 Wdw Back(S)	70.4	0.65	0.88	180	90		
5 Wdw Right(W)	70.4	0.65	0.88	270	90	LvrScrn/ 0.36	

- *Fenestration #/Type/Orien.* The # is a unique number for each different fenestration surface entry. The type is Wdw (window) Dr (door) or Sky (skylight). The *Orien* (orientation) is the side of the building (front, left, right or back) followed by the nearest 45° compass point in parenthesis (N, NE, etc.). When compliance is for all orientations, only the side of the building may be reported (front, right, etc.)
- *Area (ft^2).* The area of the surface in square feet. This should generally be the rough frame opening.
- *U-factor*. The rated U-factor of the fenestration product, in Btu/h-ft^2-°F.
- *True Azimuth.* The true (or actual) azimuth of the glazed surface after adjustment for building rotation. The convention for describing the azimuth is standardized as discussed above under opaque surfaces.
- *Tilt.* The tilt of the glazed surface. Most windows will have a 90° tilt. Skylights typically have a tilt equal to the corresponding roof surface.
- *Fenestration SHGC:* The solar heat gain coefficient of the fenestration.
- *Exterior Shade Type/SHGC*. The type of exterior shading device and its solar heat gain coefficient from Table R3-7. "*Standard/0.76*" or " " shall appear when no special exterior shading device is included in the building plans. *Standard (partial bugscreen)* shading shall automatically be given for all window area without other forms of exterior shading devices. This shading assumes that a portion of the window area is covered by bugscreens. Other valid exterior shades include louvered screens (*LvrScrn*), woven sunscreen (*WvnScrn*), and Low Sun Angle Sunscreen (*LSASnScrn*). When used for compliance purposes, ACMs shall not allow or accept input for user-defined exterior shades.

2.2.8 Solar Gain Targeting

This table is only used for special cases, such as sunspaces (an optional modeling capability, and hence a Special Feature). Solar gains that enter conditioned spaces shall be targeted to the air, but when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to mass elements located within the unconditioned space. More than one row of targeting data may be included for each glazed surface. Unassigned solar gain is targeted to the air in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface shall be targeted to high surface area lightweight mass or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. An ACM shall automatically enforce these limits and inform the user of any attempt to exceed these limits.

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

SOLAR GAIN TARGETING

Fenestration #/Type/Orien	Mass Name	Winter Fraction	Summer Fraction
1 Wdw Front(N)	SSSlb	0.30	0.30

- *Fenestration #/Type/Orien.* The fenestration surface which transmits solar gain to an interior unconditioned space thermal mass. This corresponds to an item in the fenestration surfaces table.
- *Mass Name.* The name of the mass element to which solar gains are directed. The mass name corresponds to an item in the thermal mass table.
- *Winter Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a heating mode.
- *Summer Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a cooling mode.

2.2.9 Overhangs

Overhangs are a minimum ACM capability and are described in this table.

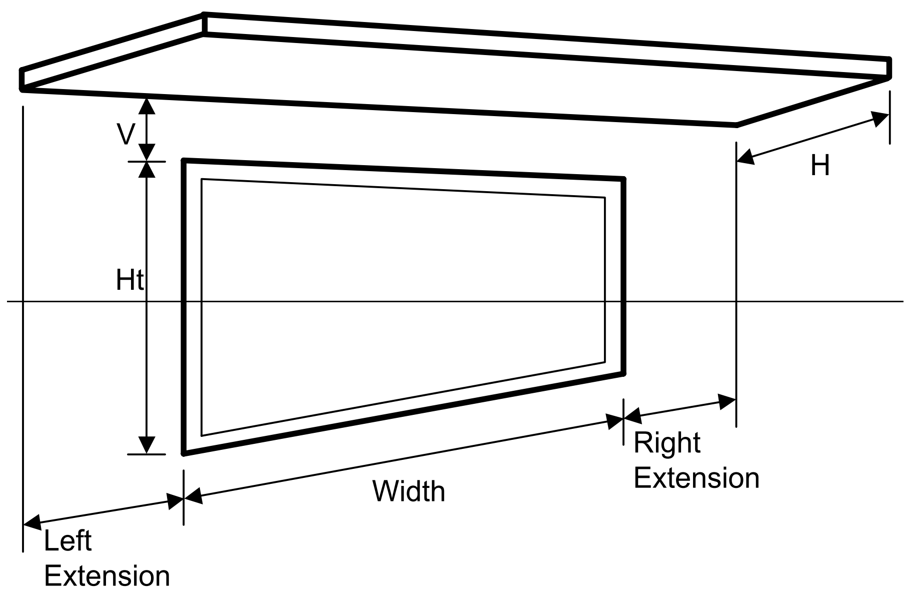


Figure R2-1 – Overhang Dimensions

OVERHANGS

Fenestration			Overhang			
#/Type/Orien	Wdth	Ht	Lngth "H"	Ht "V"	Left Extension	Right Extension
3 Wdw Back(S)	4.0	5.0	2.6	1.5	6.0	6.0

- *Fenestration #/Type/Orien.* This corresponds to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out frame opening for the fenestration (in feet) measured from the edge of the opening on one side to the edge of the opening on the other side.

□*Fenestration Ht.* The height of the rough-out frame opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.

□*Overhang Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the overhang.

□*Overhang Ht "V".* The vertical distance (in feet) from the top of the glazing frame to the bottom edge of the overhang at the distance "H" from the glazing surface. See Figure R2-1.

□*Overhang Left Extension.* The distance in feet from the left edge of the glazing frame to the left edge of the overhang. "Left" and "right" are established from an exterior view of the window.

□*Overhang Right Extension.* The distance in feet from the right edge of the glazing frame to the right edge of the overhang.

2.2.10 Side Fins

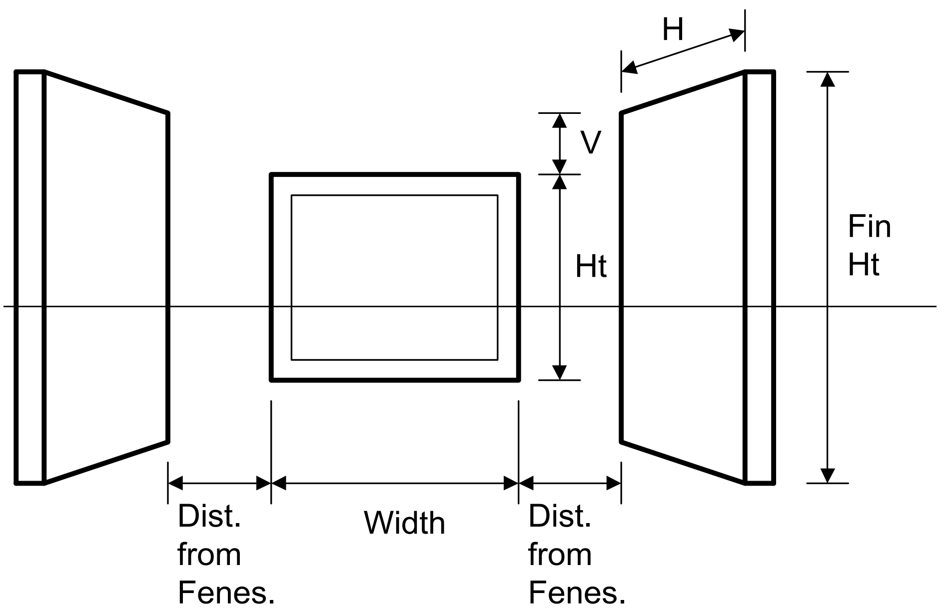


Figure R2-2 – Side Fin Dimensions

SIDE FINS

Fenestration			Left Fin				Right Fin			
#/Type/Orien	Wdth	Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht
3 Wdw Back(S)	4.0	5.0	6.0	2.0	6.0	8.0	6.0	2.0	6.0	8.0

□*Fenestration #/Type/Orien.* This shall correspond to an item in the fenestration surfaces list.

□*Fenestration Wdth.* The width of the rough-out opening for the fenestration (in feet) measured from the edge of the opening or frame on one side to the edge of the opening or frame on the other side.

□*Fenestration Ht.* The height of the rough-out opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.

□*Left Fin Dist from fenes*. The distance in feet from the nearest glazing frame edge to the fin. "Left" and "right" are established from an exterior view of the window.

□*Left Fin Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the fin.

□*Left Fin Ht "V"*. The vertical distance (in feet) from the top of the glazing frame to the top edge of the fin.

□*Left Fin, Fin Ht.* The height of the fin, in feet.

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

2.2.11 Inter-Zone Surfaces

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

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

INTER ZONE SURFACES

Surface Type	Area (ft^2)	U-factor	Cavity Insul R-val	Sheath Insul R-valu	Form 3 Reference	Location/Comments
Between Living and Sunspc						
Wall	100	0.09	R-11	na	Wall-2	Insulated partition
Glass	30	1.10	SglGls	na		Sliding glass door
Between Sleeping and Sunspc						
Wall	220	0.09	R-11	R-4	Wall-2	Insulated partition
Glass	10	1.10	SglGls	na		Window
Between Living and Sleeping						
Wall	206	0.293	R-0	na	Wall-3	Gypsum partitions
Door	40	0.33	R-0	na		Hollow core doors

□*Surface Type.* The type of surface separating the zones. Possible types are window, wall, etc.

□*Area (ft^2).* The area of the surface in square feet that separates the zones.

□*U-val.* The U-factor of the surface.

□*Cavity Insul R-val.* The R-value of insulation installed in cavity of the framed construction assembly. This does not account for framing effects, drywall, air films, etc.

□*Sheath Insul R-val.* The total R-value of all insulation layers (layers R-2 or greater) not penetrated by framing. Excludes low R-value layers such as sheetrock, building paper, and air films.

□*ACM Joint Appendix IV Reference*. A reference to a selection from ACM Joint Appendix IV.

□*Location/Comments.* User provided information on the location of the inter-zone surface or other relevant information.

2.2.12 Inter-Zone Ventilation

This listing is used for proposed designs that are modeled as multiple building zones. The modeling of multiple building zones is considered an exceptional condition that shall be reported in the *Special Features and Modeling Assumptions* listings, which shall also refer to the information in this listing when this listing is generated by the ACM to echo user inputs for Inter-Zone Ventilation. If inter-zone ventilation is modeled, it shall be reported in this listing. It describes natural and/or mechanical ventilation systems that separate the zones.

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

INTER-ZONE VENTILATION

Vent Type	Inlet Area	Outlet Area	Height Diff.	Fan Watts	Fan Flow (cfm)	Location/ Comments
Between Living and Sunspc						
Natural	20	20	3	na	na	

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

2.2.13 2.2.13 Infiltration/Ventilation

This listing is only produced when the applicant has used reduced infiltration measures (and mechanical ventilation when necessary) to improve the overall energy efficiency of the Proposed Design while maintaining adequate air quality.1 Reduced infiltration credit may be taken for duct sealing and installation of an air retarder without a blower door test. Otherwise, the use of reduced infiltration requires diagnostic blowerdoor testing by a installer and a certified HERS rater to verify the modeled reduced leakage area and to ensure minimum infiltration/ventilation rates are achieved2. Relevant information regarding infiltration and ventilation shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R. The listings shall indicate that diagnostic blower door testing shall be performed as specified in ASTM E 779-99, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. This listings shall also report the target $CFM50_H$ required for the blower door test to achieve the modeled SLA and the minimum $CFM50_H$ (corresponding to an SLA of 1.5) allowed to avoid backdraft problems. This minimum allowed value is considered by the Commission to be "unusually tight" in the requirements of the California Mechanical Code.

When the target $CFM50_H$ of the *Proposed Design* is below the value corresponding to an SLA of 3.0, mechanical ventilation with a minimum capacity of 0.047 CFM per square foot of conditioned floor area is required. This requirement for mechanical ventilation and minimum capacity shall be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R. 3Also, the *Field Verification and Diagnostic Testing* listings shall state that when the measured $CFM50_H$ is less than the minimum allowed value, corrective action shall be taken to either intentionally increase the infiltration or provide for mechanical supply ventilation adequate to maintain the dwelling unit at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating.

When mechanical ventilation is part of the Proposed Design the exhaust and supply fan wattages shall be reported in this listing and the *Field Verification and Diagnostic Testing* listings. Whenever mechanical ventilation is modeled by the user or required by modeling an SLA of 3.0 or less, the mechanical ventilation capacity selected by the user shall be greater than or equal to 0.047 cfm per square foot of conditioned floor area to be modeled by an approved ACM. If the user enters a volumetric capacity that is less than 0.047 cfm/ft^2, the ACM shall indicate an input error to the user and block compliance output.4

When reduced infiltration or mechanical ventilation is modeled, the *Special Features and Modeling Assumptions* listings shall include a statement that the homeowner's manual provided by the builder to the homeowner shall include instructions that describe how to use the operable windows or mechanical ventilation to provide for proper ventilation.

INFILTRATION/VENTILATION DETAILS *(Example Listing)*

Blower Door Leakage Target ($CFM50_H$/SLA)	Blower Door Leakage Minimum ($CFM50_H$/SLA)	Vent. Fan CFM (Supply/Exhaust)	Mechanical Vent Fans (Watts) [Supply/Exhaust]
1250/2.9	586/1.5	200/300	*50/75*

Blower Door Leakage Target ($CFM50_H$/SLA): The measured blower door leakage in cfm at 50 pascals of pressurization and its equivalent Specific Leakage Area (SLA) value.

Blower Door Leakage Minimum ($CFM50_H$/SLA): The limit for the blower door leakage test to avoid backdrafting, which corresponds to a Specific Leakage Area (SLA) of 1.5, considered to be "unusually tight" for California Mechanical Code compliance. The ACM shall report in the *Field Verification and Diagnostic Testing* listings that the Commission considers this minimum CFM and the corresponding SLA of 1.5 or less to be "unusually tight" per the Uniform Mechanical Code. In the sample listing given above a 1600 square foot house and the SLA lower limit of 1.5 is used to determine the *Blower Door Leakage Minimum* shown.

Vent. (Ventilation) Fans (CFM):[Supply/Exhaust] The total volumetric capacity of supply fans and exhaust fans listed separately, separated by a slash (or reported in separate columns). The balanced portion of mechanical ventilation is the smaller of these two numbers while the unbalanced portion is the difference between these two numbers. These values are reported in cubic feet per minute.

Mechanical Vent. (Ventilation) Fans (Watts) [Supply/Exhaust]: The total power consumption of the supply ventilation fans and the total power consumption of the exhaust ventilation fans in watts.

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

2.2.14 Slab Surfaces

This table shall be listed when the building has slab surfaces but does not qualify as a high mass design (see Thermal Mass in Chapters 3 and 4). If the building qualifies as a high mass design, this listing is omitted and the listing for high mass designs is included.

SLAB SURFACES

Mass Name	Area (ft^2)
Zone=Living	
Standard Slab	1600

Mass Name. The name of the mass element.

Area (ft^2). The area of the mass in square feet.

2.2.15 Thermal Mass for High Mass Design

This table can only appear if and when the Proposed Design qualifies as a high mass building (see Chapter 3). High mass buildings are considered to be an exceptional condition and shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R. The table specified below provides detail about the thermal mass elements in qualifying high mass building. One row is provided in the table for each mass element.

Thermal mass elements may be located within a single zone, they may separate zones or they may be located on an exterior wall. Mass elements in each of these categories shall be grouped and labeled accordingly. Additional columns may be added to the table to provide this information.

THERMAL MASS FOR HIGH MASS DESIGN

Mass Name	Area (ft^2)	Thickness (inches)	Volumetric Heat Capacity (Btu/ft^3-°F)	Conduc-tivity (Btu-in)/(hr-ft^2-°F)	Form 3 Reference	Inside Surface R-value (hr-ft^2-°F)/Btu	Location/Comments
Zone=Living							
ExpSlb-L	273	3.5	28	.98	na	0	Exposed in living
CarSlb-L	419	3.5	28	.98	na	2	Carpeted in living
Zone=Sleep							
ExpSlb-S	273	3.5	28	.98	na	0	Exposed in sleeping
CarSlb-S	419	3.5	28	.98	na	2	Carpeted in sleeping
Zone=SunSpc							
SSSlb	450	3.5	28	.98	na	0	Sunspace slab
Between Sunspc and Living							
SSWall	100	8.0	28	.98	na	0	Masonry wall

Mass Name. The name of the mass element. This name may be referenced from the optional solar gains targeting section of the fenestration surfaces table.

Area (ft^2). The area of the mass in square feet.

Thickness. The mass thickness in inches.

Heat Capacity. The volumetric heat capacity of the mass material in Btu/ºF-ft^3.

Conductivity. The conductivity of the mass material in Btu-in/h-ft^2-°F.

ACM Joint Appendix IV Reference. A reference to a lookup from ACM Joint Appendix IV..

Inside Surface R-value. The thermal resistance of any material (such as carpet or tapestry) that may exist on the inside surface of the thermal mass excluding air films. For instance, if a mass element is carpeted, a surface R-value of 2 is the fixed input. For mass elements that separate thermal zones, the surface R-value may be reported separately for each side of the mass.

Location/Comments. User provided information on the location of the mass element or other relevant information.

2.2.16 HVAC Systems

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

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

HVAC SYSTEMS

Equipment Type	Minimum Equipment Efficiency (or Water Heating System Name)	Verified Refrigerant Charge	Verified Adequate Airflow	Verified Fan Watt Draw	Verified Cooling Capacity
Zone=Living					
Furnace	0.78 AFUE	N/A	N/A	N/A	N/A
AirCond-Split	10.0 SEER/9.3 EER	Yes	Yes	240	Yes
Zone=Sleep					
CombHydro	Upper Floors	N/A	N/A	N/A	N/A
AirCond-Split	10.0 SEER	No	No	No	No

Equipment Type. The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R2-1 and Table R2-2. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows. If Gas Absorption equipment is specified, it shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R forms printed by the ACM.

Minimum Equipment Efficiency. The minimum equipment efficiency needed for compliance. The applicable efficiency units should also be reported, for instance AFUE for furnaces and boilers, HSPF for electric heating equipment, and SEER for heat pumps (cooling) and central air conditioners. In the case of combined hydronic heating, the name of the water heating system shall be identified. If the equipment type is Electric (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which use a maximum HSPF of 3.55. EER indicates that the energy efficiency ratio at ARI test conditions has been specified and will be verified according to the procedure in ACM Appendix RI - Procedures for Verifying the Presence of a Thermostatic Expansion Valve or High Energy Efficiency Ratio Equipment, and shall also be reported in the *Field Verification and Diagnostic Testing* listings.

Verified Refrigerant Charge. The choices are 'Yes' or 'No' where 'Yes' means that either refrigerant charge is verified or a TXV is installed and verifiedThe ACM shall ask the user if there are vented combustion appliances inside the conditioned space that draw air for combustion from the conditioned space prior to accepting any entry for reduced infiltration or mechanical ventilation. Cooking appliances, refrigerators and domestic clothes dryers are excluded from this requirement. If appliances other than cooking appliances, refrigerators and domestic clothes dryers are present and use conditioned air for combustion, the ACM shall instruct the user that reduced infiltration shall not be modeled when these devices are part of the Proposed Design and block data entries and ACM modeling of reduced infiltration and mechanical ventilation. When the user indicates that such devices are present or when the user models reduced infiltration or mechanical ventilation, the ACM shall report in the *Special Features and Modeling Assumptions* listings that reduced infiltration and/or mechanical ventilation are prohibited from being modeled when vented combustion appliances, not excluded above, are inside conditioned space.

When a *Proposed Design* is modeled with a reduced target infiltration ($CFM50_H$) that corresponds to an SLA less than 3.0, mechanical ventilation is required and shall be reported in the *Field Verification and Diagnostic Testing* listings.5

FIELD VERIFICATION AND DIAGNOSTIC TESTING

This house is using reduced duct leakage to comply and shall have diagnostic site testing of duct leakage performed by a certified HERS rater under the supervision of a CEC-approved HERS provider. The results of the diagnostic testing shall be reported on a CF-6R form and list the target and measured CFM duct leakage at 25 pascals.		
This house has tight construction with reduced infiltration and a target blower door test range between 586 and 1250 CFM at 50 pascals. The blower door test shall be performed using the ASTM *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, ASTM E 779-99.		
This house is using an HVAC system with all ducts and the air handler located within the conditioned space. This results in a higher distribution efficiency rating due to elimination of conduction losses (losses due to leakage are not changed) and shall be visually confirmed by a certified HERS rater under the supervision of a CEC-approved HERS provider. This verification shall be reported on a CF-6R form.		
WARNING: If this house tests below 586 CFM at 50 pascals, the house shall either be provided with a ventilation opening that will increase the tested infiltration to at least 586 CFM at 50 pascals (SLA = 1.5) OR mechanical supply ventilation shall be provided that can maintain the house at a pressure of at least -5 pascals relative the outside average air pressure while other continuous ventilation fans are operating. Note also that the Commission considers an SLA≤1.5 to be "unusually tight" per the California Mechanical Code.		
WARNING - Houses modeled with reduced infiltration are prohibited from having vented combustion appliances other than cooking appliances, refrigerators and domestic clothes dryers that use indoor air for combustion inside conditioned space.6		

2.2.24 Compliance Statement and Signatures

Signature requirements and other details on the compliance statement are included in Section 10-103(a)1 of the Administrative Regulations (Title 24, Part 1).

COMPLIANCE STATEMENT

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

3. The Proposed Design and Standard Design

3.1 Overview

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

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

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

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

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

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

While this manual describes the algorithms and calculation methods used by the reference method, compliance software may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the standard design and the proposed design and provided that the compliance software passes the applicable tests described in Chapters 5 and 6.

3.2 General Modeling Assumptions

3.2.1 Weather Data

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

Joint Appendix 2 contains information on the official CEC weather data. There are 16 standard climate zones with a complete year of 8,760 hourly weather records. Each standard climate zone is represented by a particular city. As an alternative, compliance software may use weather files provided by the Commission which have been customized for each city in Joint Appendix 2 for which design day data is provided using procedures described in Joint Appendix 2.

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

3.2.2 Ground Reflectivity

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

3.2.3 Building Physical Configuration

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

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

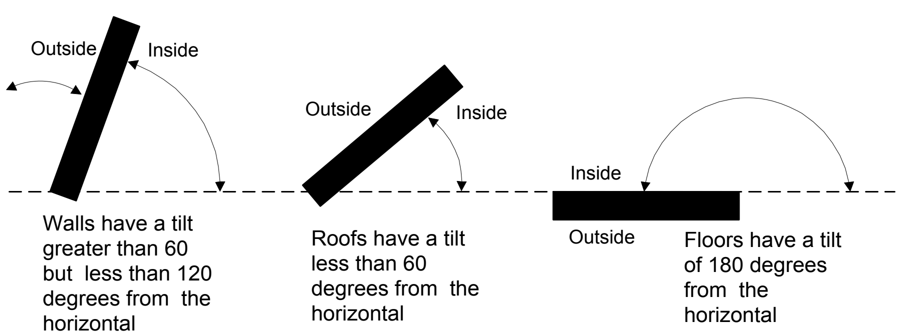


Figure R3-1 – Surface Definitions

3.2.4 Thermostats

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

Table R3-1 – Hourly Thermostat Set Points

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

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

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

Zonal Control: The alternative thermostat schedules listed in Table R3-1 above may be used for the proposed design when it meets the eligibility criteria for zonal control as defined in Chapter 6, Section 6.2.5.

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

3.2.5 Internal Gains

Basic Allocation

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

Equation R3-1

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

Where

N= Number of dwelling units

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

Additions

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

Equation R3-2

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

where

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

Equation R3-3

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

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Chapter 6). When modeled together the number of dwelling units for the proposed dwelling ($NDU_{proposed}$) remains equal to the number of dwelling units for the existing structure ($NDU_{existing}$), while the conditioned floor area ($CFA_{proposed}$) is increased to include the contribution of the addition ($CFA_{addition}$). When modeled separately, the internal gain of the addition ($IntGain_{addition}$)is based on the value of the addition's fractional dwelling unit ($FDU_{addition}$), as expressed in Equation R3-4 and Equation R3-5.

Equation R3-4

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

Equation R3-5

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

Hourly Schedules

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

Table R3-2 – Hourly Internal Gain Schedules

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

Seasonal Adjustments

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

Table R3-3 – Seasonal Internal Gain Multipliers

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

3.2.6 Joint Appendix 4

Thermal resistances (R-values) and thermal transmittance values (U-factors) shall be determined from Joint Appendix 4. Standard framed (wood and metal) walls with studs 16 in. on center shall be modeled to have 25% framing, and standard framed walls with studs located at 24 in. centers shall be modeled to have 22% framing.

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

Data from Joint Appendix 4 shall be used in compliance calculations unless the Energy Commission approves alternate values through the exceptional methods process. Joint Appendix 4 also includes pre-calculated assemblies that meet the default U-factors using a combination of batt and rigid insulation. Steel framing assemblies are also included. Joint Appendix 4 has R-values for common materials; information on a variety of masonry wall assemblies; and other data useful in determining the U-factor of an assembly.

3.2.7 Quality Insulation Installation

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

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

Compliance credit is available for low-rise residential buildings if field verification is performed to ensure that quality insulation and air barrier installation procedures are followed (see Residential Appendix RA8-2008). All newly insulated opaque surfaces in a building must be field verified to receive this credit. Compliance reports and user interfaces shall identify the building as having either *Standard* or *Improved* insulation installation quality. As discussed in Chapter 3 Section 3.2.1, the standard design shall have standard insulation installation quality. Approved compliance software must be able to model both *Standard* and *Improved* insulation installation quality (see Table R3-4).

Table R3-4 – Modeling Rules for insulation installation Quality

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

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

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

3.2.8 Reporting Requirements on CF-1R

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

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

3.3 Zone Level Data

3.3.1 Building Zone Information

Conditioned Floor Area

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

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

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

Conditioned Volume

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

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

Free Ventilation Area

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

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

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

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

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

Ventilation Height Difference

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

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

Reporting Requirements on CF-1R

The CF-1R shall include the following information:

- *Zone Name.* Each zone is given a name that is used to categorize information in subsequent tables.
- *Floor Area (ft2).* The floor area of the zone measured to outside wall. The sum of the floor area of all conditioned zones shall equal the conditioned floor area reported under "General Information".
- *Volume (ft3).* The volume of the zone. The sum of the volume of all conditioned zones shall equal the total volume reported under "General Information".
- *# of Units.* The number of dwelling units in the zone. This number may be a fraction for cases of addition alone or a building in which there are more zones than dwellings.
- *Zone Type.* This description controls some modeling restrictions, such as infiltration, internal and solar gains, etc. Possible conditioned zone entries are Conditioned, Living and Sleeping. Possible unconditioned zone entries include Unconditioned, CVCrawl and Sunspace.
- *Thermostat Type*. Possible conditioned zone entries are Setback, NoSetback, LivingStat, SleepingStat. Additional thermostat types may be allowed for optional modeling capabilities.
- *Vent Area (ft²)*. For conditioned zones, these entries are either one half of the default vent area each, for high and low based on entries in the Fenestration Surfaces table or some other value entered by the user. A Vent Area value greater than 10% of the total rough-out opening area (all windows treated as opening type: “slider”) of all fenestration shall be reported in the *Special Features Inspection Checklist* for special verification. For unconditioned zones, the high and low ventilation areas will either default to the UBC minimum values for attic vent area, otherwise the values entered by the user shall be reported.
- *Vent Height (ft)*. The height difference between the "inlet" ventilation area and the "outlet" ventilation area. The default ventilation height is determined by the number of stories: one story - 2 feet, two or more stories - 8 feet. Different vent heights may be modeled but a non-default vent height is considered a special feature or special modeling assumption that shall be reported in the *Special Features Inspection Checklist* for special verification. The ventilation height for other windows is the average height difference between the centers of the lower operable window openings and the centers of the upper operable window openings.

3.3.2 Thermal Mass

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

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

"Heavy" mass includes elements such as concrete slab floors, masonry walls, double gypsum board and other special mass elements. When the proposed design qualifies as a high mass building then each element of heavy mass is modeled in the proposed design, otherwise, the proposed design is modeled with the same heavy thermal mass as the standard design. See Chapter 3 Section 3.4 for details on what qualifies as a high mass building.

Proposed Design

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

Standard Design

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

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

Definition of High Mass Building

Additional thermal mass in the proposed design may only be modeled when the proposed design is a high mass building. A high mass building has mass equivalent to 30% of the conditioned slab floor area being exposed slab and 70% slab covered by carpet or casework, and 15% of the conditioned non-slab floor area being exposed with two inch thick concrete with the remainder low-mass wood construction. Compliance software may let users indicate a high mass design before entering mass elements for the proposed design, or compliance software can let users enter mass elements, but only consider them in the proposed design if the building qualifies as a high mass building. Thermal mass equivalency is determined through the concept of the Unit Interior Mass Capacity (UIMC) calculation described in 4.4. The thermal mass of the proposed design, other than the default standard design mass is only modeled and displayed on compliance output if the proposed design qualifies as a high mass building.

Reporting Requirements on CF-1R

Conventional Mass Designs

When the building has slab surfaces but does not qualify as a high mass design (see Thermal Mass in Chapters 3 and 4), the CF-1R shall report:

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

High Mass Designs

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

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

- *Mass Name.* The name of the mass element. This name may be referenced from the optional solar gains targeting section of the fenestration surfaces table.
- *Area (ft^2).* The area of the mass in square feet.
- *Thickness.* The mass thickness in inches.
- *Heat Capacity.* The volumetric heat capacity of the mass material in Btu/ºF-ft^3.
- *Conductivity.* The conductivity of the mass material in Btu-in/h-ft^2 -°F.
- *Joint Appendix 4 Reference.* A reference to a lookup from Joint Appendix 4..
- *Inside Surface R-value.* The thermal resistance of any material (such as carpet or tapestry) that may exist on the inside surface of the thermal mass excluding air films. For instance, if a mass element is carpeted, a surface R-value of 2 is the fixed input. For mass elements that separate thermal zones, the surface R-value may be reported separately for each side of the mass.
- *Location/Comments.* User provided information on the location of the mass element or other relevant information.

Thermal Mass Calculations

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

Solar Gain Targeting

Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the standard design run and the proposed design run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Chapter 6.

Unconditioned Sunspaces

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

3.3.3 Natural Ventilation and Infiltration

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

Infiltration

The intentional or unintentional replacement of conditioned indoor air by unconditioned outdoor air creates heat gains or heat losses for a conditioned building. This exchange of indoor and outdoor air occurs for all buildings to a greater or lesser extent. Infiltration can be affected by mechanical ventilation as mechanical ventilation may create high pressure or low pressure areas within the buildings and the air distribution system, however, the influence of the mechanical ventilation system is not considered in the calculations.

Proposed Design

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

- *Air Retarding Wrap*. An air retarding wrap can qualify for a default reduction in Specific Leakage Area (SLA) of 0.50 without confirmation by diagnostic testing. The air retarding wrap shall be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or system for Low-Rise Framed Building Walls* and have a minimum perm rating of 10. The air-retarding wrap shall be installed per the manufacturer's specifications that shall be provided to comply with ASTM E1677-95 (2000). The air retarding wrap specifications listed above shall also be reported in the *Special Features Inspection Checklist* when an air retarder is modeled by the compliance software.

- *Reduced Infiltration Due to Duct Sealing*. The default infiltration (no diagnostic testing and measurement of infiltration) credit for reduced duct leakage is also an SLA reduction of 0.50. The compliance software shall automatically apply this credit when the proposed design has sealed and tested ducts. The use of this SLA reduction credit for Low-leakage HVAC ducts shall be listed in the *Special Features Inspection Checklist* of the CF-1R. This credit may be combined with the air retarding wrap credit.

- *Diagnostic Testing for Reduced Infiltration*. Neither of the above credits shall be taken if the user chooses a diagnostic testing target for reduced infiltration. When the user chooses diagnostic testing for reduced infiltration, the diagnostic testing shall be performed using fan pressurization of the building in accordance with ASTM E 779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and the equipment used for this test shall meet the instrumentation specifications found in Residential Appendix RA-2. The specifications for diagnostic testing and the target values specified above shall be reported in the *HERS Required Verification* listings on the Certificate of Compliance. The compliance software shall require the user to enter a target value for measured $CFM50_H$ or the SLA corresponding to the target $CFM50_H$.

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

Standard Design

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

Infiltration Calculations

The reference method uses the effective leakage area method for calculating infiltration in conditioned zones.
Default Specific Leakage Area

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

Equation R3-7

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

where

ELA = Effective leakage area in square inches

CFA = Conditioned floor area (ft²)

SLA = Specific leakage area (unitless)

Effective Leakage Area (ELA) Method

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

Equation R3-8 $$CFM_{infil} = ELA \times \sqrt{A \times \Delta T_2 + B \times V^2}$$

Equation R3-9 $$CFM_{infil+unbalfan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2}$$

Equation R3-10 $$CFM_{infil+totfan} = CFM_{infil+unbalfan} + MECH_{bal}$$

The volumetric airflow (cfm) due to natural ventilation is derived from the natural ventilation cooling for the hour:

Equation R3-11 $$CFM_{natv} = \frac{Q_{natv}}{1.08 \times \Delta T_1}$$

where

CFM_{natv} = the amount of CFM delivered by mechanical ventilation

Q_{natv}

The total ventilation and infiltration (in cfm) is:

Equation R3-12 $$CFM_{total} = CFM_{natv} + CFM_{infil+totfan}$$

.

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

Equation R3-13 $$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1$$

where

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

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

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

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

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

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

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

ΔT_1 = difference between indoor and outdoor temperature for current hour (°F)

ΔT_2 = difference between indoor and outdoor temperature for previous hour (°F)

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

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

V = average wind speed for current hour (mph)

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

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

Table R3-5 – Infiltration Coefficients

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

The ELA is calculated from the SLA as follows:

Equation R3-14

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

where

CFA = conditioned floor area (ft^2)

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

ELA = effective leakage area (in^2)

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

Equation R3-15

$$ELA = 0.055 \times CFM50_H$$

where

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

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

Equation R3-16 $$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$

Controlled Ventilation Crawl Spaces and Sunspaces

Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Chapter 6. All optional capabilities that are used in the proposed design shall be reported in the *Special Features Inspection Checklist* on the Certificate of Compliance.

Infiltration Interaction with attic

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

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

Natural Ventilation

Natural Ventilation Algorithms

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

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

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

Effective Ventilation Area (EVA)

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

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

Stack Driven Ventilation

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

Equation R3-17 $$CFM_S = 9.4 \times EVA \times EFF_S \times \sqrt{H \times \Delta T}$$

where

CFM_S = Airflow due to stack effects, cfm.

9.4 = Constant.

EVA = Effective ventilation area as discussed above, ft².

EFFs = Stack effectiveness.

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

ΔT = Indoor to outdoor temperature difference, °F.

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

Wind Driven Ventilation

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

Equation R3-18 $$CFM_w = EVA \times 88 \times MPH \times WF \times EFF_o \times EFF_d$$

where

CFM_W = Ventilation due to wind, cfm.

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

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

MPH = Wind speed from the weather tape, mph.

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

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

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

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

Combined Wind and Stack Effects

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

Equation R3-19 $$CFM_t = \sqrt{CFM_w^2 + CFM_s^2}$$

where:

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

CFM_W = Ventilation rate from wind effects, cfm.

CFM_S = Ventilation rate from stack effects, cfm.

Determination of Natural Ventilation for Cooling

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

Wind Speed and Direction

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

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

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

Reporting Requirements on CF-1R

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

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

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

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

Details provided in the CF-1R shall include:

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

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

3.4 Attics

The procedures and rules in this section apply to attic roof constructions selected from the following tables of Joint Appendix 4.

Table 4.2.1 – U-factors of Wood Framed Attic Roofs

Table 4.2.4 – U-factors of Metal Framed Attic Roofs

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

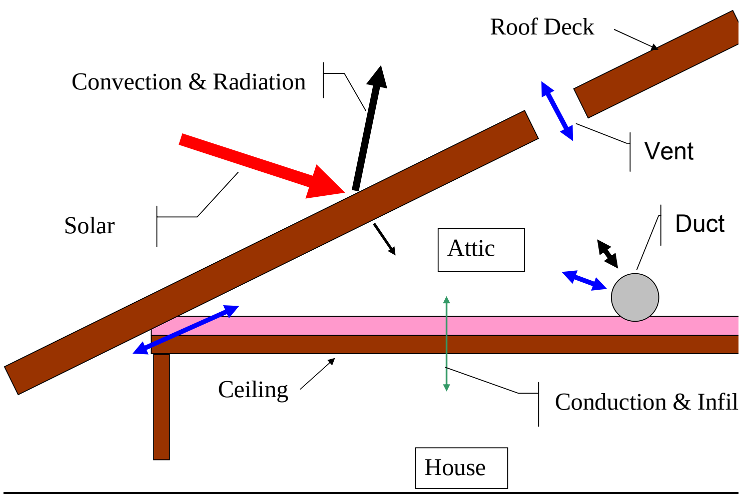


Figure R3-2 – Components of the Unconditioned Attic Model

3.4.1 Roof Pitch and Attic Geometry

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

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

3.4.2 Ceiling/Framing Assembly

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

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

Table R3-6 – Attic Constructions for the Standard Design

Building Component	Package D R-value Criteria	Description	Joint Appendix 4 Reference
Non-Attic Roof	R-30	2x4's at 24 in. o.c.	Table 4.2.1-A20
	R-38	2x4's at 24 in. o.c.	Table 4.2.4-A21

3.4.3 Attic Ventilation

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

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

3.4.4 Roof Deck

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

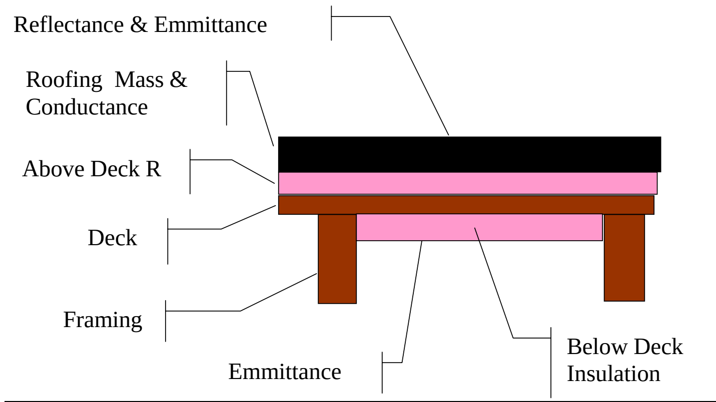


Figure R3-3 – Components of the Attic through Roof Deck

Proposed Design

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

- **Solar reflectance and emittance** of the roof surface (unitless). The aged solar reflectance shall be defaulted to 0.10 unless the roofing material is rated by the Cool Roof Rating Council (CRRC) or is an asphalt or composition shingle. For asphalt shingles or composition shingles, the default aged solar reflectance is 0.08. The default emittance for all materials is 0,85, For products rated by the CRRC, the aged reflectance and emittance shall be used. If the aged reflectance is not available from the CRRC, it shall be estimated by multiplying the initial reflectance by 0.70 and adding 0.06 and the aged emittance shall be equal to the initial emittance. Cool roofs shall be reported on the *Special Features Inspection Checklist* on the CF-1R.
- **Roofing Type**. The choice of roofing type determines the air gap characteristics between the roofing material and the deck, the thermal mass characteristics, and establishes whether other inputs are needed, as described below. The choices for roof type are shown below.
  - **Concrete or clay tile.** These are characterized by the combination of an air gap between the deck and the tiles and the tiles themselves having some weight or mass.
  - **Metal tile or wood shakes** (note that tapered cedar shingles do not qualify and are treated as a conventional roof surface). These are lightweight (no significant mass), but have an air gap between the tiles or shakes and the deck.
  - **Other high slope roofing types** including asphalt and composite shingles and tapered cedar shingles. These products are characterized by a low thermal mass and no air gap between the shingles and the structural roof deck.
  - **Low slope membranes.** These are basically flat roofs with a slope of 2:12 or less.
- **Above deck insulation**. This input defaults to 0.85 for “concrete or clay tile” or for “metal tile or wood shakes” to represent the benefit of the air gap. The default is no insulation for other roof types, but the user can enter an R-value if some form of continuous insulation is installed above the deck and below the roofing material.
- **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 choices for additional thermal mass are:
  - No mass
  - 5 lb/ft²
  - 10 lb/ft²

- o 15 lb/ft²
- o 25 lb/ft²

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

  Continuous Radiant Barrier

  Radiant Barrier over Discontinuous Sheathing

  No Radiant Barrier.

Standard Design

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

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

3.4.5 Reporting Requirements on CF-1R

The certificate of compliance (CF-1R) shall report the user inputs for attics described in the above sections. Note that information on ceilings and knee walls shall be reported separately pursuant to Section 3.5.5.

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

- *Attic Vent High.* The fraction of the vent area that is high due to the presence of ridge, roof or gable end mounted vents. Soffit vents are considered low ventilation. Default value is 0 for attics with standard ventilation. Attics with radiant barriers are required to have a vent high fraction of at least 0.3.
- *Reflectance.* A fraction that specifies the certified aged reflectance of the roofing material. The installed value must be equal to or less than the value specified here.
- *Emittance.* A fraction that specifies the certified aged emissivity of the roofing material. The installed value must be equal to or greater than the value specified here. Default value is 0.9 if certified aged reflectance value is not available.
- *Roofing Type*. The user chooses from: concrete or clay tile; metal tile or wood shakes; other high slope roofing types; or low slope membranes.
- *Roofing Mass.* The user chooses from: none, 5, 10, 15, or 25 lb/ft². Default is none. This is mass in addition to the weight of the roofing tiles themselves. This input is specified only when the roofing type is low-slope membrane.
- *Above Deck R-value.* The R-value of insulation above the roof deck. Default value is 0.
- *Framing Depth and Spacing.* The framing depth for the roof framing members. Default value is 2x4's at 24 in. o.c.
- *Below Deck R-value.* The R-value of insulation below the roof deck. Default value is 0.
- *Radiant Barrier.* The user chooses from: continuous radiant barrier, radiant barrier over discontinuous sheathing, or no radiant barrier.

Refer to drawings in sections 3.2.2 and 3.2.2.1 for more details on these inputs.

3.4.6 Calculations

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

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

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

Table R3-7 – Attic Model Inputs – Attic Ventilation

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

Table R3-8 – Attic Model Inputs – Roofing Type

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

Table R3-9 – Attic Model Inputs – Roofing Deck

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

Table R3-10 – Attic Model Inputs – Roofing Mass

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

Table R3-11 – Attic Model Inputs – Radiant Barrier

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

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

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

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

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

Table R3-14 – Attic Model Inputs – Ceiling Construction

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

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

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

Equation R3-20
$$D1 = \left(\frac{1}{U_{table}} + 1.18\right) \times coef1 + coef2$$

where

D1 = Effective depth of insulation, inches

U_{table} = U factor from Table 4.2.1 – U-factors of Wood Framed Attic Roofs or Table 4.2.4 – U-factors of Metal Framed Attic Roofs

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

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

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

Table R3-16 – Attic Model Inputs – Ceiling Framing

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

Table R3-17 – Ceiling Construction Quality

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

Table R3-18 – Attic Model Inputs – Knee Walls

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

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

- FF the framing factor from table R1-ZZZ3
- D1, the effective depth of the ceiling insulation calculated from Equation R3-21

Equation R3-21

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

where

D1 = Effective depth of insulation, inches

U_{table} = U factor from Table 4.3.1 – U-factors of Wood Framed Walls or Table 4.3.4 – U-factors for Metal Framed Walls for Low –Rise Residential Construction

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

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

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

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

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

3.5 Exterior Surfaces Other Than Attics

3.5.1 Non-Attic Ceiling and Roof Constructions

The procedures and rules in this section apply to ceiling and roof constructions selected from the following tables of Joint Appendix 4.

Table 4.2.2 – U-factors of Wood Framed Rafter Roofs

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

Table 4.2.5 – U-factors of Metal Framed Rafter Roofs

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

Table 4.2.7 – U-factors for Metal Building Roofs

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

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

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

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

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

Building Component	Package D R-value Criteria	Standard Design U-factor	Joint Appendix 4 Reference
Non-Attic Roof	R-30	0.033	Table 4.2.2-A41
	R-38	0.027	Table 4.2.2-A43

3.5.2 Exterior Walls

Proposed Design. The compliance software shall allow a user to enter one or more exterior wall areas for the proposed design. The wall areas modeled shall be consistent with the corresponding wall areas in the actual building design and the total wall area shall be equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. U-factors for proposed design wall constructions shall be selected from Joint Appendix 4. If the proposed design has *Improved* insulation installation quality, then walls are modeled accordingly (see above). Walls include all opaque surfaces with a slope greater than 60º but less than 12º from the horizontal.

Standard Design. The gross wall area in the standard design is equal to the gross wall area of the proposed design, including knee walls in the ceiling construction of the proposed design. The gross exterior wall area in the standard design (excluding knee walls) is equally divided between the four main compass points, north, east, south, and west. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. The standard design has *Standard* insulation installation quality. U-factors for the standard design walls shall be those from Table R3-22 for the appropriate Package D R-value criteria multiplied by the standard insulation installation quality factor for walls from Section 4.2.3.

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

Building Component	Package D R-value Criteria	Standard Design U-factor	Joint Appendix 4 Reference
Wall	R-13	0.102	Table 4.3.1-A3
	R-19	0.074	Table 4.3.1-A5
	R-21	0.069	Table 4.3.1-A6

3.5.3 Basement Walls and Floors

Proposed Design. Portions of basement walls above grade shall be modeled as conventional above-grade walls. For below-grade basement walls, the user shall enter the area at each of three depths: from zero to 2 feet below grade (shallow), greater than 2 feet to 6 feet below grade (medium), and greater than 6 feet below grade (deep). The compliance software shall allow users to enter as many wall types as necessary to model the proposed design. The U-factor, C-factor, and mass characteristics of below-grade walls shall be selected from Joint Appendix 4. The thermal performance characteristics for the proposed design below-grade wall constructions shall be the same as the standard design.

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

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

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

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

3.5.4 Raised Floors

Proposed Design. Compliance software users shall enter floor areas for the standard raised floor construction types listed in Table R3-24. The compliance software shall require user input to distinguish floor areas and constructions that are over crawl spaces. The U-factor for floor constructions and areas shall be consistent with the actual building design. U-factors shall be those from Joint Appendix 4. For concrete raised floors the assembly types used in Joint Appendix 4, Table 4.25 shall be used.

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

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

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

Floor Type	Package D Criteria	U-factor	Joint Appendix 4 Reference
Raised Light Floor (crawl space)	R-19	0.037	4.4.1-A4
Raised Light Floor (no crawl space)	R-19	0.048	4.4.2-A4
Raised Concrete Floor	R-0	0.269	4.25.A1
	R-4	0.138	4.25.A3
	R-8	0.092	4.25.A5

3.5.5 Reporting Requirements on CF-1R

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

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

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

- *Surface Type.* Valid types are Wall, BaseWallA (0-1.99 ft below grade), BaseWallB (2.0-5.99 ft below grade), BaseWallC (more than 6 ft below grade), and Floor. If floor is over a crawl space (FlrCrawl), then the U-factors used in the custom budget run are based on having a crawl space. Otherwise, they are not. Floor types and areas are also used to determine the default thermal mass for the proposed design and the thermal mass for the standard design.
- *Area (ft2).* The area of the surface.
- *Assembly U-factor.* The overall U-factor of the construction assembly selected from Joint Appendix 4. Note that the U-factors reported in this table are the same whether or not construction quality procedures are followed. There is a credit for construction quality, but it is embedded in the software and not reported as adjustment to the U-factor.
- *Cavity Insul R-val.* The rated R-value of the installed insulation in the cavity between framing members. This does not include framing effects or the R-value of drywall, air films, etc. When insulating sheathing is installed over a framed wall, the "Cavity Insul R-val" should report the insulation in the cavity only. This value is not entered by the user, but is determined when the user selects a standard construction from Joint Appendix 4.
- *Sheath Insul R-val.* The sum total rated R-value of all installed layers of insulating sheathing shall be reported. The sum of the R-values is reported for multiple sheathing layers. This value is not entered by the user, but is determined when the user selects a standard construction from Joint Appendix 4.
- *True Azimuth.* The actual azimuth of the surface after adjustments for magnetic north. There are various ways of describing the azimuth of surfaces. For compliance software approved by the CEC, a standard

convention shall be used. The azimuth is zero degrees for surfaces that face exactly north. From this reference the azimuth is measured in a clockwise direction. East is 90 degrees, south 180 degrees and west 270 degrees. For example, a wall facing south south west (SSW) should be documented at an azmuith of 157.5 degrees from true north.

- *Tilt.* The tilt of the surface. Vertical walls are 90°; flat roofs are 0°; floors are 180°.
- *Solar Gains.* A yes/no response is given to indicate if a surface receives solar gains. Surfaces that do not receive solar gains may include floors over crawl spaces and walls adjacent to garages. Only a yes/no response is required since the surface absorptance is a fixed input.
- *Joint Appendix 4 Reference.* A reference to the construction assembly selected from Joint Appendix 4. This name may also be referenced from the thermal mass table to indicate an exterior mass wall.
- *Location/Comments.* User provided text describing where the surface is located or other relevant information.

3.6 Slabs-on-Grade

3.6.1 Inputs for Proposed Design and Standard Design

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

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

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

3.6.2 Reporting Requirements on CF-1R

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

- *Slab Type.* The perimeter type. Possible types are slab edge, crawl space perimeter, etc. Names may be abbreviated.
- *Area (ft²).* The slab area in feet.
- *Surface Condition.* Indicate if the slab area is Exposed or Carpeted. If the default is accepted, then Default may be reported and it is not necessary to separate the slab area between Exposed and Carpeted.

- *Insulation R-Value.* The R-value of the installed insulation. "R-0" or "None" should be reported when no insulation is installed.
- *Insulation Depth (in).* The depth that the insulation extends below the top surface of the slab in inches.
- *Location/Comments.* User provided information on the location of the slab element or other relevant information.

3.6.3 Slab Calculations

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

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

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

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

where

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

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

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

A_{per} = Perimeter slab area (ft²)

A_{core} = Interior slab area (ft²)

T_{in} = Interior space temperature (F)

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

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

T_{annual} = Average annual temperature (F)

α_{1-5} = Coefficients from (Btu/h-F-ft²)

Table R3-25 – Slab Model Coefficients

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

Surface Condition	Insulation Depth	Insulation R-value	Perimeter Bi-Weekly α_1	Perimeter Monthly α_2	Perimeter Annual α_3	Interior Monthly α_4	Core Annual α_5
Carpeted	n.a.	R-0	0.1157	0.0664	0.0028	0.0517	0.0257
	8 in.	R-5	0.0529	0.0818	0.0084	0.0422	0.0297
		R-10	0.0443	0.0822	0.0105	0.0401	0.0306
	24 in.	R-5	0.0320	0.0869	0.0103	0.0390	0.0310
		R-10	0.0205	0.0874	0.0131	0.0363	0.0322
	48 in.	R-5	0.0241	0.0781	0.0147	0.0338	0.0329
		R-10	0.0205	0.0874	0.0131	0.0291	0.0350
Exposed	n.a.	R-0	0.2042	0.0797	0.0014	0.0550	0.0258
	8 in.	R-5	0.0990	0.0950	0.0069	0.0453	0.0292
		R-10	0.0841	0.0953	0.0091	0.0434	0.0300
	24 in.	R-5	0.0639	0.1001	0.0087	0.0421	0.0304
		R-10	0.0441	0.1005	0.0116	0.0395	0.0314
	48 in.	R-5	0.0503	0.0891	0.0141	0.0364	0.0324
		R-10	0.0265	0.0840	0.0198	0.0318	0.0341

Table R3-26 – Monthly and Annual Average Ground Temperatures

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

3.7 Fenestration and Doors

3.7.1 Doors

Proposed Design. Compliance software shall allow users to enter at least two different doors. For each, the inputs shall be a construction from Joint Appendix 4, areas, and orientation.

Standard Design. The standard design has 40 square feet of door area for each dwelling unit. All doors are assumed to face north and have a U-factor of 0.50 from Joint Appendix 4 Table 4.5.1. The net opaque wall area facing north is reduced by 40 ft² for each dwelling unit for the standard design run.

3.7.2 Fenestration Types and Areas

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

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

3.7.3 Overhangs and Sidefins

Proposed Design. Compliance software shall allow users to enter a set of basic generic parameters for a description of an overhang and sidefin for each individual fenestration or window area entry. The basic parameters shall include *Fenestration Height, Overhang/Sidefin Length, and Overhang/Sidefin Height.*

Compliance software user entries for overhangs may also include *Fenestration Width, Overhang Left Extension* and *Overhang Right Extension.* Compliance software user entries for sidefins may also include *Fin Left Extension* and *Fin Right Extension* for both left and right fins. Walls at right angles to windows shall be modeled as sidefins.

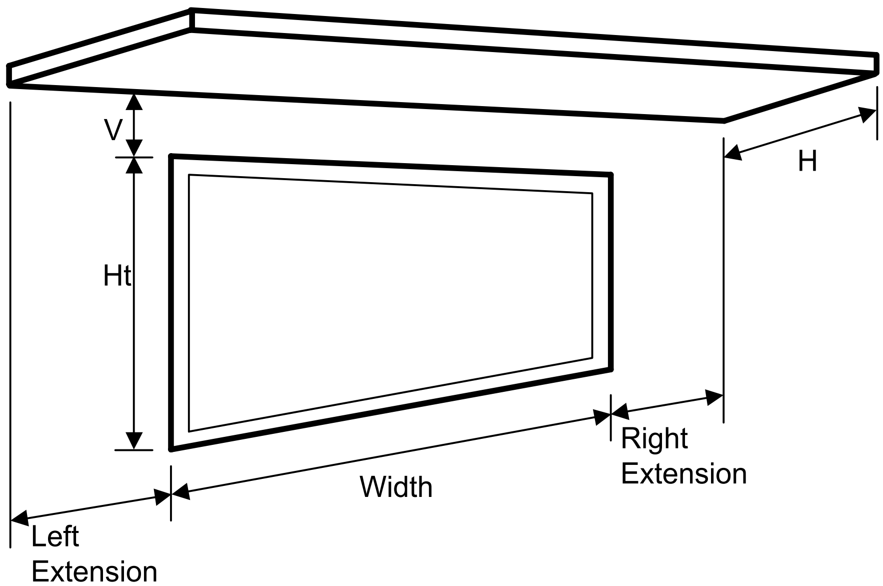


Figure R3-4 – Overhang Dimensions

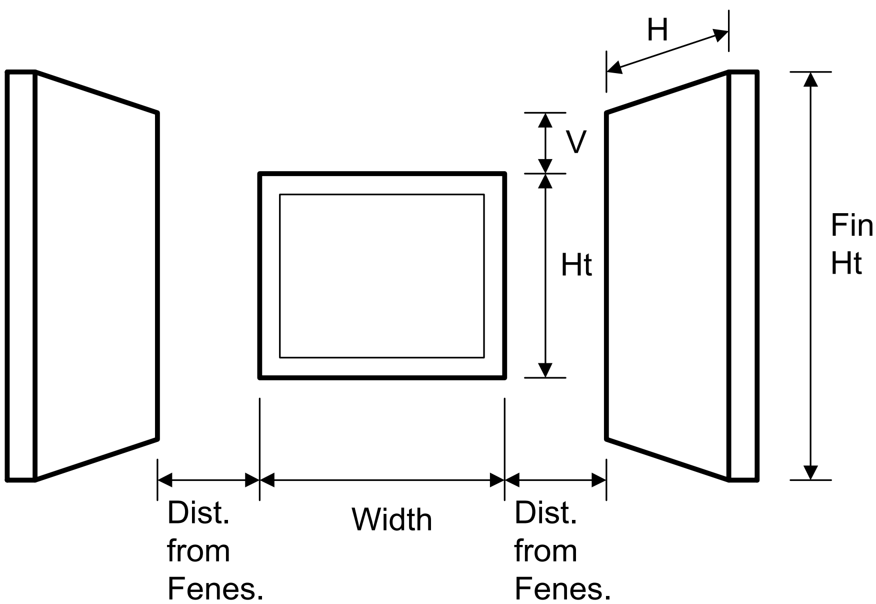


Figure R3-5 – Side Fin Dimensions

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

3.7.4 Interior Shading Devices

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

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

Proposed and Standard Design

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

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

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

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

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

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

3.7.5 Exterior Shading Screens

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

Standard Design. The standard design shall assume "Standard" which is bug screens.

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

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

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

3.7.6 Reporting Requirements for CF-1R

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

This listing shall include information about each fenestration in the proposed building. Fenestrations include every individual window, skylight, and glazing in doors or other transparent or translucent surfaces. One row is included in the listing for each unique fenestration. Compliance software shall restrict users to select from a limited list of exterior shading devices and their associated solar heat gain coefficients (SHGCs), namely, those devices and SHGCs listed in the Table R3-7. Compliance software shall not allow users to enter custom shading devices nor account for differences in alternative color, density, or light transmission characteristics. Compliance software shall not allow for shading by other structures, objects or self shading other than those allowed by modeling fins and/or overhangs. Compliance software is required to calculate, but not report, $SHGC_{open}$ and $SHGC_{closed}$ using 2008 Standards calculation procedures and assumptions.

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

The CF-1R shall include the following information:

- *Fenestration #/Type/Orien.* The # is a unique number for each different fenestration surface entry. The type is Wdw (window) Dr (door) or Sky (skylight). The *Orien* (orientation) is the side of the building (front, left, right or back) followed by the nearest 45° compass point in parenthesis (N, NE, etc.). When compliance is for all orientations, only the side of the building may be reported (front, right, etc.)
- *Area (ft2).* The area of the surface in square feet. This should be the rough frame opening.
- *U-factor*. The rated U-factor of the fenestration product, in Btu/h-ft^2-°F.
- *True Azimuth.* The true (or actual) azimuth of the glazed surface after adjustment for building rotation. The convention for describing the azimuth is standardized as discussed above under opaque surfaces.
- *Tilt.* The tilt of the glazed surface. Most windows will have a 90° tilt. Skylights typically have a tilt equal to the corresponding roof surface.
- *Fenestration SHGC:* The solar heat gain coefficient of the fenestration.
- *Exterior Shade Type/SHGC*. The type of exterior shading device and its solar heat gain coefficient from Table R3-7. "*Standard/0.76*" or " " shall appear when no special exterior shading device is included in the building plans. *Standard (partial bugscreen)* shading shall automatically be given for all window area without other forms of exterior shading devices. This shading assumes that a portion of the window area is covered by bugscreens. Other valid exterior shades include louvered screens (*LvrScrn*), woven sunscreen (*WvnScrn*), and Low Sun Angle Sunscreen (*LSASnScrn*). When used for compliance purposes, compliance software shall not allow or accept input for user-defined exterior shades.

Overhangs

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

- *Fenestration #/Type/Orien.* This corresponds to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out frame opening for the fenestration (in feet) measured from the edge of the opening on one side to the edge of the opening on the other side.
- *Fenestration Ht.* The height of the rough-out frame opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.

- *Overhang Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the overhang.
- *Overhang Ht "V".* The vertical distance (in feet) from the top of the glazing frame to the bottom edge of the overhang at the distance "H" from the glazing surface. See Figure R2-1.
- *Overhang Left Extension.* The distance in feet from the left edge of the glazing frame to the left edge of the overhang. "Left" and "right" are established from an exterior view of the window.
- *Overhang Right Extension.* The distance in feet from the right edge of the glazing frame to the right edge of the overhang.

Side Fins

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

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

Solar Gain Targeting

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

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

Information reported on the CF-1R shall include:

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

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

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

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

3.7.7 Fenestration Calculations

Solar Gain

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

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

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

and

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

where

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

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

-

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

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

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

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

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

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

vfSky = View factor of window to sky [unitless]

vfGrnd = View factor from window to ground [unitless]

GrndRf = Ground Reflectance [unitless] = 0.20

Table R3-29 – Polynomial Coefficients for Angular Dependence

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

Interior and Exterior Shading

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

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

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

Solar Heat Gain Coefficients

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

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed solar heat gain coefficients are listed in Table R3-5 and Table R3-7.

The formula for combining solar heat gain coefficients is:

Equation R3-29

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

where

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

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

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

where

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

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

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

3.8 Inter-Zone Transfer

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

3.8.1 Inter-Zone Surfaces Reporting Requirements for CF-1R

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

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

- *Surface Type.* The type of surface separating the zones. Possible types are window, wall, etc.
- *Area (ft*2*).* The area of the surface in square feet that separates the zones.
- *U-val.* The U-factor of the surface.
- *Cavity Insul R-val.* The R-value of insulation installed in cavity of the framed construction assembly. This does not account for framing effects, drywall, air films, etc.
- *Sheath Insul R-val.* The total R-value of all insulation layers (layers R-2 or greater) not penetrated by framing. Excludes low R-value layers such as sheetrock, building paper, and air films.
- *Joint Appendix 4 Reference*. A reference to a selection from Joint Appendix 4.
- *Location/Comments.* User provided information on the location of the inter-zone surface or other relevant information.

3.8.2 Inter-Zone Ventilation Reporting Requirements for CF-1R

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

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

- *Vent Type.* Possible types are natural and fan.
- *Inlet Area.* The area of the air inlet in square feet. This is used only when vent type is "natural".
- *Outlet Area.* The area of the air outlet in square feet. This is used only when vent type is "natural". The maximum area that may be modeled is 40 ft² of opening.
- *Height Diff.* The elevation difference between the inlet and the outlet in feet. This is used only when vent type is "natural". Default is two feet.

- *Fan Watts.* The fan power rating in watts. This is used only for sunspaces and only then when vent type is "fan". Fan energy may be reported as a separate line item or added to the TDV energy for heating.
- *Fan Flow (cfm).* The cubic feet per minute of air flow provided when the fan is operating. This is used only for sunspaces and then only when vent type is "fan".
- *Location/Comments*. User provided text describing where the item is located or other relevant information.

3.9 HVAC System Overview

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

3.9.1 System Type

Proposed Design

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

Standard Design

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

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

Table R3-30 – Summary of Standard Design HVAC System

Proposed Design		Standard Design		
Heating System	**Cooling System**	**Heating System**	**Cooling System**	**Detailed Specifications**
Through-the-wall heat pump		Same equipment as proposed design with no air distribution ducts		Equipment efficiency determined by CEC Appliance Efficiency Standards
Gas wall furnace with our without ducts and/or circulation fan	Any	Same equipment as proposed design with no air distribution ducts	Split system AC with air distribution ducts	
Any other electric heat including electric resistance, water source heat pump, etc.	Any	Split system heat pump with air distribution ducts		SEER per Package D Verified refrigerant charge (prescriptive requirement) No credit for sizing No credit for adequate air flow No credit for reduced fan power
All other gas heating	Any	Split system air conditioner with gas furnace and air distribution ducts.		
Note: The standard design cooling system is also used for the proposed design if the proposed design has no air conditioning				

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

This table is applicable only when the standard design system has air distribution ducts as determined in Table R3-30.

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 (prescriptive requirement) No credit for reduced duct area No credit for increased duct R-value or buried ducts No credit for low-leakage air handler
No attic but crawlspace or basement	Ducts and air handler located in the crawlspace or basement	
No attic, crawlspace or basement	Ducts and air handler located indoors	

3.9.2 Multiple System Types

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

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

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

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

3.9.3 No Cooling

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

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

3.9.4 Reporting Requirements on CF-1R

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

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

Information on the CF-1R may include:

- *Equipment Type*. The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R3-32 and Table R3-33. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows. If Gas Absorption equipment is specified, it shall be reported in the *Special Features Inspection Checklist* on the CF-1R forms printed by the compliance software.
- *Minimum Equipment Efficiency.* The minimum equipment efficiency needed for compliance. The applicable efficiency units should also be reported, for instance AFUE for furnaces and boilers, HSPF for electric heating equipment, and SEER for heat pumps (cooling) and central air conditioners. In the case of combined hydronic heating, the name of the water heating system shall be identified. If the equipment type is Electric (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which use a maximum HSPF of 3.55. EER indicates that the energy efficiency ratio at ARI test conditions has been specified and will be verified according to the procedure in Residential Appendix RA7 - Procedures for Verifying the Presence of a Thermostatic Expansion Valve or High Energy Efficiency Ratio Equipment sections RA7-3 and RA7-4, and shall also be reported in the *Hers Required Verification* listings.
- *Verified Refrigerant Charge.* The choices are 'Yes' or 'No' where 'Yes' means that either refrigerant charge is verified or a charge indicator light is installed and verified. Refrigerant charge credit is applicable to split system air conditioners and heat pumps only. The two equipment types that can comply by verifying refrigerant charge are SplitAirCond, and SplitHeatPump.
- *Verified Adequate Airflow.* Yes indicates that the air flow will be tested and verified according to the procedure in Residential Appendix RA6 - Forced Air System Fan Flow and Air Handler Fan Watt Draw section RA6-4.1 and shall also be reported in the *Hers Required Verification* listings. No indicates that the default air flow is used.
- *Verified Fan Energy*. A number such as 240 indicates the user specified air handler fan watt draw that will be tested and verified according to the procedure in Residential Appendix RA6 - Forced Air System Fan Flow and Air Handler Fan Watt Draw section RA6-4.3 and shall also be reported in the *Hers Required Verification* listings No indicates that the default fan watt draw is used.
- *Verified Maximum Cooling Capacity*. Yes indicates that the proposed design will have an air conditioner sized according to the compliance software calculations in Residential Appendix RA1 – HVAC Sizing section RA1-3 and this shall also be reported in the *Hers Required Verification* listings. Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, sealed and tested new duct systems, and proper refrigerant charge (or alternatively a charge indicator light). No indicates that no sizing credit is being taken.

Table R3-32 – HVAC Heating Equipment Descriptors

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

Table R3-33 – HVAC Cooling Equipment Descriptors

Recommended Descriptor	Cooling Equipment Reference
NoCooling	Entered when the proposed building is not air conditioned or when cooling is optional (to be installed at some future date). Both the standard design equivalent building and the proposed design use the same default system (refer to sections 3.6.2). [Efficiency Metric: SEER]
SplitAirCond	Split air conditioning systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER]
PkgAirCond	Central packaged air conditioning systems less than 65,000 Btuh cooling capacity. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER]
LrgPkgAirCond	Large packaged air conditioning systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER]
RoomAirCond	Non-central room air conditioning cooling systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called through-the-wall) air conditioning units. Distribution system shall be DuctIndoor. [Efficiency Metric: EER]
SplitHeatPump	Cooling side of split heat pump systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER<65,000 Btu/hr EER>65,000 Btu/hr]
PkgHeatPump	Cooling side of central single-packaged heat pump systems with a cooling capacity less than 65,000 Btuh. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER]
LrgPkgHeatPump	Cooling side of large packaged heat pump systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER]
GasCooling	Gas absorption cooling. Three descriptors, COP95, the rated COP for the gas portion, CAP95, the rated capacity, and PPC, the parasitic electric energy at rated conditions in Watts.
RoomHeatPump	Cooling side of non-central, room heat pump systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called "through-the-wall") units. Distribution system shall be DuctIndoor. [Efficiency Metric: EER]
EvapDirect	Direct evaporative cooling systems. Assume minimal efficiency air conditioner. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER]
EvapIndirDirect	Indirect-direct evaporative cooling systems. Assume 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]
Evap/CC	Evapratively Cooled Condensers A split mechanical system, with a water-cooled condenser coil. (Efficiency metric: EER)
IceSAC	Ice Storage Air Conditioning. Split air conditioner condensing coil in combination with ice storage. (Efficiency metric ia system performance tables)

Table R3-34 – HVAC Distribution Type and Location Descriptors

Recommended Descriptors	HVAC Distribution Type and Location Reference
Air Distribution Systems	Fan-powered, ducted distribution systems that can be used with most heating or cooling systems. When ducted systems are used with furnaces, boilers, or combined hydronic/water heating systems the electricity used by the fan shall be calculated using the methods described later in this manual. R-value shall be specified in "Duct R-value" column when a ducted system is specified
DuctsAttic	Ducts located overhead in the unconditioned attic space
DuctsCrawl	Ducts located underfloor in the unconditioned crawl space
DuctsCVC	Ducts located underfloor in a controlled ventilation crawl space
DuctsGarage	Ducts located in an unconditioned garage space.
DuctsBasemt	Ducts located in an unconditioned basement space
DuctsInEx12	Ducts located within the conditioned floor space except for less than 12 lineal feet of duct, typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space.
DuctsInAll	HVAC unit or systems with all HVAC ducts located within the conditioned floor space. Location of ducts in conditioned space eliminates conduction losses but does not change losses due to leakage. Leakage from either ducts that are not tested for leakage or from sealed ducts are modeled as leakage to outside the conditioned space.
DuctsNone	Air distribution systems without ducts such as ductless split system air conditioners and heat pumps, window air conditioners, through-the-wall heat pumps, etc.
DuctsOutdoor	Ducts located in exposed locations outdoors.
Ductless Systems	Ductless radiant or warm/cold air systems using fan-forced or natural air convection and hydronic systems relying upon circulation pumps and fan-forced or natural air convection, and
Furnaces	Heating equipment such as wall and floor furnaces
Radiant	Radiant electric panels or fanless systems used with a boiler, electric or heat pump water heater, or combined hydronic heating equipment.
LowLICod	*Verified Low Leakage Ducts in Conditioned Space - defined as duct systems for which air leakage to outside conditions is equal to or less than 25 cfm when measured in accordance with Section RA4-4.3.3, steps 1 through 9.*
LowLkAH	*Low Leakage Air Handlers – for factory sealed air handler unit tested by the manufacturer and certified to the Commission to have achieved a 2 percent or less leakage rate at 1-inch water gage – as prescribed in RA4-4.3.9.*
Baseboard	Electric baseboards or hydronic baseboard finned-tube natural convection systems

3.10 ***Heating Systems***

3.10.1 Proposed Design

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

3.10.2 Standard Design

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

3.10.3 Heating System Calculations

ACMs shall use the following inputs and algorithms to calculate heating energy use.

Equation R3-30

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

where

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

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

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

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

Furnaces and Boilers

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

Equation R3-31

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

where

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

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

Heat Pump and Electric Furnace

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

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = Defaults to 1/(0.4*HSPF)

Cap47 = Rated compressor heating capacity at 47 F. Defaults to heating load generated by program using a method similar to those specified in Residential Appendix RA1-2008.

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

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

Equation R3-32

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

Air Distribution Fans

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

Equation R3-33

$$Fan_{wh,heat} = W/BtuHeat \times NetHLoad_{hr}$$

Equation R3-34

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

where

$Fan_{wh,heat}$ = Fan consumption for an hour of the simulation

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

W/CFM Heat = 0.88 * W/CFM Cool

CFM Heat = 0.93 CFM Cool

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

3.11 ***Cooling Systems***

3.11.1 Proposed Design

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

3.11.2 Standard Design

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

3.11.3 Refrigerant Charge or Charge Indicator Light

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. Field measurements indicate that typical California air conditioning systems are installed without proper charge, and for computer software energy calculations, the F_{chg} factor is set to 0.90 to account for the impact of this condition. If the system has a charge indicator light (CIL) that is installed, certified and verified according to the procedures of Residential Appendix RA3-2008 the F_{chg} factor may be set to 0.96 for computer software energy calculations. See Equation R3-40 and Equation R3-41. Credit for refrigerant charge is only available for split system air conditioners and heat pumps.

Proposed Design. The compliance software shall allow the user to indicate if split system air conditioners or heat pumps have diagnostically tested refrigerant charge or a field verified charge indicator light. This applies only to split system air conditioners and heat pumps. It does not apply to package air conditioners and heat pumps. These features require field verification or diagnostic testing and shall be reported in the *Hers Required Verification* listings on the CF-1R. Details on refrigerant charge measurement are discussed in Residential Appendix RA3. Information on the requirements for charge indicator lights is located in Residential Appendix RA10

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

3.11.4 Maximum Cooling Capacity Credit

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

The Design Cooling Capacity shall be calculated using the procedure in Residential Appendix RA1-2008. The Maximum Cooling Capacity for ACM Credit shall be calculated using the procedure in Residential Appendix RA1-2008. For ACM energy calculations all loads are assumed to be met in the hour they occur regardless of the compressor size.

Proposed Design. The compliance software shall allow the user to specify that the maximum cooling capacity determined using Residential Appendix RA1-2008 will be met. Compliance credit may be taken if the installed cooling capacity is less than or equal to the maximum cooling capacity, and if the system will have verified adequate airflow, sealed and tested ducts and proper refrigerant charge (or alternatively a charge indicator light). The compliance software shall not allow compliance credit to be taken for cooling capacity less than the maximum cooling capacity if any of these other features are not also specified for compliance. If this alternative is not used, the proposed design shall make no adjustment to the duct efficiency of the standard design for this feature. If compliance credit is taken for this alternative, it must be reported in the *Hers Required Verification* listings of the CF-1R along with the other measures that are required to take the credit.

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

Reporting Requirements on CF-1R

This listing is always provided, however, the column for maximum cooling capacity is completed only when compliance credit is specified for verified cooling capacity is specified in Section 2.2.16 HVAC Systems. Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, sealed and tested new duct systems, and proper refrigerant charge (or alternatively a charge indicator light). The design loads are calculated in accordance with Residential Appendix RA1 section RA1-2.15 using the 1.0% Summer Design Dry Bulb and 1.0% Summer Design Wet Bulb outdoor design temperature data from Joint Appendix 2 table 2.3 and inside design temperatures from Standards Section 150(h). Heating system sizing is not required, but may be included at the compliance software vendors option.

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

Equipment Type. The type of heating or cooling equipment.

Sizing Location. Location for sizing calculation from list in the Joint Appendices 2 Table 2-2.

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

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

Inside Design Temperature (°F). As required in Standards Section 150(h).

Sensible Design Cooling Load (Btu/hr). Total sensible cooling load at design conditions including duct losses. Calculated in accordance with Residential Appendix RA1 Section RA1-2.2.

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

Maximum Allowable Cooling Capacity for compliance software Credit for the building. Maximum total rated system cooling capacity that may be installed if claiming the sizing credit. For buildings with more than one system the sum of the sizes of the equipment installed must be less than the total Allowable Cooling Capacity for compliance software Credit for the building. Calculated in accordance with Residential Appendix RA1 section RA1-3.2.

3.11.5 Adequate Airflow

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

Standard Design. The standard design shall assume verified airflow in excess of 350 cfm per ton when charge testing is required by Package D. When charge testing is not required by Package D, the standard design shall assume 300 cfm per ton.

Air Handler Airflow

The efficiency of an air conditioning system is affected by airflow across the evaporator coil. Cooling system airflow is specified in cubic feet per minute per ton (cfm/ton) where one ton of capacity is 12,000 Btu/hour at ARI rated conditions. Cooling airflow is the flow achieved under normal air conditioning operation.

Adequate Airflow Verification

Adequate airflow is required to allow air conditioning systems to operate at their full efficiency and capacity. Computer software calculations account for airflow by setting the F_{air} factor (see Equation R3-40 and Equation R3-41). If values other than the default are used, airflow shall be tested, certified and verified using the procedures of Residential Appendix RA6-2008 section 3.3 and the duct design, layout, and calculations shall be submitted to the local enforcement agency and to a certified HERS rater.

The installer shall measure and certify the airflow. The certified HERS rater shall verify the existence of the duct design layout and calculations, verify that the field installation is consistent with this design, and diagnostically test and verify the airflow rate.

Sufficient Flow for Valid Standard Refrigerant Charge Test

Sufficient airflow is also required to ensure that the refrigerant charge procedure in Residential Appendix RA2-2008 will produce valid results. Verifying sufficient airflow is a prerequisite for the refrigerant charge test. Either the flow measurement procedure or the temperature split test of Residential Appendix RA3-2008 may be used to demonstrate Sufficient Airflow.

Air Handler Fan Flow

Table R3-35 shows the criteria used for calculations and measurement of airflow for cooling systems. If a flow test is done using the fan only switch on the air handler.

Table R3-35 – Airflow Criteria

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

Test and Condition	Cooling airflow (Wet Coil)
Default Cooling Airflow	300 cfm/ton
Flow needed for a valid refrigerant charge test	300 cfm/ton (See Note 1)
Adequate Airflow	350cfm/ton
Note 1. In lieu of airflow measurements, the system can pass the temperature split test documented in Residential Appendix RA2-2008.	

3.11.6 Fan Energy

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

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

For systems with low fan watts and adequate airflow as verified using the procedures of Residential Appendix RA3-2008, credit may be taken for reduced fan energy in computer software calculations. This credit is applied if the actual installed fan watts/cfm are less than or equal to the standard design value of 0.58 W/cfm. The watt draw and airflow must be certified by the installer and verified by a HERS rater using the procedure in Residential Appendix RA3-2008. Fan watts and adequate airflow must be measured simultaneously. The air handler airflow measured simultaneously must meet the adequate airflow criteria.

3.11.7 Cooling System Calculations

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

Cooling System Energy

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

Equation R3-35

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

Equation 3-36

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

where

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

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

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

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

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

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

Electric Compressor Systems

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

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

Equation R3-37

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

where

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

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

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

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

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

Equation R3-38

$$CE_t = EER_t \times \left(0.88 + 0.00156 \times \left(DB_t - 95\right)\right)$$

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

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

Equation R3-39

when

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

where

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

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

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

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

where

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

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

F_{chg} = The refrigerant charge factor, default = 0.9. For systems with a verified charge indicator light (Residential Appendix RA7-2008) or verified refrigerant charge (Residential Appendix RA3-2008), the factor shall be 0.96.

F_{air} = The system airflow factor, default = 0.925. The system airflow factor depends on the evaporator air flow described in Residential Appendix RA3.3-2008. If the fan flow rate is below 300 cfm/ton, Fair = 0.925. If the fan flow rate is above 400 cfm/ton, Fair = 1.0. Between 300 and 400 cfm/ton, interpolation is used.

F_{size} = Compressor sizing factor, default = 0.95. For systems sized according to the Maximum Cooling Capacity for ACM Credit (see Section 3.11.4), the factor shall be 1.0.

Equation R3-42

When

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

Gas Absorption Systems

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

Equation R3-43 $$Absorption_{Btu} = \frac{CLoad_{hr}}{\eta_{seasonal,dist} \times AE_t} + \frac{Fan_{wh} x3.413}{AE_t} + Qneed/AE_t$$

Equation R3-44 $$PPC_{wh} = \frac{CLoad_{hr}}{\eta_{seasonal,dist} \times PE_t} + Qneed/PE_t$$

where:

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

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

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

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

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

Equation R3-45

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

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

COP_t = COP (coefficient of performance for the gas consumption) of the gas absorption system at a particular dry bulb temperature calculated using Equation R3-47.

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

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

Equation R3-46

$$PE_t = PEER_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

Equation R3-47

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

Equation R3-48

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

where

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

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

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

COP_{82} = COP_{95} * 1.056

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

PEER82= PEER$_{95}$ * 1.056

Fan Energy for Cooling

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

Equation R3-49

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

where

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

:

FanCfm/ton = Fan cfm per ton of capacity (cfm/ton). Default to 300. Alternatively, if airflow verification as described in Residential Appendix RA3 is specified, then a higher verified value may be used.

FanW/cfm = Fan Watts per cfm (W/cfm). Default to 0.80. Alternatively, a lower value may be used if reduced air handler fan watt draw verification is specified as described in RA3.3.

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

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

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

3.12 Air Distribution Systems

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

3.12.1 Air Distribution Ducts

Proposed Design. Compliance software shall be able to model the basic types of HVAC distribution systems and locations listed in Table R2-3. As a default, for ducted systems HVAC ducts and the air handler are located in the attic. Proposed HVAC systems with a duct layout and design on the plans may locate the ducts in the crawlspace or a basement if the layout and design specify that all of the supply registers are located in the floor or within two feet of the floor, and show the appropriate locations for the ducts. Otherwise, the default location is the attic as shown in Table R3-12. If all supply registers are at the floor, but the building has both a crawlspace and a basement, the duct location may be taken as a floor area weighted average of the duct efficiencies of a crawlspace and a basement. If the modeled duct location is not in the attic, the compliance software shall specify that all supply registers for the building are located in the floor or within two feet of the floor, and this shall be noted in the *Special Features Inspection Checklist* of the CF-1R.

Proposed HVAC systems with a complete duct design, including the duct layout and design on the plans, may allocate duct surface area in more detail in the compliance software model but the distribution of duct surface areas by location shall appear on the *Hers Required Verification* list of the CF-1R. The HERS rater shall verify the existence of duct design and layout and the general consistency of the actual HVAC distribution system with the design. The HERS rater shall also measure and verify adequate fan flow, see Section 3.6.9.

The compliance software shall allow users to specify if they will be using diagnostic testing of HVAC distribution efficiency of a fully-ducted system during the construction of the building to confirm the modeling of improved HVAC distribution efficiency measures such as duct leakage. The default shall be that no diagnostic testing will be done. Duct efficiency credits may not be taken and diagnostic testing may not be done on any HVAC system that uses nonducted building cavities such as plenums or platform returns, to convey conditioned air unless they are defined or constructed with sealed sheet metal or duct board Building cavities, including support platforms, may contain ducts. If the user does not select diagnostic testing, the compliance software shall require users to input at least two (2) basic parameters to determine HVAC distribution efficiency: the total conditioned floor area of the building as specified above and the R-value of the duct insulation which may be defaulted to the minimum duct insulation requirements. Additional data may be required to determine seasonal distribution system efficiency. The default input parameters are presented in Chapter 4. If the user specifies diagnostic testing to be performed during construction, the compliance software shall prompt the user to enter the data described Section 4.8.2, *Seasonal Distribution System Efficiency* and shall report all required measurements and the features used to achieve higher HVAC distribution efficiencies in the *Hers Required Verification* listings on the CF-1R. When the user chooses diagnostic testing, the diagnostic testing shall be performed as described in compliance software RC-2008. The duct leakage factors in Table R3-14 shall be used when Low Leakage Air Handlers or Low Leakage Ducts in Conditioned Space are specified.

Standard Design. The standard heating and cooling system for central systems is modeled with non-designed air distribution ducts located in an attic space, with the duct leakage factor for sealed and tested new duct systems (see Table R3-14) and a radiant barrier in climate zones where required by Package D. The standard design duct insulation is determined by the Package D specifications for the applicable climate zone. The standard design building is assumed to have the same number of stories as the proposed design for purposes of determining the duct efficiency. HVAC distribution system efficiencies shall be calculated using the algorithms and equations in Chapter 4 of this manual for both the proposed design and the standard design. The standard design calculation shall use the default values of that procedure. For non-central HVAC systems, the standard design shall have no ducts.

3.12.2 Building Information and Defaults

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

Table R3-36 – Duct Efficiency Input Parameters and Defaults

Parameter	Standard Design Value	Proposed Design Default
1. Duct Location	Ducts in the attic	Ducts in the attic
2. Insulation level of ducts	Package D requirement	Mandatory Minimum Requirement
3. The surface area of ducts	27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories.	
4. The leakage level	Sealed and tested.	Untested
5. Fan flow	Default Cooling Airflow (Table R3-10)	
6. Attic radiant barrier.	Yes in climate zones where required by Package D, otherwise No	No radiant barrier

When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

See Section 3.8 for information on existing HVAC systems that are extended to serve an addition.

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

3.12.3 Special Credit

Diagnostic Supply Duct Location, Surface Area and R-Value

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

Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Note that the area of supply ducts located in conditioned space shall be ignored in calculating conduction losses but supply duct leakage is not affected by supply duct location.

Return Duct Location

If return ducts are located entirely in the basement, the calculation shall assume basement conditions for the return duct efficiency calculation. Otherwise, the return duct shall be entirely located in the attic for the purposes of conduction and leakage calculations. Return duct surface area is not a compliance variable.

Default Supply Duct Location

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

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

Diagnostic Supply Duct Location

Supply duct location and areas other than the defaults shown in Table R3-37may be used following the procedures of 4.8.5.

Duct Surface Area

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

Return Duct Surface Area

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

Equation R3-50 $$A_{r,out} = K_r \times A_{floor}$$

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

Default Supply Duct Surface Area

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

Equation R3-51 $$A_{S,out} = 0.27 \times A_{floor} \times K_S$$

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

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

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

Equation R3-52 $$A_{s,out} = 0.027 \times A_{floor}$$

Diagnostic Duct Surface Area

Proposed designs may claim credit for reduced surface area using the procedures in 4.8.5.

Surface Area and Location

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

3.12.4 Duct System Insulation

General

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

Standard Design Duct Insulation R-value

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

Proposed Design Duct Insulation R-value

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

Credit for systems with mixed insulation levels or ducts buried in the attic require the diagnostic procedure in 4.8.5.

Effective R-value

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

Equation R3-53

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

where

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

A_N = Area of duct segment n, square feet.

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

Buried Attic Ducts

Ducts partly or completely buried in blown attic insulation in dwelling units meeting the requirements for High Insulation Quality (Residential Appendix RA8-2008) and Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems (Residential Appendix RA4-2008) may take credit for increased effective duct insulation using the following procedure. The duct design shall identify the segments of the duct that meet the requirements for being buried, and these shall be separately input into the computer software. Ducts to be buried shall have a minimum of R-4.2 duct insulation prior to being buried. The computer software shall calculate the correct R-value based on the specified attic insulation R-value, insulation type, and duct size for ducts installed on the ceiling, and whether the installation meets the requirements for deeply buried ducts for duct segments buried in lowered areas of ceiling. Correct installation of the duct system and attic insulation shall be certified by the installer and verified by a certified HERS rater (including that the requirements of Residential Appendix RA8-2008 and Residential Appendix RA4-2008 are met).

Buried Ducts on the Ceiling

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

Deeply Buried Ducts

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

Table R3-38 – Buried Duct Effective R-values

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

3.12.5 Duct/Air Handler Leakage

Duct/air handler leakage factors shown in Table R3-39 shall be used in calculations of delivery effectiveness. Table R3-39 shows default duct leakage factors for dwelling units. Sealed and tested duct systems require the diagnostic leakage test by the installer and verification by a HERS rater meeting the criteria described in Residential Appendix RA3-2008. The duct leakage factors for sealed and tested new duct systems correspond to sealed duct requirements in newly constructed dwelling units, to entirely new duct systems in existing dwelling units, and to duct systems in alterations and additions that have been sealed to meet the duct leakage requirements of newly constructed buildings. The duct leakage factors for sealed and tested duct systems in existing dwelling units apply only to sealed duct requirements for alterations to existing dwelling units and to extensions of existing duct systems to serve additions. See Section 3.8 for ducts in existing dwelling units that are sealed and tested in conjunction with alterations or additions. The credit for low leakage air handlers requires HERS verification that a certified low leakage air handler is installed and must be used in combination with the existing credit for verified duct leakage. To qualify, air handlers must be factory sealed units tested by the manufacturer and certified to the Commission to have achieved a 2 percent or less leakage rate at 1-inch water gauge when all air inlets, air outlets and condensate drain port(s), when present, are sealed. Qualifying duct systems may take credit for 0.97 leakage factor if they pass the Sealed and Tested New Duct Criteria or a higher Factor if they show leakage less than 2 x (1-Factor).

Table R3-39 – Duct/Air Handler Leakage Factors

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

3.12.6 Reporting Requirements on CF-1R

General Information

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

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

Supply Duct System Details

This listing shall be displayed any time credit for ducts in conditioned space, reduced duct surface area, and/or combinations of higher performance insulation (including ducts buried under the attic insulation) are specified. The portions of duct run located on the floor of the attic within 3.5 inches of the ceiling gypsum board and covered or partially covered with blown attic insulation of R-30 or greater in houses meeting the criteria for Insulation Installation Quality (Residential Appendix RA3-2008) may take credit for increased effective duct insulation. As many rows as necessary may be used to describe each duct run. These credits shall also be reported in the *Special Features Inspection Checklist*.

Information on the CF-1R may include:

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

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

3.12.7 Seasonal Distribution System Efficiency

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

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

Equation R3-54
$$\eta_{dist,seasonal} = 0.98\, DE_{seasonal} \times F_{recov}$$

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

3.12.8 Seasonal Delivery Effectiveness

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

Equation R3-55
$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$

where

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

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

ΔT_e = Temperature rise across heat exchanger, ºF. This value changes for heating and cooling modes.

ΔT_r = Temperature difference between indoors and the ambient for the return, ºF. This value changes for heating and cooling modes.

ΔT_s = Temperature difference between indoors and the ambient for the supply, ºF. This value changes for heating and cooling modes.

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

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

Equation R3-56
$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 \times Q_e \times R_s}\right)$$

Equation R3-57

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

where

$A_{s,out}$ = Surface area of supply duct outside conditioned space, ft². See Sections 3.12.1, 9.512.5 and 9.0.5.

$A_{r,out}$ = Surface area of return duct outside conditioned space, ft^2. See Sections 3.12.1, 3.0.5 and 9.512.5.

Q_e = Flow through air handler fan at operating conditions, cfm. This is determined from Equation R3-53

R_r = The effective thermal resistance of return duct, h ft^2 F/Btu. See Section __ and 3.12.3.

R_s = The effective thermal resistance of supply duct, h ft^2 F/Btu. See Section __ and 3.12.3.

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

Equation R3-58

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

where

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

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

3.12.9 Calculation of Duct Zone Temperatures for Multiple Locations

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

Equation R3-59

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

Equation R3-60

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

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

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

3.12.10 Temperature Difference Across Heat Exchanger

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

For heating:

Equation R3-61

$$\Delta Te = 55$$

And Equation R3-62 for cooling:

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

3.12.11 Indoor to Duct Location Temperature Differences

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r , shall be calculated using the indoor and the duct ambient temperatures.

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

Equation R3-64 $\Delta Tr = Tin - Tamb,r$

3.12.12 Thermal Regain (F_{regain})

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

Table R3-40 – Thermal Regain Factors

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

3.12.13 Recovery Factor (F_{recov})

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

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

3.13 Mechanical Ventilation

The Standards require mechanical ventilation that complies with ASHRAE Standard 62.2-2007 to provide acceptable indoor air quality. Standard 62.2-2007 provides several ways to comply with the requirement for mechanical ventilation and these will be described in the compliance manual.

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

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

To calculate the energy use of central air handler fan systems that introduce outdoor air to meet the IAQ requirement, the systems are assumed to be on for at least 20 minutes each hour as described below. The fan flow rate and fan power ratio may be different than the values used when the system is on to provide for heating or cooling depending on the design or controls on the IAQ ventilation portion of the system.

If the central air handler fan system is configured to mix the indoor air without introducing outdoor air, the energy to run the central air handler fans must be included. In this case, a standalone IAQ system must also be modeled.

The minimum ventilation rate for continuous ventilation is given in the equation below (see also RA-5).

Equation R3-66 $Q_{fan} = 0.01A_{floor} + 7.5(N_{br} + 1)$

where

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

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

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

3.13.1 Proposed Design

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

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

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

- If a central air handler fan that mixes indoor air but that does not introduce outside air is used, then the inputs for both the standalone IAQ fan system and the central air handler fan above must be entered.

3.13.2 Standard Design

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

3.13.3 Reporting Requirements on CF-1R

The required ventilation rate to comply with Standard 62.2-2007 and the means to achieve compliance shall be indicated on the CF-1R.

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

IAQ System Name	IAQ System Type	Air Flow Rate (cfm)	Fan Power Ratio (W/cfm)

3.14 *Special Systems - Hydronic Distribution Systems and Terminals*

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

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

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

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

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

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

3.15 Water Heating

Proposed Design. Compliance software shall be able to model the basic types of water heaters listed in Table R2-7, the water heating distribution system choices (within the dwelling unit) listed in Table R3-8 (and R2-5), and the multiple dwelling unit recirculating system control choices listed in R3-9 (and R2-6). compliance software users shall specify the following information about each water heating system:

- The number of dwelling units served by the water heating system (needed only when the system serves multiple dwelling units).
- The number of water heaters that are a part of the system
- The performance characteristics of each water heater:

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

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

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

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

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

Distribution System Measure	Code
No Control	NoCtrl
Timer Control	STD

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

Table R3-44 – Specification of Standard Design Water Heater

<table>
<tr><td rowspan="4">Does the water heating system serve a single dwelling unit?</td><td>Yes</td><td colspan="5">Standard design is a 50 gallon gas or LPG storage type water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
EF is equal to 0.575, which is the NAECA minimum for the 50 gallon basecase water heater. EF = 0.67 – 0.0019 V, where V is the volume in gallons.
A standard distribution system with no circulation system. Actual efficiency depends on the size of the dwelling unit and the number of stories.</td></tr>
<tr><td rowspan="3">No</td><td rowspan="3">Does the proposed water heating system have a storage tank?</td><td rowspan="2">Yes</td><td rowspan="2">Is the input rating of each water heater in the proposed design less than or equal to 75,000 Btu/h or if electric, less than or equal to 12 kW.</td><td>Yes</td><td>Standard design is one or more NAECA gas or LPG water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
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 100 gallon 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 0.48, which is the NAECA minimum. If the standard design is less than 100 gallons, then the EF = 0.67 – 0.0019 V.
See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td>Standard design is composed of the same number of large storage gas or LPG water heaters as in the proposed design with a storage volumes the same as the storage volumes of the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
The thermal efficiency is 0.80 and stand-by losses are as specified in Table 113A.
See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td colspan="3">Standard design is the same number of natural gas or LPG instantaneous water heaters as in the proposed design with input ratings equal to those in the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
Thermal efficiency of the instantaneous water heaters shall be equal to the requirements in Section 111.
See specification of distribution system in the note below.</td></tr>
</table>

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

1. When the distribution system is a recirculating system, the standard design shall be a recirculating system with timer controls, e.g. the coefficients in Table RG-5 for “Timer Controls” shall be used in the calculation of energy use for the standard design, otherwise the standard design shall be a non-recirculating system.
2. Pipe length and location in the standard design shall be the same as the proposed design. There are three possible locations defined in Appendix RG-2008.
3. The pipes in the recirculation system shall be insulated in accordance with Section 150(j).
4. The pumping head and motor size for the standard design shall be equal to the pumping head and motor size in the proposed design.
5. The motor efficiency of the recirculation pump in the standard design shall be equal to the requirements in the CEC appliance efficiency standards, e.g. NEMA high efficiency motors.
6. The distribution losses within the dwelling units shall be calculated based on one story and the average dwelling unit size for all the dwelling units served by the water heating system (see Appendix RG-3.2).

3.15.1 Water Heating (from 2)

Water Heating Systems

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

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

Reported elements of the water heating system may include:

Notes

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

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

Distribution System Measure	Code	Description
Pipe Insulation (kitchen lines ≥ 3/4 inches) – Standard Case	STD	Standard (non-recirculating) potable water heating system with tank storage remote from points of consumptive use. The portions of the pipe run from the water heater to the kitchen fixtures are insulated, as required by Section 151 (f) 8 D.
Pipe Insulation (all lines)	PIA	All pipes from the water heater to the fixtures are insulated,
Standard pipes with no insulation	SNI	Standard water heating system with no insulation on pipes to the kitchen.
Point of Use	POU	Point-of-use potable water heating system, within 8' of fixtures
Parallel Piping	PP	A system of individual pipe runs from a manifold at the water heater to each fixture. This is also sometimes called homerun piping.
Uninsulated Pipe below Grade	UPBG	Below grade piping is installed with no insulations or protective covering.
Insulated and Protected pipe below grade	IPBG	Below grade piping is installed with insulations and a protective covering.
Recirculation (no control)	RNC	Recirculation system, with no control. The pump runs continuously.
Recirculation + timer control	RTm	Recirculation system, with timer control. The pump operates on a timeclock.
Recirculation + temperature control	RTmp	Recirculation system, with the pump controlled to maintain a minimum temperature in the circulation system.
Recirculation + timer/temperature	RTmTmp	Recirculation system, with combination timer control and temperature control.
Recirculation + demand control	RDmd	Recirculation system, with demand control.
Temperature Buffering Tank	TBT	A small storage electric water heater installed in the distribution system.

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

Type of Control	Code	Description
Uncontrolled Recirculation	NoCtrl	Circulation pump runs continuously.
Timer Control	STD	Recirculation system, with timer control. The pump operates on a timeclock.

Table R3-47 – Water Heater Types

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

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

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

Water Heater/Boiler Equipment Detail

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

Included details on the CF-1R may include:

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

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

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

Table R3-49 – Water Heater Input Summary

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

Special Water Heating System Credits

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

- *System Name.* This is a name corresponding to a system name defined in the Water Heating Systems table.
- *Solar Savings Fraction (SF) or Solar Energy Factor (SEF)*. If the water heating system has a solar system to provide part of the water heating, the SF or SEF is entered in this column. The SF shall be determined using the procedures defined with the optional modeling capability in Chapter 6.

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

3.15.2 Water Heating Calculations

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards (see Section 3.7 for details). The calculation procedure is documented in Appendix RE-2008.

3.16 Additions and Alterations

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

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

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

3.16.1 Whole Building Approach

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

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

Proposed Design. Entire building (including additions, alterations and existing building) modeled the same as new construction as described throughout the ACM manual.

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

3.16.2 Addition Alone Approach

The proposed addition alone is modeled the same as a newly constructed building except that the internal gains are prorated to the size of the dwelling as described in Chapter 4 section 4.1.4, and any surfaces such as walls or ceilings that are between the existing building and the addition are modeled as adiabatic and not included in the calculations. Water heating is not modeled when using this approach. The addition complies if the proposed design uses equal or less space heating and space cooling TDV energy than the standard design.

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

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

Proposed Design. The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. The number of dwelling units shall be set to the fractional dwelling unit as specified in Section 4.1.4. Any surfaces that are between the existing building and the addition are not modeled or treated as an adiabatic surfaces. All other features of the addition shall be modeled as for a newly constructed building.

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

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

Standard Design. The addition alone is modeled the same as newly constructed building as described throughout the ACM manual.

3.16.3 Existing + Addition + Alteration Approach

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

Valid tags include:

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

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

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

When modeling an existing building, the compliance software shall allow the use of the default assumptions specified in

Table R3-50 for modeling the existing structure according to the vintage of the existing building. If the user enters higher U-factors, higher F-factors, higher SHGCs, lower efficiencies, or lower energy factors than the vintage defaults from

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

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

- Existing features are included in the standard design
- Deleted features are included in the standard design
- Added features are assigned standard design values in the same manner as for an addition alone, as described above
- Altered features are modeled in the standard design as follows:

General Approach. Each altered feature is compared to the prescriptive requirements in Section 152(b)1. Fenestration shading and area have additional modeling requirements described below:

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

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

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

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

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

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

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

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

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

Equation R3-67

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

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

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

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

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

Equation R3-68

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

Where

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

EU_{e} = the energy use for the unaltered portion of the existing building

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

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

3.16.4 Duct Sealing in Additions and Alterations

Section 152(a)1 establishes prescriptive requirements for duct sealing in additions and Sections 152(b)1.D. and 152(b)1.E. establish prescriptive requirements for duct sealing and duct insulation for installation of new and replacement duct systems and duct sealing for installation of new and replacement space conditioning equipment. Table R3-14 provides Duct Leakage Factors for modeling of sealed and tested new duct systems, sealed and tested existing duct systems, and untested duct systems built prior to and after June 1, 2001. Residential Appendix RA4 provides procedures for duct leakage testing and Table RC-2 provides duct leakage tests and leakage criteria for sealed and tested new duct systems and sealed and tested existing duct systems. These requirements, factors, procedures, tests and criteria apply to performance compliance for duct sealing in Additions and Alterations.

Condition	Proposed Design	Standard Design
Additions Served by Entirely New Duct Systems	The proposed design shall be either sealed and tested new duct systems or untested duct systems.	The standard design shall be sealed and tested new duct systems.
Additions Served by Extensions of Existing Duct Systems	The proposed design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems in homes built after June 1, 2001; or 4) untested duct systems in homes built prior to June 1, 2001.	The standard design shall be sealed and tested existing duct systems.
Alterations with Prescriptive Duct Sealing Requirements when Entirely New Duct Systems are Installed	The proposed design shall be either 1) sealed and tested new duct systems; 2) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	The Prescriptive Alteration Requirement is sealed and tested new duct systems. Determine the standard design by the standard design rules in Section 3.8.3.
Alterations with Prescriptive Duct Sealing Requirements when Existing Duct Systems are extended or replaced or when new or replacement air conditioners are installed	The proposed design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	Prescriptive Alteration Requirement is sealed and tested existing duct systems. Determine the standard design by the standard design rules in Section 3.8.3.
Alterations for which Prescriptive Duct Sealing Requirements do not apply	The proposed design shall be either 1) sealed and tested new duct systems, if the new duct system or the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	The standard design shall be either 1) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.

Table R3-50 – Default Assumptions for Existing Buildings

	Default Assumptions for Year Built (Vintage)							
Conservation Measure	**Before 1978**	**1978 to 1983**	**1984 to 1991**	**1992 to 1998**	**1999 - 2000**	**2001-2003**	**2004-2005**	**2006 and Later**
INSULATION U-FACTOR								
Roof/Ceiling	0.079	0.049	0.049	0.049	0.049	0.049	0.049	0.049
Wall	0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102
Raised Floor –CrawlSp	0.099	0.099	0.099	0.046	0.046	0.046	0.046	0.046
Cool Roof	.0.1	.0.1	.0.1	.0.1	.0.1	.0.1	0.1	Pres Pkg.
Radiant Barrier	None	None	None	None	None	None	Pres Pkg.	Pres Pkg.
Raised Floor-No CrawlSp	0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064
Slab Edge F-factor =	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ducts	R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	Pres Pkg.
LEAKAGE								
Building (SLA)	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Duct Leakage Factor (See Table 4-13)	0.86	0.86	0.86	0.86	0.86	0.89	0.89	0.89
FENESTRATION								
U-factor	Use Table 116-A - Title 24, Part 6, Section 116 for all Vintages							
SHGC	Use Table 116-B - Title 24, Part 6, Section 116 for all Vintages							
Shading Dev.	Use **Table R3-28** for all Vintages							
SPACE HEATING EFFICIENCY								
Gas Furnace (Central) AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Gas Heater (Room) AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Hydronic/Comb Hydronic	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Heat Pump HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4
Electric Resistance HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413
Electric Resistance Radiant HSPF	3.55	3.55	3.55	3.55	3.55	3.55	3.55	3.55
SPACE COOLING EFFICIENCY								
All Types, SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	13.0
WATER HEATING								
Energy Factor	0.525	0.525	0.525	0.525	0.575	0.575	0.575	0.575

Roofs shall assume the properties of the proposed design.

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

3.Defining the Proposed and Standard Designs

The space conditioning energy budget for the residential Standards is a custom budget, that is, the energy that would be used by a building similar to the *Proposed Design*, but that is modified to just meet the requirements of the prescriptive standards. The building that is modeled to create the custom budget is the *Standard Design*. This section of the *ACM Approval Manual* describes how the *Proposed Design* and *Standard Designs* are defined.

For the *Proposed Design,* the user enters information to describe the thermal characteristics of the proposed building envelope including its surface areas, air leakage, shading structures and attachments, thermal mass elements, heating and cooling equipment and distribution systems, and water heating equipment and distribution systems. These inputs are subject to a variety of restrictions which are defined in this section. Modeling assumptions and algorithms for making energy calculations are described in Chapter 4.

The process of generating the *Standard Design* and calculating the custom budget shall be performed automatically by the program, based on the allowed and default inputs for the *Proposed Design* as well as the fixed and restricted inputs and assumptions for both designs. The process of custom budget generation shall not be accessible to program users for modification when the program is used for compliance purposes or when compliance forms are generated by the program. The *Standard Design* generator shall automatically take user input about the *Proposed Design* and create the *Standard Design*, using all the applicable fixed and restricted inputs and assumptions described in this Chapter and in Chapter 4. All assumptions and algorithms used to model the *Proposed Design* shall also be used in a consistent manner in the *Standard Design* building.

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

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

3.1Building Physical Configuration

Proposed Design. The building configuration is defined by the user through entries for floor areas, wall areas, roof and ceiling areas, fenestration areas, and door areas. Each are entered along with performance characteristics such as U-factors, SHGC, thermal mass, etc. Information about the orientation and tilt is required for walls, fenestration and other elements. The user entries for all of these building elements shall be consistent with the actual building design and configuration. If the ACM models the specific geometry of the building by using a coordinate system or graphic entry technique, the data entered shall be as consistent as necessary to achieve thermal modeling accuracy.

Standard Design. The *Standard Design* building has the same floor area, volume, and configuration as the *Proposed Design*, except that wall and window area are distributed equally between the four main compass points, North, East, South, and West. The details are described below.

3.1.1Conditioned Floor Area

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

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

Note. ACMs shall keep track of the conditioned floor area and shall at least be able to keep separate track of the total conditioned floor area and conditioned slab floor area. These areas are used to determine the default thermal mass for the *Proposed Design* and the thermal mass for the *Standard Design*.

3.1.2 Conditioned Volume

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

Standard Design. The volume of the *Standard Design* building is the same as the *Proposed Design*.

3.2 Opaque Envelope Elements

3.2.1 Insulation Installation Quality

Proposed Design. The ACM user may specify either *Standard* or *Improved* insulation installation quality for the *Proposed Design*. The presence of *Improved* insulation installation quality shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R. *Improved* insulation installation quality shall be certified by the installer and field verified.

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

Note. Chapter 4 has the modeling rules for Standard and Improved insulation installation quality.

3.2.2 Ceilings/Roofs

Proposed Design. The ACM shall allow a user to enter one or more ceiling/roof areas for the *Proposed Design*. The roof/ceiling areas, construction assemblies, orientations, and tilts modeled shall be consistent with the corresponding areas, construction assemblies, and tilts in the actual building design and shall equal the overall roof/ceiling area with conditioned space on the inside and unconditioned space on the other side. U-factors shall be selected from ACM Joint Appendix IV. If new ceiling and wall construction assemblies do not meet the mandatory minimum U-factor required by Title 24, the building shall not pass compliance. If the *Proposed Design* has *Improved* insulation installation quality, then all ceiling/roof assemblies in the *Proposed Design* are modeled accordingly (see Section 1.2.1 and Chapter 4).

Standard Design. The ceiling/roof areas of the *Standard Design* building are equal to the ceiling/roof areas of the *Proposed Design*. The *Standard Design* roof and ceiling surfaces are assumed to be horizontal (no tilts) and have a U-factor specific to the package D requirements. The U-factors in Table R3-1 shall be used in the *Standard Design* for the appropriate R-value criteria in Package D. The *Standard Design* generator shall consider all exterior surfaces in the *Proposed Design* with a tilt less than 60 degrees as roof elements. Surfaces that tilt 60 degrees or more are treated as walls. The *Standard Design* is modeled with *Standard* insulation installation quality.

Table R3-1 – Ceiling/Roof U-factors for Standard Design

Building Component	R-value Requirement	U-factor	ACM Joint Appendix IV Refere8ce
Roof			
	R-30	0.032	IV1-A7
	R-38	0.026	IV1-A8

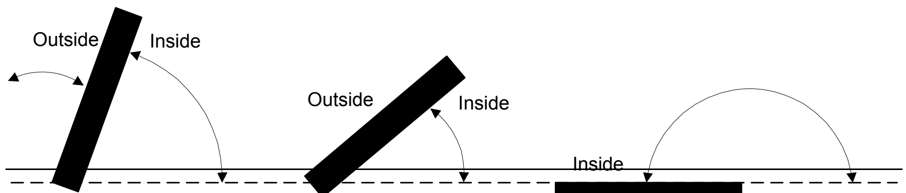


Figure R3-1 – Surface Definitions

Radiant Barriers

Proposed Design. The ACM shall allow the user to input a radiant barrier. The presence of a radiant barrier shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall have a radiant barrier in accordance with Package D requirements. When required by Package D, radiant barriers are required on all ceiling/roof surfaces. See Section 4.2.1 for radiant barrier eligibility criteria.

Cool Roofs

Proposed Design. The ACM shall allow the user to input a cool roof. The presence of a cool roof shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall be modeled without a cool roof.

3.2.3Walls

Proposed Design. The ACM shall allow a user to enter one or more wall areas for the *Proposed Design*. The wall areas modeled shall be consistent with the corresponding wall areas in the actual building design and the total wall area shall be equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. U-factors for *Proposed Design* wall constructions shall be selected from ACM Joint Appendix IV. If the *Proposed Design* has *Improved* insulation installation quality, then walls are modeled accordingly (see Chapter 4). Walls include all opaque surfaces with a slope greater than 60º but less than 120º from the horizontal (see Figure R3-1).

Standard Design. The gross wall area in the *Standard Design* run is equal to the gross wall area of the *Proposed Design*, including knee walls in the ceiling construction of the *Proposed Design*. The gross wall area in the *Standard Design* is equally divided between the four main compass points, North, East, South, and West. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. The *Standard Design* has *Standard* insulation installation quality. U-factors for the *Standard Design* walls shall be those from Table R3-2 for the appropriate Package D R-value criteria.

Table R3-2 – Wall U-factors for the Standard Design

Building Component	Package D R-value Criteria	Standard Design U-factor	ACM Joint Appendix IV Reference
Wall	R-13	0.074	IV9-A3
	R-19	0.065	IV9-A5
	R-21	0.061	IV9-A6

3.2.4 Basement Walls and Floors

Proposed Design. Portions of basement walls above grade shall be modeled as conventional walls above grade. For below-grade basement walls, the user shall enter the area at each of three depths: from zero to 2 feet below grade (shallow), greater than 2 feet to 6 feet below grade (medium), and greater than 6 feet below grade (deep). The ACM shall allow users to enter as many wall types as necessary to model the *Proposed Design*. The U-factor, C-factor, and mass characteristics of below-grade walls shall be calculated using methods consistent with ACM Joint Appendix IV. The thermal performance characteristics for the *Proposed Design* below-grade wall constructions shall be the same as the *Standard Design*.

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

3.2.5 Raised Floors

Proposed Design. In addition to the total conditioned floor area and total conditioned slab floor area (see 1.1.1), ACM users shall enter floor areas for the standard raised floor construction types listed in Table R3-3. The ACM shall require user input to distinguish floor areas and constructions that are over crawl spaces. The U-factor for floor constructions and areas shall be consistent with the actual building design. U-factors shall be those from ACM Joint Appendix IV.

Standard Design. The floor areas of the *Standard Design* are equal to the areas of the *Proposed Design*. The raised floor U-factor for the *Standard Design* is taken from Table R3-3 and depends on whether or not the floor assembly in the *Proposed Design* is located over a crawl space. For this reason, the ACM shall keep track of which raised floor surfaces are over crawl spaces and which are not.

Notes. The effect of a conventional crawl space is modeled with a thermal resistance of R-6; however, for controlled ventilation crawl spaces (an optional capability), the crawl space is modeled as a separate thermal zone and R-6 is not assumed. The R-6 value for a conventional crawlspace shall be automatically calculated by the ACM and shall not be allowed as a user input. The U-factors in Table R3-3 account for the additional R-6.

Table R3-3 – Floor U-factors for the Standard Design

Floor Type	Package D Criteria	U-factor	ACM Joint Appendix IV Reference
Raised Floor (crawl space)	R-19	0.037	IV20-A4
Raised Floor (no crawl space)	R-19	0.048	IV21-A4

3.2.6 Slab-on-Grade Perimeter

Proposed Design. The ACM shall allow users to enter at least two different slab perimeter constructions and their corresponding lengths. Typically, ACMs have no practical limit on the number of slab perimeter constructions that may be entered. The default condition for the *Proposed Design* is that 80% of any slab edge length entered is adjacent to rug-covered (R-2 for carpet and pad) slab and 20% is adjacent to exposed slab on the conditioned side. F-factors for slab loss shall be taken from Table R3-4 or be calculated using methods consistent with ACM Joint Appendix IV and accurately represent the conditions in the actual building. The ACM shall be able to determine the amount of slab edge adjacent to unconditioned spaces separately from the slab edge adjacent to the outside. In the *Proposed Design*, the F factor(s) may account for slab perimeter insulation for both slab edges exposed to the outside and slab edges adjacent to unconditioned spaces such as garages. In climate zone 16, slab edges adjacent to garages and unconditioned spaces may be considered to be insulated with R-7 insulation and have an F-factor of 0.51.

Standard Design. The total slab perimeter length in the *Standard Design* is the same as in the *Proposed Design*. For the *Standard Design*, the slab edge F-factor, is 0.76 for all climate zones except Climate Zone 16 where the F-factor is 0.51. See Package D. For the *Standard Design* unconditioned spaces such as the garage are assumed to be detached.

Table R3-4 – Slab Edge F-factors for the Standard Design

Slab Edge Condition	Package D Criteria	F-factor	ACM Joint Appendix IV Reference
No Insulation	None	0.73	IV25-A1
R-7 Insulation	R-7	0.56	IV25-C7

3.3 Fenestration and Doors

3.3.1 Doors

Proposed Design. ACMs shall allow users to enter at least two different door construction types, their U-factors, areas, and orientations. Door U-factors shall accurately represent the doors installed in the building and be calculated in a manner consistent with ACM Joint Appendix IV.

Standard Design. The *Standard Design* has 40 square feet of door area for each dwelling unit. All doors are assumed to face north and have a U-factor of 0.50 from Joint Appendix IV reference IV28-A3. The net opaque wall area facing north is reduced by 40 ft² for each dwelling unit for the *Standard Design* run.

3.3.2 Fenestration Types and Areas

Proposed Design. ACMs shall allow users to enter fenestration or window types, specify the U-factor, SHGC, area, orientation, and tilt. Performance data (U-factors and SHGC) shall be NFRC values or taken from the CEC default tables.

Standard Design. If the *Proposed Design* fenestration area is less than 20%, 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% of the conditioned floor area. The *Standard Design* fenestration area is distributed equally between the four main compass points—North, East, South and West. The *Standard Design* has no skylights. The net wall area on each orientation is reduced by the fenestration area (and door area) on each facade. The U-factor and SHGC performance factors for the *Standard Design* are taken from the Package D specification.

3.3.3 Overhangs and Sidefins

Proposed Design. ACMs shall allow users to enter a set of basic generic parameters for a description of an overhang and sidefinfor each individual fenestration or window area entry. The basic parameters shall include *Fenestration Height, Overhang/Sidefin Length, and Overhang/Sidefin Height.* ACM user entries for overhangs may also include *Fenestration Width, Overhang Left Extension* and *Overhang Right Extension.* ACM user entries for sidefins may also include *Fin Left Extension* and *Fin Right Extension* for both left and right fins. (See Sections 2.2.9 and 2.2.10.)

Standard Design. The *Standard Design* does not have overhangs.

~~3.3.4 Solar Heat Gain Coefficients~~

~~***Proposed Design.*** ACMs shall require the user to enter the fenestration Solar Heat Gain Coefficient for each window, skylight, or other fenestration system type. This requirement may be met by having the user select from a default list of fenestration systems or by direct entry using NFRC-certified values for windows, doors with glass or skylights. In addition, for each fenestration element the ACM shall allow the user to select an exterior shading treatment from the lists given in Table R3-7. The ACM will then determine the overall SHGC for the complete fenestration system based on the fenestration SHGC and the SHGCs assigned to the Commission-approved exterior shading devices and assigned interior shading devices from Table R3-5 and Table R3-7.~~

~~***Standard Design.*** The *Standard Design* fenestration Solar Heat Gain Coefficients (SHGCs) are determined by the appropriate Package D specifications for the applicable climate zone. Note that the frame type and the presence or absence of muntins or dividers is irrelevant for the *Standard Design* as the Package D values for $SHGC_{fen}$ and the U-factor include the effects of fenestration features such as framing, dividers, and muntins.~~

~~3.3.5 Interior Shading Devices~~

~~Internally, ACMs shall use two values to calculate solar heat gain through windows: $SHGC_{open}$ and $SHGC_{closed}$. $SHGC_{open}$ is the total solar heat gain coefficient of the fenestration and its exterior shading device when the operable interior shading device is open. $SHGC_{closed}$ is the total solar heat gain coefficient when the interior shading device is closed. $SHGC_{open}$ is the setting that applies when the air conditioner is not operating, which typically is most of the 24-hour period, while $SHGC_{closed}$ applies only for periods when the air conditioner operates. The *Standard Design* values for these SHGCs are shown in Table R3-6 below. $SHGC_{open}$ and $SHGC_{closed}$ are not user specified inputs. See Chapter 4 for more details.~~

~~The ACM shall require the user to directly or indirectly specify $SHGC_{fen}$ and frame type. The ACM shall assign an interior shading device as listed in Table R3-5 and require the user to specify exterior shading device as listed in Table R3-7. The ACMs shall calculate the overall SHGC for the fenestration with shading devices as shown in Chapter 4.~~

~~For both the *Proposed Design* and the *Standard Design,* all windows are assumed to have draperies and skylights are assumed to have no interior shading.~~

Table R3-5 – Allowed Interior Shading Devices and Recommended Descriptors

Recommended Descriptor	Interior Shading Attachment Reference	Solar Heat Gain Coefficient
Standard	Draperies or No Special Interior Shading - Default Interior Shade	0.68 (see Note 1)
None (see Note 2)	No Interior Shading - Only for Skylights (Fenestration tilt <60 degrees)	1.00

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

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

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

Table R3-6 – Standard Design *Shading Conditions*

	Package Specification	
Characteristic	$SHGC_{fen}$ = NR	$SHGC_{fen}$ = 0.37
$SHGC_{fen}$	0.67	0.37
$SHGC_{open}$	0.649	0.358
$SHGC_{closed}$	0.614	0.339
Glazing	Double Clear	Double Low Solar Low E
Interior Shade	Drapes (*Standard*)	Drapes (*Standard*)
$SHGC_{int}$	0.68	0.68
Exterior Shade	Bugscreen (*Standard*)	BugScreen (*Standard*)
$SHGC_{ext}$	0.76	0.76

3.3.6 Exterior Shading Devices

Proposed Design. The ACM shall require the user to either accept the default exterior shading device or select from a specific Commission-approved list of exterior shading devices for each fenestration element. The default choice for exterior shading device is *Standard,* which is assigned an average SHGC of 0.76. The ACM Compliance Supplement shall explicitly indicate that credit is allowed only for one exterior shading device. See Table R3-7 for other choices.

Standard Design. The *Standard Design* shall assume the default exterior shading, which is the standard bug screen.

Table R3-7 – Allowed Exterior Shading Devices and Recommended Descriptors

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

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

3.4Thermal Mass

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

Proposed Design. The *Proposed Design* will be modeled with the same thermal mass as the Standard design unless the Proposed Design is a high mass building as defined below.

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

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

Definition of High Mass Building. Additional thermal mass in the proposed design may only be modeled when the *Proposed Design* is a high mass building. A high mass building has mass equivalent to 30% of the conditioned slab floor area being exposed slab and 70% slab covered by carpet or casework, and 15% of the conditioned non-slab floor area being exposed with two inch thick concrete with the remainder low-mass wood construction. ACMs may let users indicate a high mass design before entering mass elements for the proposed design, or ACMs can let users enter mass elements, but only consider them in the proposed design if the building qualifies as a high mass building. Thermal mass equivalency is determined through the concept of the Unit Interior Mass Capacity (UIMC) described in ACM RB-2005. The thermal mass of the *Proposed Design,* other than the default *Standard Design* mass is only modeled and displayed on compliance output if the *Proposed Design* qualifies as a high mass building.

3.5Infiltration/Ventilation

The intentional or unintentional replacement of conditioned indoor air by unconditioned outdoor air creates heat gains or heat losses for a conditioned building. This exchange of indoor and outdoor air occurs for all buildings to a greater or lesser extent. Mechanical ventilation gives a certain degree of control of the rate of this exchange and depending on the balancing of the ventilation may create building pressurization.

Proposed Design. As a default, ACMs shall not require the user to enter any values related to infiltration and shall set the infiltration level to be the same as the standard design. Specific data on infiltration may be entered if the building will be diagnostically tested during building construction or if a qualifying air-retarding wrap is specified.

Air Retarding Wrap. An air retarding wrap can qualify for a default reduction in Specific Leakage Area (SLA) of 0.50 without confirmation by diagnostic testing. The air retarding wrap shall be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or system for Low-Rise Framed Building Walls* and have a minimum perm rating of 10. The air-retarding wrap shall be installed per the manufacturer's specifications that shall be provided to comply with ASTM E1677-95 (2000). The air retarding wrap specifications listed above shall also be reported in the *Special Features and Modeling Assumptions* listings when an air retarder is modeled by the ACM.

Reduced Infiltration due to Duct Sealing. The default infiltration (no diagnostic testing and measurement of infiltration) credit for reduced duct leakage is also an SLA reduction of 0.50. The ACM shall automatically apply this credit when the *Proposed Design* has sealed and tested ducts. The use of this SLA reduction credit for Low-leakage HVAC ducts shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R.

Diagnostic Testing for Reduced Infiltration. Neither of the above credits shall be taken if the user chooses a diagnostic testing target for reduced infiltration. When the user chooses diagnostic testing for reduced infiltration, the diagnostic testing shall be performed using fan pressurization of the building in accordance with ASTM E 779-1987 (Reapproved 1992), *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and the equipment used for this test shall meet the instrumentation specifications found in ACM RF. The specifications for diagnostic testing and the target values specified above shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R.

If the user specifies they will be using diagnostic testing during construction for reduced infiltration, the ACM shall require the user to enter a target value for measured $CFM50_H$ or the SLA corresponding to the target $CFM50_H$

Tested infiltration below a value corresponding to an SLA of 1.5 is not allowed unless mechanical *supply* ventilation is installed adequate to maintain the residence at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating.

Standard Design. The *Standard Design* assumes infiltration corresponding to a Specific Leakage Area (SLA) of 3.8 for ducted HVAC systems and an SLA of 3.2 for non-ducted HVAC systems. See Chapter 4 for more detailed information.

3.5.1Free Ventilation Area

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

Equation R3-1 $$Vent_{Area} = (Area_{Slider} \times 0.1) + (Area_{Hinged} \times 0.2) + (Area_{Fixed} \times 0.0)$$

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

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

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

3.5.2 Ventilation Height Difference

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

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

3.6 Heating and Cooling System

3.6.1 System Type

Proposed Design. ACMs shall require the user to enter simple heating and cooling seasonal efficiencies that characterize basic package single zone HVAC systems used to heat and/or cool the modeled building. ACMs shall be able to distinguish what fuel is being used to heat the building and what fuel is used to cool the dwelling. This may be based on direct user input or indirectly determined from the user's selection of HVAC equipment types. ACMs shall require the user to enter the type of distribution system that is used in the proposed design.

For building using more than one system type, equipment type or fuel type, and the types do not serve the same floor area, the user shall either zone the building or enter the floor area served by each type. The ACM shall weight the load to each type by zone or floor area.

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

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

Standard Design. The standard heating and cooling system for central HVAC systems is a single zone system with ducts in the attic. The standard heating and cooling system for non-central HVAC systems is an unducted system.

For buildings using more than one system, equipment, or fuel type where each conditions a different floor area within the building, the *Standard Design* shall use the weighted allocation of loads to each system, equipment, or fuel type as used for the *Proposed Design.*

For floor areas in the proposed design served by more than one system, equipment, or fuel type, loads for those floor areas shall be assumed to be satisfied in the *Standard Design* as specified in Section 3.6.3 and 3.6.4 for each system, equipment, and fuel type the user specifies in the proposed design.

3.6.2 No Cooling

Proposed Design: When the *Proposed Design* has no air conditioning system, the *Proposed Design* is required to model a split system air conditioner meeting Package D requirements. If the heating system is ducted, the location and R-value of those ducts shall be used for the cooling system. If the heating system has no ducts the cooling system ducts shall be modeled as located in the attic, insulated to Package D levels. Since the Standard Design has these same features, there is no penalty or credit related to the lack of ducts.

Standard Design: The *Standard Design* has a split system air conditioning system meeting the Package D requirements and with air distribution ducts located in the attic. The *Proposed Design* is assumed to have the same features so there is no penalty or credit.

3.6.3 Heating Equipment

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

Standard Design. When electricity is used for heating, the heating equipment for the *Standard Design* shall be an electric split system heat pump with a Heating Seasonal Performance Factor (HSPF), meeting the Appliance Efficiency Regulations requirements for split systems. However, when the *Proposed Design* uses a single package heat pump, the *Standard Design* shall have a heat pump with an HSPF meeting the Appliance Efficiency Regulations requirements for single package equipment. When a *Proposed Design* uses both a single package heat pump and another type of electric heat, the *Standard Design* HSPF shall be a conditioned floor area weighted average of the minimum single package HSPF for the floor area conditioned by single package equipment and the minimum split system HSPF for the remaining floor area. When electricity is not used for heating, the equipment used in the *Standard Design* building shall be either a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) meeting the Appliance Efficiency Regulations minimum efficiency for central systems, or shall be a gas furnace of the type specified in the proposed design at the efficiency level shown in the Appliance Efficiency Regulations for Gas Fired Wall Furnaces, Floor Furnaces and Room Heaters. When a *Proposed Design* uses both a nonelectric central system and another type of nonelectric system, the *Standard Design* efficiency shall be a conditioned floor area weighted average of the efficiencies of the heating equipment.

Note: Minimum efficiencies for heat pumps change effective January 23, 2006 (see Table C-2 of the Appliance Efficiency Regulations). The *Standard Design* shall use those new efficiencies after that date.

3.6.4 Cooling Equipment

Proposed Design. ACMs shall be able to model the basic types of cooling equipment and the efficiency metrics listed in Table R2-2. ACMs shall require the user to enter the basic information to model the energy use of these pieces of equipment. At the minimum this includes some type of seasonal distribution system efficiency for cooling, identification of whether the cooling system is ducted or non-ducted and whether it is central or non-central and the type of equipment as identified in the Appliance Efficiency Regulations. If the cooling system is non-ducted, non-central, the ACM shall require the user to select the type and size of the equipment from the Appliance Efficiency Regulations for Room Air Conditioners, Room Air Conditioning Heat Pumps, Package Terminal Air Conditioners and Package Terminal Heat Pumps.

Standard Design. The cooling system for the *Standard Design* building with a central system shall be of the same type identified in the Appliance Efficiency Regulations and selected for the proposed design with a SEER meeting the Appliance Efficiency Regulations minimum requirements. For non-ducted non-central cooling equipment, the efficiencies shall be from the Appliance Efficiency Regulations for Room Air Conditioners, Room Air Conditioning Heat Pumps, Package Terminal Air Conditioners and Package Terminal Heat Pumps for the type and size in the *Proposed Design* where the size may be a user input or shall default to 24 Btu per hour per square foot of conditioned floor area. When a *Proposed Design* uses both a split system air conditioner and another type of air conditioner, the *Standard Design* SEER shall be a conditioned floor area weighted average of the SEERs of the cooling equipment.

Note: Minimum efficiencies for air conditioners and heat pumps change effective January 23, 2006 (see Table C-2 of the Appliance Efficiency Regulations). The *Standard Design* shall use those new efficiencies after that date.

3.6.5Refrigerant Charge or TXV

Proposed Design. The ACM shall allow the user to indicate if split system air conditioners or heat pumps have diagnostically tested refrigerant charge or a field verified thermostatic expansion valve (TXV). This applies only to split system air conditioners and heat pumps. It does not apply to package air conditioners and heat pumps. These features require field verification or diagnostic testing and shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R.

Standard Design. If a split system ducted central air conditioner or heat pump (*SplitAirCond* or *SplitHeatPump*) is used for the *Proposed Design* then the cooling system used in the *Standard Design* building shall be modeled with either diagnostically tested refrigerant charge or a field verified TXV if required by Package D.

3.6.6Air Distribution Ducts

Proposed Design. ACMs shall be able to model the basic types of HVAC distributions systems and locations listed in Table R2-3. As a default, for ducted systems HVAC ducts and the air handler are located in the attic. Proposed HVAC systems with a duct layout and design on the plans may locate the ducts in the crawlspace or a basement if the layout and design specify that all of the supply registers are located in the floor or within two feet of the floor, and show the appropriate locations for the ducts. Otherwise, the default location is the attic as shown in Table R4-11. If all supply registers are at the floor, but the building has both a crawlspace and a basement, the duct location may be taken as a floor area weighted average of the duct efficiencies of a crawlspace and a basement. If the modeled duct location is not in the attic, the ACM shall specify that all supply registers for the building are located in the floor or within two feet of the floor, and this shall be noted in the *Special Features and Modeling Assumptions* listings of the CF-1R.

Proposed HVAC systems with a complete duct design, including the duct layout and design on the plans, may allocate duct surface area in more detail in the ACM model but the distribution of duct surface areas by location shall appear on the *Field Verification and Diagnostic Testing* list of the CF-1R. The HERS rater shall verify the existence of duct design and layout and the general consistency of the actual HVAC distribution system with the design. The HERS rater shall also measure and verify adequate fan flow, see Section 3.6.9.

The ACM shall allow users to specify if they will be using diagnostic testing of HVAC distribution efficiency of a fully-ducted system during the construction of the building to confirm the modeling of improved HVAC distribution efficiency measures such as duct leakage. The default shall be that no diagnostic testing will be done. Duct efficiency credits may not be taken and diagnostic testing may not be done on any HVAC system that uses nonducted building cavities such as plenums or platform returns, to convey conditioned air unless they are defined or constructed with sealed sheet metal or duct board Building cavities, including support platforms, may contain ducts. If the user does not select diagnostic testing, the ACM shall require users to input at least two (2) basic parameters to determine HVAC distribution efficiency: the total conditioned floor area of the building as specified above and the R-value of the duct insulation which may be defaulted to the minimum duct insulation requirements. Additional data may be required to determine seasonal distribution system efficiency. The default input parameters are presented in Chapter 4. If the user specifies diagnostic testing to be performed during construction, the ACM shall prompt the user to enter the data described Section 4.8.2, *Seasonal Distribution System Efficiency* and shall report all required measurements and the features used to achieve higher HVAC distribution efficiencies in the *Field Verification and Diagnostic Testing* listings on the CF-1R. When the user chooses diagnostic testing, the diagnostic testing shall be performed as described in ACM RC-2005.

Standard Design. The standard heating and cooling system for central systems is modeled with non-designed air distribution ducts located in an attic space, with the duct leakage factor for sealed and tested new duct systems (see Table R4-13) and a radiant barrier in climate zones where required by Package D. The *Standard Design* duct insulation is determined by the Package D specifications for the applicable climate zone. The *Standard Design* building is assumed to have the same number of stories as the *Proposed Design* for purposes of determining the duct efficiency. HVAC distribution system efficiencies shall be calculated using the algorithms and equations in Chapter 4 of this manual for both the *Proposed Design* and the *Standard Design*. The *Standard Design* calculation shall use the default values of that procedure. For non-central HVAC systems, the *Standard Design* shall have no ducts.

3.6.7Fan Energy

Proposed Design. The ACM shall allow the user to specify whether or not the proposed design will take credit for reduced fan Watts, see Chapter 4. The credit for reduced fan Watts shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall have the default fan watts.

3.6.8Maximum Cooling Capacity Credit

Proposed Design. The ACM shall allow the user to specify that the maximum cooling capacity determined using ACM RF-2005 will be met. Compliance credit may be taken if the installed cooling capacity is less than or equal to the maximum cooling capacity, and the system will have verified adequate airflow, sealed and tested ducts and proper refrigerant charge (or alternatively a TXV). The ACM shall not allow compliance credit to be taken for cooling capacity less than the maximum cooling capacity if any of these other features are not also specified for compliance. If this alternative is not used, the *Proposed Design* shall make no adjustment to the duct efficiency of the *Standard Design* for this feature. If compliance credit is taken for this alternative, it must be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R along with the other measures that are required to take the credit.

Standard Design. When this alternative is selected, the *Standard Design* shall model the Maximum Allowable Cooling Capacity as calculated using the procedure in ACM RM-2005, otherwise the *Standard Design* shall match the *Proposed Design*.

3.6.9Adequate Airflow

Proposed Design. The default for the Proposed Design assumes inadequate airflow (see Section 4.7.4). However, compliance credit may be taken if adequate airflow is diagnostically tested using the procedures of Appendix RE. Adequate airflow shall be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R. The Proposed Design shall use a fan schedule that is fixed ON for 33% of the time each hour, to meet mechanical ventilation requirements of the Standard.

Standard Design. The standard design shall assume inadequate airflow as specified in section 4.7.4. The Standard Design shall use a fan schedule that is fixed ON for 33% of the time each hour, to meet mechanical ventilation requirements of the Standard.

3.7Water Heating

Proposed Design. ACMs shall be able to model the basic types of water heaters listed in Table R2-7, the water heating distribution system choices (within the dwelling unit) listed in Table R3-9 (and R2-5), and the

~~multiple dwelling unit recirculating system control choices listed in R3-10 (and R2-6). ACM users shall specify the following information about each water heating system:~~

- ~~The number of dwelling units served by the water heating system (needed only when the system serves multiple dwelling units).~~
- ~~The number of water heaters that are a part of the system~~
- ~~The performance characteristics of each water heater:~~
    - ~~For gas water heaters with an input rating of 75,000 Btu/h or less and for electric water heaters with an input rating of 12 kW or less, the energy factor (EF) is entered.~~
    - ~~For small instantaneous gas or oil water heaters as defined in the Appliance Efficiency Standards, the Energy Factor (EF) is entered.~~
    - ~~For large instantaneous gas or oil water heaters as defined in the Appliance Efficiency Standards, the thermal efficiency (TE), pilot light energy (Pilot), standby loss (SBE or SBL), tank surface area (TSA), and R-value of exterior insulation wrap (REI) is entered.~~
    - ~~For large storage water heaters, the hourly jacket loss, thermal efficiency (TE), and type (indirect or direct) and pilot light energy (Pilot) are entered. If not available from the manufacturer, jacket loss may be calculated from the tank surface area (TSA), the R-value of exterior insulating wrap (REI) and the standby loss expressed either as a fraction of the heat content of the stored water (SBL) or in Btu/hr (SBE). Tank surface area may also be calculated based on the tank capacity in gallons. See ACM RN for details.~~
- ~~Information about any solar or wood stove supplementary heating that is provided. See ACM RN for details.~~
- ~~The type of distribution system used within the dwelling unit. This is a selection from Table R3-8. For recirculating systems that serve multiple dwelling units, the brake horsepower of the circulation pump (hp), the efficiency of the pump, the efficiency of the motor, and the type of control (choose from Table R3-9).~~
- ~~If multiple water heating systems serve a single dwelling unit, then the ACM shall keep track of the conditioned floor area served by each water heating system.~~
- ~~For water heating systems serving multiple dwelling units, the ACM shall keep track of the dwelling units served by each system.~~

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

~~Table R3-8 – Water Heater Distribution System Choices (Within the Dwelling Unit)~~

~~Distribution System Measure~~	~~Code~~
~~Pipe Insulation (kitchen lines ≥ 3/4 inches) – Standard Case~~	~~STD~~
~~Pipe Insulation (all lines)~~	~~PIA~~
~~Standard pipes with no insulation~~	~~SNI~~
~~Point of Use~~	~~POU~~
~~Parallel Piping~~	~~PP~~
~~Recirculation (no control)~~	~~RNC~~
~~Recirculation + timer control~~	~~RTm~~
~~Recirculation + temperature control~~	~~RTmp~~
~~Recirculation + timer/temperature~~	~~RTmTmp~~
~~Recirculation + demand control~~	~~RDmd~~

Table R3-9 – Multiple Dwelling Unit Recirculating System Control Choices

Distribution System Measure	Code
No Control	NoCtrl
Timer Control	STD

Standard Design. For multiple dwelling unit systems, the *Standard Design* shall have the same number of water heating systems as the *Proposed Design*. For single dwelling unit systems, the *Standard Design* shall have one water heating system, regardless of the number of systems in the *Proposed Design*. Each *Standard Design* water heating system shall have the characteristics specified in Table R3-10.

Table R3-10 – Specification of Standard Design Water Heater

<table>
<tr><td rowspan="4">Does the water heating system serve a single dwelling unit?</td><td>Yes</td><td colspan="5">Standard design is a 50 gallon gas or LPG storage type water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
EF is equal to 0.575, which is the NAECA minimum for the 50 gallon basecase water heater. EF = 0.67 – 0.0019 V, where V is the volume in gallons.
A standard distribution system with no circulation system. Actual efficiency depends on the size of the dwelling unit and the number of stories.</td></tr>
<tr><td rowspan="3">No</td><td rowspan="3">Does the proposed water heating system have a storage tank?</td><td rowspan="2">Yes</td><td rowspan="2">Is the input rating of each water heater in the proposed design less than or equal to 75,000 Btu/h or if electric, less than or equal to 12 kW.</td><td>Yes</td><td>Standard design is one or more NAECA gas or LPG water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
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 100 gallon 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 0.48, which is the NAECA minimum. If the standard design is less than 100 gallons, then the EF = 0.67 – 0.0019 V.
See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td>Standard design is composed of the same number of large storage gas or LPG water heaters as in the proposed design with a storage volumes the same as the storage volumes of the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
The thermal efficiency is 0.80 and stand-by losses are as specified in Table 113A.
See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td colspan="3">Standard design is the same number of natural gas or LPG instantaneous water heaters as in the proposed design with input ratings equal to those in the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.
Thermal efficiency of the instantaneous water heaters shall be equal to the requirements of Table 113A.
See specification of distribution system in the note below.</td></tr>
</table>

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

1. When the distribution system is a recirculating system, the standard design shall be a recirculating system with timer controls, e.g. the coefficients in Table RG-5 for "Timer Controls" shall be used in the calculation of energy use for the standard design, otherwise the standard design shall be a non-recirculating system.
2. Pipe length and location in the standard design shall be the same as the proposed design. There are three possible locations defined in ACM RG-2005.

3. The pipes in the recirculation system shall be insulated in accordance with Section 150(j).
4. The pumping head and motor size for the standard design shall be equal to the pumping head and motor size in the proposed design.
5. The motor efficiency of the recirculation pump in the standard design shall be equal to the requirements in the CEC appliance efficiency standards, e.g. NEMA high efficiency motors.
6. The distribution losses within the dwelling units shall be calculated based on one story and the average dwelling unit size for all the dwelling units served by the water heating system (see RG-3.2).

3.8Additions and Alterations

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

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

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

3.8.1Whole Building Approach

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

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

Proposed Design. Entire building (including additions, alterations and existing building) modeled the same as new construction as described throughout the ACM manual.

Standard Design. Entire building modeled the same as new construction as described throughout the ACM manual.

3.8.2Addition Alone Approach

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

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

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

Proposed Design. The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. The number of dwelling units shall be set to the fractional dwelling unit as specified in Section 4.1.4 below. Any surfaces that are between the existing building and the addition are not modeled or treated as an adiabatic surfaces. All other features of the addition shall be modeled as for a newly constructed building.

When an existing HVAC system is extended to serve the addition, the Proposed Design shall assume the same efficiency for the HVAC equipment as the Standard Design.

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

Standard Design. The addition alone is modeled the same as newly constructed building as described throughout the ACM manual.

3.8.3 Existing + Addition + Alteration Approach

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

Valid tags include:

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

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

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

When modeling an existing building, the ACM shall allow the use of the default assumptions specified in Table R3-11 for modeling the existing structure according to the vintage of the existing building. If the user enters higher U-factors, higher F-factors, higher SHGCs, lower efficiencies, or lower energy factors than the vintage defaults from Table R3-11 for the existing building's *Proposed Design*, the ACM shall report such values as special features in the *Special Features and Modeling Assumptions* listings.

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

- Existing features are included in the standard design
- Deleted features are included in the standard design
- Added features are assigned standard design values in the same manner as for an addition alone, as described above

- Altered features are modeled in the standard design as follows:

  General Approach. Each altered feature is compared to the prescriptive requirements in Section 152(b)1. Fenestration shading and area have additional modeling requirements described below:

  - If the altered feature meets or exceeds the prescriptive alteration requirements the Standard Design is the unaltered existing feature (note that the prescriptive alteration requirements are the mandatory requirements for all altered components plus additional prescriptive requirements for altered fenestration, HVAC equipment (refrigerant charge measurement or TXV), and ducts);
  - Otherwise, the Standard Design is the prescriptive alteration requirement (i.e., the mandatory requirement for altered components other than altered fenestration, HVAC equipment and ducts, which have additional prescriptive requirements beyond the mandatory requirements)

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

  - For climate zones with an SHGC requirement, where the annual TDV energy for the combination of the proposed altered fenestration and the shading of that altered fenestration by existing overhangs or sidefins is less than or equal to the annual TDV energy due to the prescriptive alteration fenestration shading requirement with no shading from overhangs or sidefins, the Standard Design is the unaltered existing feature (existing fenestration products plus existing shading). Otherwise, the Standard Design is the prescriptive alteration requirement.
  - For climate zones without an SHGC requirement, the Standard Design is the unaltered existing feature (existing fenestration products plus existing shading).

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

  - If no fenestration area is being added, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces.
  - If fenestration area is being added and the existing fenestration area is less than or equal to 20% of the existing floor area and the combination of the existing plus added fenestration is less than or equal to 20% of the existing floor area, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces plus the added fenestration surfaces.
  - If fenestration area is being added and the existing fenestration area is less than or equal to 20% of the existing floor area and the combination of the existing plus added fenestration is greater than 20% of the existing floor area, then the fenestration area in the Standard Design is 20% of the existing floor area. The fenestration surfaces in the Standard Design are the existing fenestration surfaces plus the added fenestration surfaces with the added surface areas scaled so that the total area of existing plus added fenestration surfaces equals 20% of the existing floor area. For example, if the existing floor area is 2,000 square feet, the existing fenestration is 300 square feet, and the added fenestration is 200 square feet, the scaling factor applied to each added fenestration surface would be:

$$\text{ScalingFactor} = \frac{(0.20\text{xExistingCFA}) - (\text{ExistingFenArea})}{\text{AddedFenArea}}$$

Equation R3-2

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

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

  - Otherwise, if fenestration area is being added and the existing fenestration area is greater than 20% of the existing floor area, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces.

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

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

Equation R3-3 $$EU_{e+ad+al} \leq EU_e + EB_{ad} + EB_{al}$$

Where

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

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

EB_{ad} = the Standard Design energy use for the addition alone

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

3.8.4 Duct Sealing in Additions and Alterations

Section 152(a)1 establishes prescriptive requirements for duct sealing in additions and Sections 152(b)1.D. and 152(b)1.E. establish prescriptive requirements for duct sealing and duct insulation for installation of new and replacement duct systems and duct sealing for installation of new and replacement space conditioning equipment. Table R4-13 provides Duct Leakage Factors for modeling of sealed and tested new duct systems, sealed and tested existing duct systems, and untested duct systems built prior to and after June 1, 2001. Appendix RF provides procedures for duct leakage testing and Table RF-2 provides duct leakage tests and leakage criteria for sealed and tested new duct systems and sealed and tested existing duct systems. These requirements, factors, procedures, tests and criteria apply to performance compliance for duct sealing in Additions and Alterations.

Condition	*Proposed Design*	*Standard Design*
Additions Served by Entirely New Duct Systems	The Proposed Design shall be either sealed and tested new duct systems or untested duct systems.	**The Standard Design shall be sealed and tested new duct systems.**
Additions Served by Extensions of Existing Duct Systems	The Proposed Design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems in homes built after June 1, 2001; or 4) untested duct systems in homes built prior to June 1, 2001.	The Standard Design shall be sealed and tested existing duct systems.
Alterations with Prescriptive Duct Sealing Requirements when Entirely New Duct Systems are Installed	The Proposed Design shall be either 1) sealed and tested new duct systems; 2) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	The Prescriptive Alteration Requirement is sealed and tested new duct systems. Determine the Standard Design by the Standard Design rules in section 3.1.3.

~~*Condition*~~	~~*Proposed Design*~~	~~*Standard Design*~~
~~Alterations with Prescriptive Duct Sealing Requirements when Existing Duct Systems are extended or replaced or when new or replacement air conditioners are installed~~	~~The Proposed Design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.~~	~~Prescriptive Alteration Requirement is sealed and tested existing duct systems. Determine the Standard Design by the Standard Design rules in section 3.1.3.~~
~~Alterations for which Prescriptive Duct Sealing Requirements do not apply~~	~~The Proposed Design shall be either 1) sealed and tested new duct systems, if the new duct system or the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.~~	~~The Standard Design shall be either 1) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.~~

~~Table R3-11 – Default Assumptions for Existing Buildings~~

	~~**Default Assumptions for Year Built (Vintage)**~~							
~~**Conservation Measure**~~	~~**Before 1978**~~	~~**1978 to 1983**~~	~~**1984 to 1991**~~	~~**1992 to 1998**~~	~~**1999 - 2000**~~	~~**2001-2003**~~	~~**2004-2005**~~	~~**2006 and Later**~~
~~INSULATION U-FACTOR~~								
~~Roof~~	~~0.079~~	~~0.049~~	~~0.049~~	~~0.049~~	~~0.049~~	~~0.049~~	~~0.049~~	~~0.049~~
~~Wall~~	~~0.356~~	~~0.110~~	~~0.110~~	~~0.102~~	~~0.102~~	~~0.102~~	~~0.102~~	~~0.102~~
~~Raised Floor - CrawlSp~~	~~0.099~~	~~0.099~~	~~0.099~~	~~0.046~~	~~0.046~~	~~0.046~~	~~0.046~~	~~0.046~~
~~Raised Floor-No CrawlSp~~	~~0.238~~	~~0.238~~	~~0.238~~	~~0.064~~	~~0.064~~	~~0.064~~	~~0.064~~	~~0.064~~
~~Slab Edge F-factor =~~	~~0.73~~	~~0.73~~	~~0.73~~	~~0.73~~	~~0.73~~	~~0.73~~	~~0.73~~	~~0.73~~
~~Ducts~~	~~R-2.1~~	~~R-2.1~~	~~R-2.1~~	~~R-4.2~~	~~R-4.2~~	~~R-4.2~~	~~R-4.2~~	~~R-4.2~~
~~LEAKAGE~~								
~~Building (SLA)~~	~~4.9~~	~~4.9~~	~~4.9~~	~~4.9~~	~~4.9~~	~~4.9~~	~~4.9~~	~~4.9~~
~~Duct Leakage Factor (See Table 4-13)~~	~~0.86~~	~~0.86~~	~~0.86~~	~~0.86~~	~~0.86~~	~~0.89~~	~~0.89~~	~~0.89~~
~~FENESTRATION~~								
~~U-factor~~	~~Use Table 116-A - Title 24, Part 6, Section 116 for all Vintages~~							
~~SHGC~~	~~Use Table 116-B - Title 24, Part 6, Section 116 for all Vintages~~							
~~Shading Dev.~~	~~Use Table R3-7 for all Vintages~~							
~~SPACE HEATING EFFICIENCY~~								
~~Gas Furnace (Central) AFUE~~	~~0.75~~	~~0.78~~	~~0.78~~	~~0.78~~	~~0.78~~	~~0.78~~	~~0.78~~	~~0.78~~
~~Gas Heater (Room) AFUE~~	~~0.65~~	~~0.65~~	~~0.65~~	~~0.65~~	~~0.65~~	~~0.65~~	~~0.65~~	~~0.65~~
~~Heat Pump HSPF~~	~~5.6~~	~~5.6~~	~~6.6~~	~~6.6~~	~~6.8~~	~~6.8~~	~~6.8~~	~~7.4~~
~~Electric Resistance HSPF~~	~~3.413~~	~~3.413~~	~~3.413~~	~~3.413~~	~~3.413~~	~~3.413~~	~~3.413~~	~~3.413~~
~~SPACE COOLING EFFICIENCY~~								
~~All Types, SEER~~	~~8.0~~	~~8.0~~	~~8.9~~	~~9.7~~	~~9.7~~	~~9.7~~	~~9.7~~	~~12.0~~
~~WATER HEATING~~								
~~Energy Factor~~	~~0.525~~	~~0.525~~	~~0.525~~	~~0.525~~	~~0.58~~	~~0.58~~	~~0.575~~	~~0.575~~
~~Rated Input, MBH~~	~~28.0~~	~~28.0~~	~~28.0~~	~~28.0~~	~~28.0~~	~~28.0~~	~~28.0~~	~~28.0~~

4. Required Modeling Assumptions and Algorithms

Most of the modeling assumptions and algorithms about building operation and climate are either fixed or restricted when an ACM is used for compliance.

All approved ACMs shall include and automatically use all the appropriate fixed and restricted inputs and calculation methods with no special entry required by the user. Users may not override the fixed inputs when the ACM is used for compliance calculations, nor are users allowed to go beyond the limitations of the restricted assumptions.

The fixed and restricted modeling assumptions apply to both the *Standard Design* run and to the *Proposed Design* run. The *standard* fixed and restricted modeling assumptions always apply to the *Standard Design* run and are the *default* for the *Proposed Design*. In some cases, the CEC has approved *alternate* fixed and restricted modeling assumptions that may be used in the *Proposed Design* run. When the assumptions differ between the *Standard Design* and the *Proposed Design*, this is called to the attention of the reader in this chapter. The alternate modeling assumptions may only be used when the *Proposed Design* run has a special building feature (e.g. zonal control) that is recognized for credit, and the ACM has been approved with this modeling capability. The modeling of such building features for compliance purposes shall always be documented in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance.

While this manual describes the algorithms and calculation methods used by the reference method, an ACM may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the *Standard Design* and the *Proposed Design* and provided that the ACM passes the applicable tests described in Chapters 5 and 6.

4.1 General Modeling Assumptions

4.1.1 Weather Data

All ACMs shall use standard hourly weather data for compliance runs. The same hourly weather data and weather data format shall be used for both the *Standard Design* and the *Proposed Design* calculations.

ACM Joint Appendix II contains information about how to obtain the official CEC weather data. There are 16 climate zones with a complete year of 8,760 hourly weather records. Each climate zone is represented by a particular city.

Time Dependent Valuation (TDV) energy is the parameter used to compare the energy consumption of proposed designs to energy budgets. TDV replaces the source energy multipliers of one for natural gas and 3 for electric. TDV is explained in ACM Joint Appendix III in more detail.

4.1.2 Ground Reflectivity

ACMs shall assume that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter. This applies to both the *Standard Design* and *Proposed Design*.

4.1.3 Thermostats

The *standard* thermostat settings are shown in Table R4-1 below. The values for the “Whole House” apply to the *Standard Design* run and are the default for the *Proposed Design* run. See the explanation later in this section regarding the values for Zonal Control.

Table R4-1 – Hourly Thermostat Set Points

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

Determining Heating Mode vs. Cooling Mode. When the building is in the heating mode, the heating setpoints for each hour are set to the "Heating" values in Table R4-1, the cooling setpoint is set to a constant 78°F and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode, the "Cooling" values are used. The heating setpoint is set to a constant 60°F, and the cooling and venting setpoints are set to the values in Table R4-1.

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

Zonal Control: An optional capability, described in Chapter 6, allows alternative thermostat schedules to be used for the *Proposed Design* run when the HVAC system meets the requirements for zonal control. With zonal control and has verified adequate airflow and verified air handler fan watt draw less than the default, the building is divided into sleeping and living areas and a separate schedule is used for each area. If the user selects this option the ACM shall use the appropriate alternative schedules based on the user's designations for sleeping and living zones and shall automatically report the use of this optional capability in the *Special Features and Modeling Assumptions* listings in the CF1-R. The setpoints for zonal control are also shown in Table R4-1.

*Setback Thermostat Exceptions***.** Certain types of heating and/or cooling equipment are excepted from the mandatory requirement for setback thermostats, including wall furnaces and through-the-wall heat pumps. If setback thermostats are not installed, then the ACM shall model the *Proposed Design* with the standard thermostat schedule, except that the heating mode setback setpoint shall be 66°F. In cases where setback thermostats are not mandatory but nonetheless are installed by the builder, the ACM shall model the *Proposed Design* using the standard heating setback setpoint of 65°F. The *Standard Design* always assumes the setback schedule shown in Table R4-1.

4.1.4 Internal Gains

Basic Allocation

Internal gain from lights, appliances, people and other sources shall be set to 20,000 Btu/day for each dwelling unit plus 15 Btu/day for each square foot of conditioned floor area (CFA) as shown in Equation R4-1.

Equation R4-1 $$IntGain_{total} = (20,000 \times N) + \left(15 \times \sum_{i=1}^{N} CFA_i\right)$$

Where

N= Number of dwelling units

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

Zonal Control

For zonal control, an optional modeling capability, the internal gains are split between the living areas and the sleeping areas as indicated in the following equations. The 20,000 Btu/day fixed component is assigned 100% to the living areas and the 15 Btu/ft² component is allocated according to floor area. See Equation R4-2 and Equation R4-3.

Equation R4-2 $$IntGain_{Living} = 15 \times CFA_{Living}$$

Equation R4-3 $$IntGain_{Sleeping} = 15 \times CFA_{Sleeping}$$

Additions

For addition-alone compliance (single-zone), the internal gains are apportioned according to the fractional conditioned floor area, referred to as the Fractional Dwelling Unit (FDU). For zone j, the internal gain is determined by Equation R4-4.

Equation R4-4 $$IntGainZone_j = IntGain_{tot} \times FDU_j$$

where

FDU_j = Fractional Dwelling Unit of j^{th} zone, calculated from Equation R4-5

Equation R4-5 $$FDU_j = \frac{CFA_j}{CFA_{total}}$$

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Chapter 6). When modeled together the number of dwelling units for the proposed dwelling ($NDU_{proposed}$) remains equal to the number of dwelling units for the existing structure ($NDU_{existing}$), while the conditioned floor area ($CFA_{proposed}$) is increased to include the contribution of the addition ($CFA_{addition}$). When modeled separately, the internal gain of the addition ($IntGain_{addition}$)is based on the value of the addition's fractional dwelling unit ($FDU_{addition}$), as expressed in Equation R4-6 and Equation R4-7.

Equation R4-6 $$IntGain_{addition} = IntGain_{total} \times FDU_{addition}$$

Equation R4-7 $$FDU_{addition} = \frac{CFA_{addition}}{CFA_{existing} + CFA_{addition}}$$

Hourly Schedules

The standard hourly internal gain schedule is shown in Table R4-2. “Hour one” is between midnight and 1:00 am. The whole building schedule shall always be used for the *Standard Design* run. The whole building is also used for the *Proposed Design* unless the *Proposed Design* has zonal control. For zonal control, the Living Areas schedule is used for the living areas and the Sleeping Areas schedule is used for sleeping areas.

Table R4-2 – Hourly Internal Gain Schedules

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

Seasonal Adjustments

Daily internal gain shall be modified each month according to the multipliers shown in Table R4-1. These multipliers are derived from the number of daylight hours for each month.

Table R4-1 – 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

4.2 Heat Gains and Losses Through Opaque Surfaces

4.2.1 Radiant Barriers

Algorithm

The benefits of radiant barriers are modeled in two ways. First, the ceiling U-factor is modified for each season (heating mode and cooling mode) to account for reduced heat gain (attics are not modeled as separate unconditioned thermal zones in residential ACMs). Second, the seasonal temperatures for attics are lower with radiant barriers, which results in better HVAC distribution efficiency for ducts located in the attic. See the algorithms for HVAC air distribution ducts for more details.

When the building is in a heating mode, (see Section 4.1.3), Equation R4-8 provides the U-factor modifier due to the presence of a radiant barrier. When the building is in a cooling mode, Equation R4-9 is used. To determine the U-factor for a ceiling with a radiant barrier, multiply the U-factor of the ceiling assembly located beneath a radiant barrier times the U-factor modifier. These modifiers may only be used for installed insulation greater than R-8, otherwise the modifer is 1.00.

Equation R4-8 $$UvalMod_{heating} = (-11.404 \times U^2) + (0.21737 \times U) + 0.92661$$

Equation R4-9 $$UvalMod_{cooling} = (-58.511 \times U^2) + (3.22249 \times U) + 0.64768$$

Eligibility Criteria

Radiant barriers shall meet specific eligibility and installation criteria to be modeled by any ACM and receive energy credit for compliance with the energy efficiency standards for low-rise residential buildings.

The emittance of the radiant barrier shall be less than or equal to 0.05 as tested in accordance with ASTM C-1371 or ASTM E408.

Installation shall conform to ASTM C-1158 (Standard Practice For Use and Installation Of Radiant Barrier Systems (RBS) In Building Construction.), ASTM C-727 (Standard Practice For Installation and Use Of Reflective Insulation In Building Constructions.), ASTM C1313 (Standard Specification for Sheet Radiant Barriers for Building Construction Applications), and ASTM C-1224 (Standard Specification for Reflective Insulation for Building Applications), and the radiant barrier shall be securely installed in a permanent manner with the shiny side facing down toward the interior of the building (ceiling or attic floor). Moreover, radiant barriers shall be installed at the top chords of the roof truss/rafters in ***any*** of the following methods:

1. Draped over the truss/rafter (the top chords) before the upper roof decking is installed.
2. Spanning between the truss/rafters (top chords) and secured (stapled) to each side.

3. Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space shall be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.

4. Attached [laminated] directly to the underside of the roof decking. The radiant barrier shall be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.

In addition, the radiant barrier shall be installed to cover all gable end walls and other vertical surfaces in the attic.

The attic shall be ventilated to:

1. Conform to the radiant barrier manufacturer's instructions.

2. Provide a minimum free ventilation area of not less than one square foot of vent area for each 150 square feet of attic floor area.

3. Provide no less than 30 percent upper vents.

Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full airflow to the venting.

The radiant barrier (except for radiant barriers laminated directly to the roof deck) shall be installed to have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier have a minimum of six (6) inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier.

When installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters, a minimum air space of 1 inch shall be provided between the radiant barrier and the top of the ceiling insulation, and ventilation shall be provided for every rafter space. Vents shall be provided at both the upper and lower ends of the enclosed rafter space.

The product shall meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.

The use of a radiant barrier shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and described in detail in the ACM Compliance Supplement.

4.2.2 Cool Roofs

Algorithm

Cool roofs are modeled to have an impact equal to the cooling savings for radiant barriers. The calculations for cool roofs are the same as radiant barriers, except that $UvalMod_{heating}$ (see Equation R4-8) is assigned a value of 1.00. In the event that both a cool roof and radiant barrier are specified, there is no credit for the cool roof.

Eligibility Criteria

Cool roofs shall meet specific eligibility and installation criteria to receive credit for compliance. The solar reflectance shall be 0.4 or higher for tile roofs or 0.7 or higher for other roof materials; and the emittance shall be 0.75 or higher. Liquid applied cool roof products shall meet the requirements of Section 118(i)3 of the standards. All products qualifying for this credit shall be rated and labeled by the Cool Roof Rating Council in accord with Section 10-113 of the standards. The use of a cool roof shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and described in detail in the ACM Compliance Supplement.

4.2.3 R-Value/U-factor Determinations

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

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

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

4.2.4 Insulation Installation Quality

Compliance credit is available for low-rise residential buildings if field verification is performed to ensure that quality insulation and air barrier installation procedures are followed (see ACM RH-2005). All newly insulated opaque surfaces in a building must be field verified to receive this credit. Compliance reports and user interfaces shall identify the building as having either *Standard* or *Improved* insulation installation quality. As discussed in Chapter 3, the *Standard Design* shall have standard insulation installation quality. Approved ACMs must be able to model both *Standard* and *Improved* insulation installation quality (see Table R4-3).

Table R4-3 – Modeling Rules for insulation installation Quality

		insulation installation Quality	
Component	Mode	Standard	Improved
Walls	Both	Increase heat gains and losses by 19%, i.e., multiply all wall U-factors by 1.19.	Increase heat gains and losses by 5%, i.e., multiply all wall U-factors by 1.05.
Ceilings/Roofs	Heating	Add 0.02 times the area to the UA of each ceiling surface i.e., add 0.02 to the U-factor.	Add 0.01 times the area to the UA of each ceiling surface i.e., add 0.01 to the U-factor.
	Cooling	Add 0.005 times the area to the UA of each ceiling surface i.e., add 0.005 to the U-factor.	Add 0.002 times the area to the UA of each ceiling surface i.e., add 0.002 to the U-factor.

When credit is taken for Improved insulation installation quality, the *Field Verification and Diagnostic Testing* section of the CF-1R shall show that field verification is required (see Chapter 2) and the Installation Certificate (CF-6R) and the Field Verification and Diagnostic Testing Certificate (CF-4R) must be completed and signed by the installer and HERS Rater, respectively.

4.2.5 Perimeters of Slab Floors and Carpeted Slabs

For *Standard and Proposed Designs* all ACMs shall use slab edge F2 values assuming that 20% of the slab floor perimeter is exposed to the conditioned air and 80% of the slab floor perimeter is carpeted or covered with an R-2 insulating layer between the slab and the conditioned air. See ACM Joint Appendix IV.

The monthly ground temperatures shown in Table R4-4 shall be used as the exterior temperature when calculating slab edge heat loss.

Table R4-4 – Monthly and Annual Average Ground Temperatures

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

4.2.6 Basement Modeling - Basement Walls and Floors

Below grade walls shall be modeled with no solar gains, i.e., absorptivity is zero. Below grade walls are modeled with three exterior conditions depending on whether the depth is shallow, medium, or deep. The temperature of the earth depends on the depth of the wall and is given in Table R4-5. Thermal resistance also shall be increased to account for earth near the construction (see Table R4-5).

Table R4-5 – Earth Temperatures for Modeling Basement Walls and Floors

Class	Depth	Assumed Temperature of the Earth	Thermal Resistance of Earth
Shallow Depth Walls	Up to 2 ft	Average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days -8 through -2).	A thermal resistance with an R-value of 1.57 (hr.ft^2.°F/Btu) is added to the outside of the below grade wall.
Medium Depth Walls	2+ to 6 ft	Exterior earth temperature is assumed to be the monthly average temperature from Table R4-4.	A thermal resistance with an R-value of 7.28 (hr.ft2.°F/Btu) is added to the outside of the below grade wall.
Deep Walls	More than 6 ft	Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-4.	A thermal resistance with an R-value of 13.7 (hr.ft2.°F/Btu) is added to the outside of the below grade wall.
Basement Floors	Any	Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-4.	A thermal resistance with an R-value of 17.6 (hr.ft2.°F/Btu) is added to the bottom of the basement floor.

4.3 Heat Gains and Losses Through Fenestration

4.3.1 Fenestration Products

Information concerning fenestration products, specifically the default table for fenestration U-factors and the default table for fenestration SHGC values, is included in Section 116 of Title 24, Part 6.

4.3.2 Solar Gain

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

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

Equation R4-10 $$G_{dir} = SHGC_{fen} * Area * [fsunlit * CosI * P(CosI) + GrndFac]$$

and

Equation R4-11 $$G_{dif} = SHGC_{fen} * Area * DMSHGC * (vfSky + vfGrnd * GrndRf)$$

where

Equation R4-12 $$P(CosI) = C1 * CosI + C2 * Cos^2 I + C3 * Cos^3 I + C4 * Cos^4 I$$

Equation R4-13 $$GrndFac = vfGrnd \times CosG \times GrndRf \times DMSHGC$$

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

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

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

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

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

C1, ...,C4 = Polynomial coefficients for angular dependence (cosine of the angle of incidence) of solar heat gain - see Table R4-6.

vfSky = View factor of window to sky [unitless]

vfGrnd = View factor from window to ground [unitless]

GrndRf = Ground Reflectance [unitless] = 0.20

Table R4-6 – Polynomial Coefficients for Angular Dependence

Glazing Type:	Single Pane (1 light)	More Than One Pane (2 or more lites)
$SHGC_{fen}$	0.860	0.695
C1	3.549794	1.881643
C2	-4.597536	1.014431
C3	2.432124	-4.009235
C4	-0.384382	2.113160
DMSHGC	0.905814	0.828777

4.3.3 Interior and Exterior Shading

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

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

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

The standard assumptions for operation of interior shading devices and sunscreens shall apply to both the *Standard Design* and the *Proposed Design*.

4.3.4 Solar Heat Gain Coefficients

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

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed solar heat gain coefficients are listed in Table R3-5 and Table R3-7.

The formula for combining solar heat gain coefficients is:

Equation R4-14 $$SHGC_{comb} = \left[(0.2875 \times SHGC_{max}) + 0.75 \right] \times SHGC_{min}$$

where

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

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

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

where

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

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

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

4.4 Thermal Mass

ACMs shall be capable of modeling thermal mass in buildings. Thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. There are two types of thermal mass, *Light Mass* which reacts very quickly to absorb or release heat, and *Heavy Mass* which reacts more slowly. *Light Mass* is modeled in the same way for both the *Proposed Design* and the *Standard Design*. The modeled mass includes common elements such as framing, furniture, ½ in. gypsum board, and household appliances. Light mass is modeled through an input in the reference program called building heat capacity and is assumed to be fixed at 3.5 Btu/ºF-ft² of conditioned floor area for both the *Proposed Design* and the *Standard Design*. Other values may be used for unconditioned zones (see Chapter 6).

"Heavy" mass includes elements such as concrete slab floors, masonry walls, double gypsum board and other special mass elements. When the *Proposed Design* qualifies as a high mass building then each element of heavy mass is modeled in the *Proposed Design*, otherwise, the *Proposed Design* is modeled with the same heavy thermal mass as the *Standard Design*. See Chapter 3 for details on what qualifies as a high mass building. The default thermal mass for the *Proposed Design* and the fixed thermal mass for the *Standard Design* is based on 20% of the slab floor being exposed and 80% covered with carpet or casework. In addition 5% of the non-slab floor is exposed with a topping of 2 in. of concrete. ACM RB-2005 has procedures for quantifying the value of various types of thermal mass.

Solar Gain Targeting. Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the *Standard Design* run and the *Proposed Design* run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Chapter 6.

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

4.5 Infiltration and Natural Ventilation

4.5.1 Infiltration/Ventilation

The reference method uses the effective leakage area method for calculating infiltration in conditioned zones. Calculations shall use Shielding Class 4 as defined in the 2001 *ASHRAE Handbook of Fundamentals*.

Default Specific Leakage Area. The default specific leakage area (SLA) is 4.93.8 for designs with ducted HVAC systems and 3.83.2 for non-ducted HVAC systems. The default is always used for the *Standard Design*. The *Proposed Design* may use an alternate value, but only with diagnostic testing. The specific leakage area (SLA) is the ratio of the effective leakage area to floor area in consistent units. The value is then increased by 10,000 to make the number more manageable. If the effective leakage area (ELA) is known in inches, then the SLA may be calculated with Equation R4-15.

Equation R4-15 $$SLA = \left(\frac{ELA}{CFA}\right)\left(\frac{ft^2}{144in^2}\right)(10000) = \left(\frac{ELA}{CFA}\right)69.444$$

where

ELA = Effective leakage area in square inches

CFA = Conditioned floor area (ft²)

SLA = Specific leakage area (unitless)

Minimum Outside Air. For both the *Standard Design* and the *Proposed Design*, ACMs shall assume that occupants will open the windows if the air becomes stagnant. When natural ventilation, infiltration, and mechanical ventilation fall below a threshold value of 0.35 air changes per hour (ACH) , the occupants are assumed to open the windows at the beginning of the next hour sufficient to provide a combination of infiltration and ventilation equal to 0.35 ACH for an eight foot high ceiling. The windows are assumed to remain partially open to provide a minimum of 0.35 ACH as long as the previous hour's infiltration and mechanical ventilation rate is below the threshold.

Effective Leakage Area (ELA) Method. The Effective Leakage Area (ELA) method of calculating infiltration for conditioned zones is documented below and in Chapter 26 of the 2001 ASHRAE Handbook of Fundamentals. The ELA for the *Standard Design* and for the default values for the *Proposed Design* (if diagnostic tests are not used), is calculated from Equation R4-15. The energy load on the conditioned space from infiltration heat gains or losses are calculated as follows.

Equation R4-16 $$CFM_{infil} = ELA \times \sqrt{A \times \Delta T_2 + B \times V^2}$$

Equation R4-17 $$CFM_{infil+unbalfan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2}$$

Equation R4-18 $$CFM_{infil+totfan} = CFM_{infil+unbalfan} + MECH_{bal}$$

The volumetric airflow (cfm) due to natural ventilation is derived from the natural ventilation cooling for the hour:

Equation R4-19 $$CFM_{natv} = \frac{Q_{natv}}{1.08 \times \Delta T_1}$$

The total ventilation and infiltration (in cfm) including indoor air quality window operation is:

Equation R4-20 $$CFM_{total} = CFM_{natv} + CFM_{infil+totfan}$$

The value of CFM_{iaq} depends on the sum of CFM_{natv} and $CFM_{infil+totfan}$ from the previous time step:

When

Equation R4-21 $$CFM_{natv} + CFM_{infil+totfan} < \frac{(AFT \times CFA)}{7.5}$$

then

Equation R4-22 $$CFM_{iaq} = \frac{(0.35 \times CFA)}{7.5}$$

otherwise

Equation R4-23 $$CFM_{iaq} = 0.000$$

where

CFA = the total conditioned floor area of the residence

AFT = 0.18 for Climate Zones 2 through 15 inclusive, and;

AFT = 0.25 for Climate Zones 1 and 16.

When the windows are opened they provide an overall ventilation rate equal to 0.35 air changes per hour for a residence of the same floor area but with eight foot high ceilings. CFM_{iaq} simulates the opening of windows to achieve an acceptable indoor air quality by the occupants when ventilation and infiltration from other sources does not provide an adequate quantity of outdoor air to dilute pollutants and refresh the indoor air.

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

Equation R4-24 $$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1$$

where

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

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

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

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

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

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

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

ΔT_1 = difference between indoor and outdoor temperature for current hour (°F)

ΔT_2 = difference between indoor and outdoor temperature for previous hour (°F)

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

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

V = average wind speed for current hour (mph)

ELA = effective leakage area (in^2), measured or calculated using Equation R4-25.

The stack (A) and wind (B) coefficients to be used are shown in Table R4-7.

Table R4-7 – Infiltration Coefficients

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

The ELA is calculated from the SLA as follows:

Equation R4-25 $$ELA = CFA \times SLA \times \left(\frac{144\,in^2}{1ft^2}\right) \times \left(\frac{1}{10,000}\right)$$

where

CFA = conditioned floor area (ft^2)

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

ELA = effective leakage area (in^2)

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

Equation R4-26 $$ELA = 0.055 \times CFM50_H$$

where

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

Substituting Equation R4-26 into Equation R4-15 gives the relationship of the measured airflow rate to SLA:

Equation R4-27 $$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$

Reduced Infiltration. ACM users may take credit for reduced infiltration (with mechanical ventilation when it is required) for low-rise, single-family dwellings when verified by on-site diagnostic testing. While credit is offered for reduced infiltration, the model also assumes that dwelling occupants will open windows when natural ventilation and infiltration do not provide a minimum of 0.35 ACH.

The Effective Leakage Area (ELA) of the dwelling may be reduced and the algorithm will result in less energy use due to infiltration unless windows are opened for ventilation. Lower ELAs will result in windows being opened more frequently and at some point energy use may increase. Air quality ventilation may also be added and if this ventilation plus infiltration and cooling ventilation provides adequate air exchange, window ventilation will no longer occur or will occur very infrequently. The energy use of both ventilation exhaust fans and ventilation supply fans shall be entered. These ventilation fans Exhaust fans used for ventilation are assumed to operate continuously and the energy use of these fans shall be included as energy use in the *Proposed Design*. Both rReduced ELA/SLA and ventilation fans are conditions which requires field verification or diagnostic testing and shall be reported in the *Field Verification and Diagnostic Testing* listings on the Certificate of Compliance.

Controlled Ventilation Crawl Spaces and Sunspaces. Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Chapter 6. All optional capabilities that are used in the *Proposed Design* shall be reported in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance.

4.5.2 Natural Ventilation

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

Wind driven ventilation includes consideration of wind speed, prevailing direction and local obstructions, such as nearby buildings or hills.

Stack driven ventilation includes consideration of the temperature difference between indoor air and outdoor air and the difference in elevation between the air inlet and the outlet.

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

Effective Ventilation Area (EVA)

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

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

Stack Driven Ventilation

Stack driven ventilation results when there is an elevation difference between the inlet and the outlet, and when there is a temperature difference between indoor and outdoor conditions. See Equation R4-28.

Equation R4-28

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

where

CFM_S = Airflow due to stack effects, cfm.

9.4 = Constant.

EVA = Effective ventilation area as discussed above, ft².

EFF_S = Stack effectiveness.

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

ΔT = Indoor to outdoor temperature difference, °F.

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

Wind Driven Ventilation

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

Equation R4-29

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

where

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

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

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

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

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

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

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

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

~~*Combined Wind and Stack Effects*~~

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

~~Equation R4-30~~

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

~~where:~~

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

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

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

~~*Determination of Natural Ventilation for Cooling*~~

~~The value of CFM_t described in Equation R4-30 above gives the maximum potential ventilation when the windows are open. Natural ventilation is available during cooling mode when there is venting shown in Table R4-1. The amount of natural ventilation used by ACMs for natural cooling is the lesser of this maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint temperature when natural cooling is needed and available. When natural cooling is not needed or is unavailable no natural ventilation is used. ACMs shall assume that natural cooling is needed when the building is in “cooling mode” and when the outside temperature is below the estimated zone temperature and the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature down to the natural ventilation setpoint temperature is used and the natural ventilation setpoint temperature shall be constrained by the ACM to be greater than the heating setpoint temperature.~~

Wind Speed and Direction

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

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

The reference method, CALRES, adjusts the wind speed used in calculations through a WF of 0.25. See Equation R4-29.

4.6 Heating Systems

ACMs shall use the following inputs and algorithms to calculate heating energy use.

Equation R4-31 $$NetHLoad_{hr} = \frac{HLoad_{hr} \times HDEM_{hr}}{\eta_{seasonal,dist}}$$

where

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

$HLoad_{hr}$ = Space heating load for the hour from the ACM simulation, Btu.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the heating season from Equation R4.

$HDEM_{hr}$ = Heating duct efficiency multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 (no hourly adjustment) is used unless the supply ducts are located in the attic.

4.6.1 Furnaces and Boilers

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

Equation R4-32 $$FurnFuel_{hr} = \frac{NetHLoad_{hr}}{AFUE_{eff}}$$

where

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

$NetLoad_{hr}$ = The hourly load calculated from Equation R4-31 and using algorithms similar to those described in this chapter.

4.6.2 Heat pump and Electric Furnace

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

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = Defaults to 1/(0.4*HSPF)

Cap47 = Rated compressor heating capacity at 47 F. Defaults to rated cooling capacity.

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

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

Equation R4-33 $$HSPF = (3.2 \times COP) - 2.4$$

4.6.3 Air Distribution Fans

The test method for calculating AFUE ignores electric energy used by air distribution fans and the contribution of the fan motor input to the heating output. With TDV, electric energy shall be calculated separately from gas energy. For forced-air heating systems, ACMs shall calculate fan energy at the rate of 0.005 watt-hours per Btu of heat delivered by the equipment. The vast majority of residential furnaces have the fan motor in the air stream so the heat generated by the motor contributes to heating the house. This effect may be considered in calculating the TDV energy for heating.

4.7 Air Conditioning Systems

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

4.7.1 Cooling System Energy

The reference ACM calculates the hourly cooling electricity consumption in kWh using Equation R4-34. In this equation, the energy for the air handler fan and the electric compressor or parasitic power for the outdoor unit of a gas absorption air conditioner are combined. The ACM calculates the hourly cooling gas consumption in therms using Equation 4-35.

Equation R4-34 $$AC_{kWh} = \frac{Fan_{Wh} + Comp_{Wh} + PPC_{Wh}}{1{,}000}$$

Equation 4-35 $$AC_{therms} = \frac{Absorption_{Btu}}{100{,}000}$$

where

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

Fan_{Wh}= Fan watt-hours for a particular hour of the simulation. See Equation R4-48.

$Comp_{Wh}$= Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R4-36.

PPC_{Wh}= Parasitic Power watt-hours for gas absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4- 44.

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

$Absorption_{Btu}$ = Gas consumption in Btu for absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4-43.

Electric Compressor Systems

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

Compressor watt-hours for a particular hour of the simulation shall be calculated using Equation R4-36.

Equation R4-36
$$Comp_{wh} = \frac{CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist} \times CE_t} + \frac{Fan_{wh} x3.413}{CE_t}$$

where

$CLoad_{hr}$ = Space sensible cooling load for the hour from the ACM simulation (Btu).

$CDEM_{hr}$ = Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54

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

CE_t = Sensible energy efficiency at a particular outdoor dry bulb temperature. This is calculated using Equation R4-37 below.

Fan_{wh} = Fan watts this hour. This is calculated using Equation R4-48.

Equation R4-37
$$CE_t = EER_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

EER_t = Energy efficiency ratio at a particular dry bulb temperature. EER_t is calculated using Equation R4-38 below.

Equation R4-38

When	
$DB_t < 82$ ºF	$EER_t = SEER_{nf}$
$82 \le DB_t < 95$	$EER_t = SEER_{nf} + ((DB_t - 82)*(EER_{nf} - SEER_{nf}) / 13)$
$DB_t \ge 95$	$EER_t = EER_{nf} - (DB_t - 95) * 0.12$

where

$SEER_{nf}$ = Seasonal energy efficiency ratio without distribution fan consumption (“nf” = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-39.

EER_{nf} = Energy efficiency ratio at ARI conditions without distribution fan consumption (“nf” = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-40.

Equation R4-39
$$SEER_{nf} = (1.0452 \times SEER + 0.0115 \times SEER^2 + 0.000251 \times SEER^3) \times F_{txv} \times F_{air} \times F_{size}$$

Equation R4-40 $$EER_{nf} = \left(1.0452 \times EER + 0.0115 \times EER^2 + 0.000251 \times EER^3\right) \times F_{txv} \times F_{air} \times F_{size}$$

where

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

EER = Energy efficiency ratio at ARI test conditions, if not input, then values are taken from Equation R4-41.

F_{txv} F_{chg} = The refrigerant charge factor, default = 0.9. For systems with a verified TXV (ACM RI-2005)charge indicator light or verified refrigerant charge (ACM RD-2005), the factor shall be 0.96.

F_{air} = The system airflow factor, default = .925. For systems with airflow verified according to 4.7.4, F_{air} shall be 1.00.

F_{size} = Compressor sizing factor, default = 0.95. For systems sized according to the Maximum Cooling Capacity for ACM Credit (see Section 4.7.2), the factor shall be 1.0.

Equation R4-41

When

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

SEER >= 11.5 EER = 10

Gas Absorption Systems

To determine the electric and gas energy use of gas absorption air conditioning systems the algorithms described in this section should be used.

Equation R4-42 $$Absorption_{Btu} = \frac{CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist} \times AE_t} + \frac{Fan_{wh} x3.413}{AE_t}$$

Equation R4-43 $$PPC_{wh} = \frac{CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist} \times PE_t}$$

where:

$CLoad_{hr}$ = Space sensible cooling load for the hour from the ACM simulation (Btu).

$CDEM_{hr}$ = Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{seasonal, dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54.

AE_t = Sensible energy efficiency of the gas absorption system at a particular outdoor dry bulb temperature. This is calculated Equation R4-44 using below.

PE_t = Sensible energy efficiency of the parasitic power at a particular outdoor dry bulb temperature. This is calculated using Equation R4-45 below.

Fan_{wh} = Fan watts this hour. This is calculated using Equation R4-48.

Equation R4-44 $$AE_t = COP_t \times \left(0.88 + 0.00156 \times \left(DB_t - 95\right)\right)$$

Equation R4-45 $PE_t = PEER_t \times (0.88 + 0.00156 \times (DB_t - 95))$

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

COP_t = COP (coefficient of performance for the gas consumption) of the gas absorption system at a particular dry bulb temperature calculated using Equation R4-46.

$PEER_t$ = PEER (parasitic electricity energy efficiency for the gas absorption system) at a particular outdoor dry bulb temperature calculated using Equation R4-48.

Equation R4-46

DB_t < 83 ºF	COP_t = COP82
83 < DB_t < 95	COP_t = COP82 + ((DB_t - 82)*(COP95 - COP82) / 13)
DB_t > 94	COP_t = COP95 - (DB_t - 95) * 0.00586

Equation R4-47

DB_t < 83 ºF	$PEER_t$ = PEER82
83 < DB_t < 95	$PEER_t$ = PEER82 + ((DB_t - 82)*(PEER95 - PEER82) / 13)
DB_t > 94	$PEER_t$ = PEER95 - (DB_t - 95) * 0.00689

where

CAP95= Rated capacity of the gas absorption system, Btuh, input by the compliance user

COP95 = Rated COP of the gas absorption system, input by compliance user

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

COP82 = COP95 * 1.056

PEER95= CAP95 / PPC, Btu / Wh

PEER82= PEER95 * 1.056

Fan Energy for Cooling

While in a cooling mode, the fan energy associated with the air conditioner is calculated separately from the compressor energy according to Equation R4-48. Calculations are performed hourly.

Equation R4-48 $$Fan_{wh} = \frac{FanW/Btu \times CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist}}$$

where

FanW/Btu = Fan watts per Btu of rated cooling capacity. This defaults to 0.015 W/Btu. The default value shall be used for the Standard design. Alternate FanW/Btu may be used in ACM calculations for the Proposed design if the actual installed fan watts are less than or equal to the simulation value based on measurements certified by the installer and verified by a rater using the procedure in ACM RF-2005.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54.

4.7.2 Compressor Sizing

The Design Cooling Capacity shall be calculated using the procedure in ACM RF-2005. The Maximum Cooling Capacity for ACM Credit shall be calculated using the procedure in ACM RF-2005. For ACM energy calculations all loads are assumed to be met in the hour they occur regardless of the compressor size.

Correctly sized systems installed so they operate at full capacity are desirable because oversized cooling systems have been shown to result in larger peak electrical demands. Systems which have the combination of verified adequate airflow, sealed and tested new duct systems, and proper charge (or alternatively a TXVcharge indicator display) and also meet the requirements for Maximum Cooling Capacity for ACM Credit may take credit in ACM calculations by setting the Fsize factor (see Equation R4-39 and Equation R4-40) to 0.95. For all other systems the Fsize factor shall be set to 1.0.

4.7.3 Cooling System Refrigerant Charge

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. The presence of a thermostatic expansion valve (TXV) mitigates the impact of charge problems. Field measurements indicate that typical California air conditioning systems are installed without proper charge, and for ACM energy calculations, the F_{txv} F_{chg} factor is set to 0.90 to account for the impact of this condition. If the system without a TXV is properly charged or a TXV is installedor a charge indicator display is installed, certified and verified according to the procedures of ACM RD-2005 and ACM RJ-2005 the F_{txv} F_{chg} factor may be set to 0.96 for ACM energy calculations. See Equation R4-39 and Equation R4-40. Credit for refrigerant charge is not available for packaged systems.

4.7.4 Air Handler Airflow

The efficiency of an air conditioning system is affected by airflow across the evaporator coil. Cooling system airflow is specified in cubic feet per minute per ton (cfm/ton) where one ton of capacity is 12,000 Btu/hour at ARI rated conditions. Cooling airflow is the flow achieved under normal air conditioning operation with the cooling coil wet from condensation.

Adequate Airflow Verification

Verifying adequate airflow is required to allow air conditioning systems to operate at their full efficiency and capacity. Credit may be taken for adequate airflow in ACM calculations by setting the F_{air} factor (see Equation R4-39 and Equation R4-40) to 1.0, but airflow shall be tested, certified and verified using the procedures of ACM RE-2005. When an adequate airflow credit is claimed, the duct design, layout, and calculations shall also be submitted to the local enforcement agency and to a certified HERS rater. Without airflow tests, no credit is allowed for ACM energy calculations and the F_{air} multiplier shall be set to 0.925.

The installer shall measure and certify the airflow. The certified HERS rater shall verify the existence of the duct design layout and calculations, verify that the field installation is consistent with this design, and diagnostically test and verify the airflow rate.

Sufficient Flow for Valid Standard Refrigerant Charge Test

Sufficient airflow is also required to ensure that the refrigerant charge procedure in ACM RD-2005 will produce valid results. Verifying sufficient airflow is a prerequisite for the refrigerant charge test. Either the flow measurement procedure or the temperature split test of ACM RD-2005 may be used to demonstrate Sufficient Airflow.

Air Handler Fan Flow

Table R4-8 shows the criteria used for calculations and measurement of airflow for cooling systems. If a flow test is done using the fan only switch on the air handler, the coil will be dry allowing higher airflow, and the Dry Coil criterion shall be used.

Table R4-8 – Airflow Criteria

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

Test and Condition	Cooling airflow (Wet Coil)	Test Flow if Dry Coil
Default Cooling Airflow	300 cfm/ton	N/A
Flow needed for a valid refrigerant charge test	350 cfm/ton (See Note 1)	400 cfm/ton
Adequate Airflow	400 cfm/ton	450 cfm/ton
Note 1. In lieu of airflow measurements, the system can pass the temperature split test documented in ACM RD-2005.		

4.8 Duct Efficiency

The procedures in this section shall be used to calculate the efficiency of duct systems. For the purposes of duct efficiency calculations, the supply duct begins at the exit from the furnace or air handler cabinet.

4.8.1 Building Information and Defaults

The ACM shall use values for the parameters in Table R4-9 to calculate duct efficiencies. Standard design values and proposed design defaults are also shown. Proposed designs may claim credit for other values using the procedures in the following sections.

Table R4-9 – Duct Efficiency Input Parameters and Defaults

Parameter	Standard Design Value	Proposed Design Default
1. Duct Location	Ducts in the attic	Ducts in the attic
2. Insulation level of ducts	Package D requirement	Mandatory Minimum Requirement
3. The surface area of ducts	27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories.	
4. The leakage level	Sealed and tested.	Untested
5. Fan flow	Default Cooling Airflow (Table R4-9)	
6. Attic radiant barrier.	Yes in climate zones where required by Package D, otherwise No	No radiant barrier

When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

See Section 3.8 for information on existing HVAC systems that are extended to serve an addition.

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

4.8.2 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Note that the area of supply ducts located in conditioned space shall be ignored in calculating conduction losses but supply duct leakage is not affected by supply duct location.

Return Duct Location

If return ducts are located entirely in the basement, the calculation shall assume basement conditions for the return duct efficiency calculation. Otherwise, the return duct shall be entirely located in the attic for the purposes of conduction and leakage calculations. Return duct surface area is not a compliance variable.

Default Supply Duct Location

Default supply duct locations shall be as shown in Table R4-10. The supply duct surface area for crawl space and basement applies only to buildings or zones with all supply ducts installed in the crawl space or basement. If the supply duct is installed in locations other than crawl space or basement, the default supply duct location shall be "Other." For houses with 2 or more stories 35% of the default duct area may be assumed to be in conditioned space as shown in Table R4-10. The surface area of supply ducts located in conditioned space shall be ignored in calculating conduction losses. 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 R4-10 – Location of Default Supply Duct Area

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

DiagnosticSupply Duct Location

Supply duct location and areas other than the defaults shown in Table R4-10may be used following the procedures of 4.8.5.

4.8.3 Duct Surface Area

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

Return Duct Surface Area

Return duct surface area is not a compliance variable and shall be calculated using Equation R4-49.

Equation R4-49 $$A_{r,out} = K_r \times A_{floor}$$

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

Default Supply Duct Surface Area

The standard design and default supply duct surface area shall be calculated using Equation R4-50.

Equation R4-50 $$A_{S,out} = 0.27 \times A_{floor} \times K_S$$

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

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

For proposed design HVAC systems with air handlers located outside the conditioned space but with less than 12 lineal feet of duct located outside the conditioned space including air handler and plenum, the supply duct surface area outside the conditioned space shall be calculated using Equation R4-51.

Equation R4-51 $$A_{s,out} = 0.027 \times A_{floor}$$

Diagnostic Duct Surface Area

Proposed designs may claim credit for reduced surface area using the procedures in 4.8.5.

4.8.4 Duct System Insulation

General

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

Standard Design Duct Insulation R-value

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

Proposed Design Duct Insulation R-value

The default duct wall thermal resistance shall be the mandatory requirement. Higher insulation levels may be used in the proposed design if all the ducts outside conditioned space are insulated to this value or greater. Credit for systems with mixed insulation levels or ducts buried in the attic require the diagnostic procedure in 4.8.5.

4.8.5 Diagnostic Supply Duct Location, Surface Area and R-factor

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

Surface Area and Location

The surface area of each supply duct system segment shall be calculated based on its inside dimensions and length. The total supply surface area in each unconditioned space location (attic, attic with radiant barrier, crawl space, basement, other) shall be the sum of the area of all duct segments in that location. The ACM shall assign duct segments located in "other" locations to the attic location for purposes of calculation. The surface area of supply ducts completely inside conditioned space need not be input in an ACM 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.

~~Effective R-value~~

~~The effective R-value of a supply or return duct system constructed entirely of materials of one rated R-value shall be the rated R-value plus the film coefficient. If materials of more than one R-value are used, the area weighted effective R-value shall be calculated by the ACM using Equation R4-52 and including each segment of the duct system which has a different R-value.~~

~~Equation R4-52~~

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

~~where~~

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

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

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

~~Buried Attic Ducts~~

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

~~Buried Ducts on the Ceiling~~

~~The portions of duct runs directly on or within 3.5 inches of the ceiling gypsum board and surrounded with blown attic insulation of R-30 or greater may take credit for increased effective duct insulation as shown in Table R4-11. Credit shall be allowed for buried ducts on the ceiling only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.~~

~~Deeply Buried Ducts~~

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

Table R4-11 – 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

4.8.6 Fan Flow

Default System Fan Flow

The default fan flow for an air conditioner and for heating with a heat pump in all climate zones shall be obtained from Table R4-8.

The default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:

Equation R4-53 $Q_e = 0.50 \times A_{floor}$

4.8.7 Duct Leakage

Duct leakage factors shown in Table R4-12 shall be used in calculations of delivery effectiveness. Table R4-12 shows default duct leakage factors for dwelling units. Sealed and tested duct systems require the diagnostic leakage test by the installer and verification by a HERS rater meeting the criteria described in ACM RC-2005. The duct leakage factors for sealed and tested new duct systems correspond to sealed duct requirements in newly constructed dwelling units, to entirely new duct systems in existing dwelling units, and to duct systems in alterations and additions that have been sealed to meet the duct leakage requirements of newly constructed buildings. The duct leakage factors for sealed and tested duct systems in existing dwelling units apply only to sealed duct requirements for alterations to existing dwelling units and to extensions of existing duct systems to serve additions. See Section 3.8 for ducts in existing dwelling units that are sealed and tested in conjunction with alterations or additions.

Low leakage air handlers, defined in Section 10-102, that are factory-sealed and field verified may take credit for reduced duct leakage as shown in Table R4-13. The credit for low leakage ducts in conditioned space requires HERS verification as specified in Section RC 4.3.3 of the Standards Residential Appendices.

Table R4-12 – Duct Leakage Factors

Case	$a_s = a_r =$
Untested duct systems in homes built prior to June 1, 2001	0.86
Untested duct systems in homes built after June 1, 2001	0.89
Sealed and tested duct systems in existing dwelling units	0.915
Sealed and tested new duct systems	0.96
Factory-sealed and field-verified low leakage air handlers[1]	0.97
Factory-sealed and field-verified air handlers with measured air leakage rate Lr[2]	1 – Lr/2
Verified low leakage ducts in conditioned space[3]	1.00

1.Factory-sealed ducts require HERS verification per procedures in Residential Appendix ACM-RC.
2. With this option the user specifies the measured leakage rate as a fraction of fan flow. The air hander must be installed before diagnostic duct leakage is measured.
3.The credit for low leakage ducts requires HERS verification and must be used in combination with the existing credit for verified ducts in conditioned space.

4.8.8 Seasonal Distribution System Efficiency

ACMs shall use the following algorithms to calculate duct and HVAC distribution efficiency.

The seasonal distribution system efficiency shall be calculated separately for the heating and cooling seasons using Equation R4-54 based on the seasonal delivery effectiveness from Equation R4-55 and the thermal recovery factor from Equation R4-64. Note that $DE_{seasonal}$, F_{recov} shall be calculated separately for cooling and heating seasons. Distribution system efficiency shall be determined using the following equation:

Equation R4-54
$$\eta_{dist,seasonal} = 0.98\, DE_{seasonal} \times F_{recov}$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass. F_{recov} is calculated in Equation R4-64.

4.8.9 Seasonal Delivery Effectiveness

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using Equation R4-55. This value shall be calculated separately for the heating season and the cooling season.

Equation R4-55
$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$

where

B_s = Conduction fraction for supply as calculated in Equation R4-56.

B_r = Conduction fraction for return as calculated in Equation R4-57.

ΔT_e = Temperature rise across heat exchanger, ºF. This value changes for heating and cooling modes.

ΔT_r = Temperature difference between indoors and the ambient for the return, ºF. This value changes for heating and cooling modes.

ΔT_s = Temperature difference between indoors and the ambient for the supply, ºF. This value changes for heating and cooling modes.

a_r = Duct leakage factor (1-return leakage) for return ducts. A value is selected from Table R4-12

a_s = Duct leakage factor (1-supply leakage)p for supply ducts. A value is selected from Table R4-12

Equation R4-56 $$B_s = \exp\left(\frac{-A_{s,out}}{1.08Q_e \times R_s}\right)$$

Equation R4-57 $$B_r = \exp\left(\frac{-A_{r,out}}{1.08Q_e \times R_r}\right)$$

where

$A_{s,out}$ = Surface area of supply duct outside conditioned space, ft². See Sections 4.8.1, 4.8.2 and 4.8.3.

$A_{r,out}$ = Surface area of return duct outside conditioned space, ft^2. See Sections 4.8.1, 4.8.2 and 4.8.3.

Q_e = Flow through air handler fan at operating conditions, cfm. This is determined from Section 4.7.4.

R_r = The effective thermal resistance of return duct, h ft^2 F/Btu. See Section 4.8.4 and 4.8.5.

R_s = The effective thermal resistance of supply duct, h ft^2 F/Btu. See Section 4.8.4 and 4.8.5.

4.8.10 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space

Duct ambient temperature for both heating and cooling for different duct locations shall be obtained from Table R4-13. Attic temperatures for houses with radiant barriers also shall be obtained from Table R4-13. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be applied to cooling calculations. The eligibility criteria for radiant barriers is given in Section 4.2.1. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F.

Table R4-13 – Assumptions for Duct Ambient Temperature (ºF)

	Ambient Temperature for Heating, $T_{heat,amb}$			Ambient Temperature for Cooling, $T_{cool,amb}$				
Climate zone	Attic	Crawl Space	Basement	Attic	Attic w/ radiant barrier (supply)	Attic w/ radiant barrier (return)	Crawl Space	Basement
1	52.0	52.2	48.9	60.0	65.4	61.2	54.0	49.1
2	48.0	48.7	56.5	87.0	84.3	84.2	78.0	64.5
3	55.0	54.9	58.3	80.0	79.4	78.2	71.8	62.8
4	53.0	53.1	56.6	79.0	78.7	77.4	70.9	61.4
5	49.0	49.6	52.3	74.0	75.2	73.1	66.4	56.8
6	57.0	56.7	59.9	81.0	80.1	79.1	72.7	64.1
7	62.0	61.1	60.4	74.0	75.2	73.1	66.4	61.6
8	58.0	57.6	60.1	80.0	79.4	78.2	71.8	63.9
9	53.0	53.1	59.6	87.0	84.3	84.2	78.0	66.4
10	53.0	53.1	61.1	91.0	87.1	87.6	81.6	68.9
11	48.0	48.7	59.5	95.0	89.9	91.0	85.1	69.5
12	50.0	50.4	59.3	91.0	87.1	87.6	81.6	67.8
13	48.0	48.7	58.4	92.0	87.8	88.4	82.4	67.6
14	39.0	40.7	55.4	99.0	92.7	94.4	88.7	68.6
15	50.0	50.4	63.4	102.	94.8	96.9	91.3	74.6
16	32.0	34.4	43.9	80.0	79.4	78.2	71.8	54.1

4.8.11 Calculation of Duct Zone Temperatures for Multiple Locations

The temperatures of the duct zones outside the conditioned space are determined in Table R4-13 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures.

Equation R4-58
$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out}}$$

Equation R4-59
$$T_{amb,r} = \frac{A_{r,attic}\ T_{attic} + A_{r,crawl} \times T_{crawl} + A_{r,base} \times T_{base}}{A_{r,out}}$$

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

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

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

4.8.12 Temperature Difference Across Heat Exchanger

The temperature difference across the heat exchanger is determined by Equation R4-60:

For heating:

Equation R4-60
$$\Delta T_e = 55$$

And Equation R4-61 for cooling:

Equation R4-61 $\Delta T_e = -20$

4.8.13 Indoor to Duct Location Temperature Differences

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r, shall be calculated using the indoor and the duct ambient temperatures.

Equation R4-62 $\Delta T_s = T_{in} - T_{amb,s}$

Equation R4-63 $\Delta T_r = T_{in} - T_{amb,r}$

4.8.14 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The thermal regain factors that are required to be used are provided in Table R4-14.

Table R4-14 – Thermal Regain Factors

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

4.8.15 Recovery Factor (F_{recov})

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

Equation R4-64
$$F_{recov} = 1 + F_{regain}\left(\frac{1 - a_sB_s + a_sB_s(1-B_r)\frac{\Delta T_r}{\Delta T_e} + a_s(1-B_s)\frac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right)$$

4.9 Hourly Attic Duct Efficiency Multipliers

The algorithm in this section shall be used to model the hourly variation in duct efficiency for ducts located in attics. No hourly variation is modeled for ducts located in spaces other than attics. The multipliers are determined as described in Section 4.9.1 below:

4.9.1 Hourly Duct Efficiency Multipliers

The hourly duct efficiency multiplier for ducts in attics shall be calculated for each hour using Equation R4-65 through Equation R4-68.

Equation R4-65
$$DEM_{hr} = 1 + C_{DT} \times \left(\frac{\Delta T_{sol,hr}}{\Delta T_{sol,season}} - 1\right)$$

Equation R4-66 $$\Delta T_{sol,hr} = T_{solair,hr} - T_{in,hr}$$

Equation R4-67 $$T_{solair,hr} = T_{amb,hr} + \left(\frac{\alpha}{h_o}\right) \times I_{hor,hr} - \Delta T_{sky}$$

Equation R4-68 $$C_{DT} = C_0 + C_R / R_{duct} + C_L L_{duct}$$

where

DEM_{hr} = The hourly duct efficiency multiplier for ducts located in all locations. This value is calculated for each hour and separately for the heating season ($HDEM_{hr}$) and cooling season ($CDEM_{hr}$).

$T_{solair,\ hr}$ Sol-air temperature, ºF. See Equation R4-67.

$T_{in,hr}$ Indoor air dry-bulb temperature from simulation, °F.

$T_{amb,hr}$ Outdoor air dry-bulb temperature, °F. From the CEC weather file.

ΔT_{sky} Reduction of sol-air temperature due to sky radiation, = 6.5 ºF.

$I_{hor,hr}$ Global solar radiation on horizontal surface, Btu/h-ft². From the CEC weather file.

α Solar absorptivity of roof = 0.50.

h_o Outside surface convection coefficient, = 3.42 Btu/h-ft²-ºF.

$\Delta T_{sol,\ season}$ Energy weighted seasonal average difference between sol-air and indoor temperatures. This is taken from Table R4-16.

R_{duct} Duct insulation R-value, hr ft^2°F/Btu.

L_{duct} Duct leakage as fraction of supply airflow, dimensionless. See Table R4-12.

C_{DT}, C_0, C_R, C_L Regression coefficients. See Table R4-15.

Table R4-15 – Coefficients

		Cooling		Heating	
		Radiant Barrier	No Radiant Barrier	Radiant Barrier	No Radiant Barrier
C_0	(Unitless)	0.0078	0.0186	0.0350	0.0205
C_R	(h-ft²-°F/Btu)	0.1222	0.0877	0.0794	0.1202
C_L	(Unitless)	0.5480	0.2995	0.0714	0.2655

Table R4-16 – Seasonal Sol-Air Temperature Difference, °F

Climate Zone	Cooling	Heating
1	23.00	-20.01
2	31.69	-23.64
3	23.66	-18.90
4	26.29	-21.13
5	26.02	-20.25
6	23.79	-17.12
7	25.17	-17.16
8	30.89	-19.46
9	32.73	-18.85
10	33.34	-21.53
11	34.24	-24.38
12	34.65	-23.31
13	34.53	-22.92
14	35.29	-25.64
15	33.33	-20.32
16	29.43	-29.86

4.10 Water Heating Calculations

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards (see Section 3.7 for details). The calculation procedure is documented in ACM RG-2005.

4. Minimum Capabilities Tests

This chapter describes the methods used to test the minimum modeling capabilities of candidate ACMs. There are separate tests for space conditioning tests and water heating tests. Most of the space conditioning tests are performed using a simple square building prototype (see Figure R4-7). The water heating tests are performed relative to two prototype water heating systems. Most of the tests are performed in only five climate zones, but some are performed in all sixteen climate zones.

4.1 Overview

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

4.1.1 Accuracy Tests

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

General Procedure

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

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

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

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

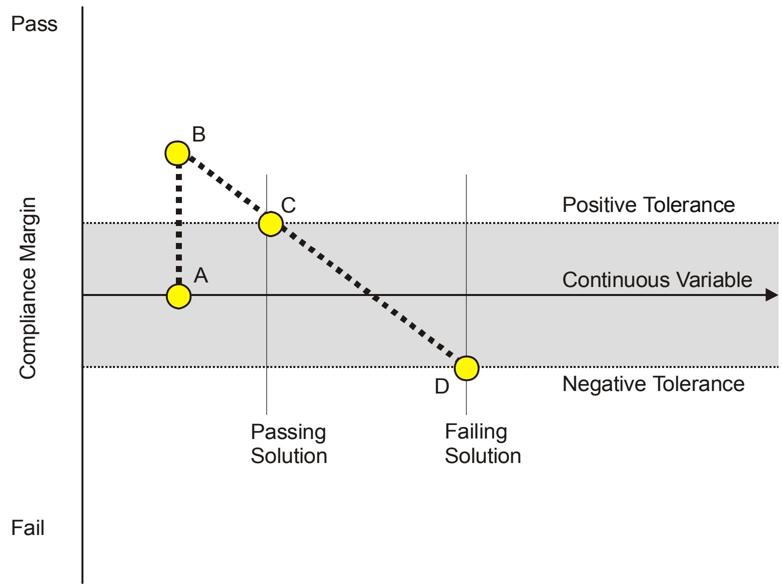


Figure R4-1 – Testing Concept – Discrete Modifications Produce Positive Compliance Margin
The discrete modifications produce a positive compliance margin that exceeds positive tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.

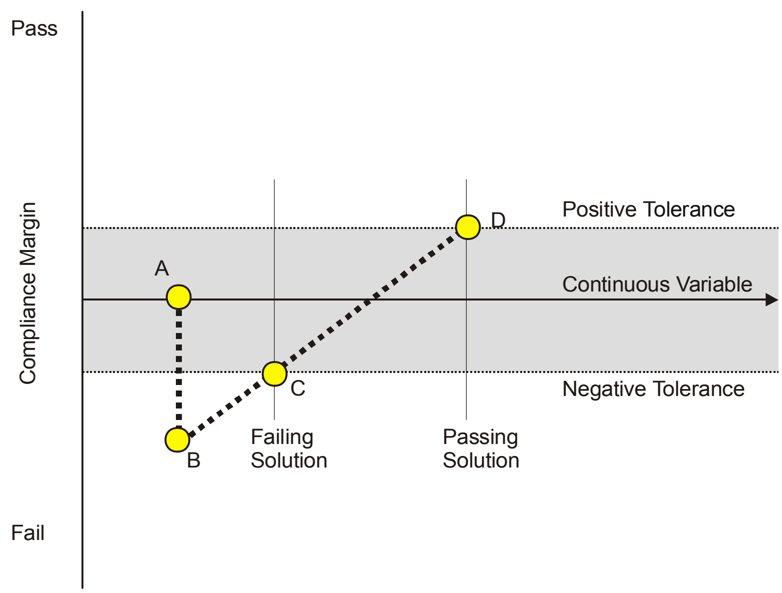


Figure R4-2 – Testing Concept – Discrete Modifications Produce Negative Compliance Margin
The discrete modifications produce a negative compliance margin that exceeds negative tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.

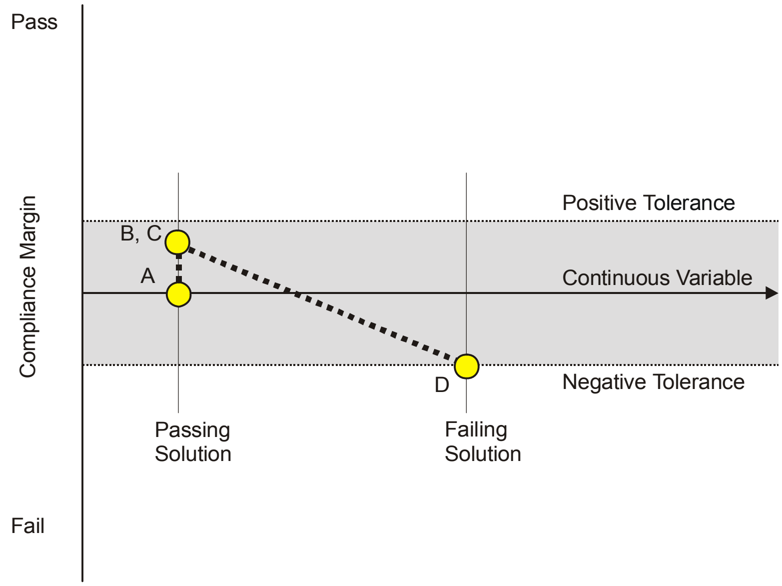


Figure R4-3 – Testing Concept – Discrete Modifications Produce Positive But Small Compliance Margin
The discrete modifications produce a positive compliance margin that is less than the positive tolerance. The passing solution for the continuous variable is equal to the basecase; the failing solution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

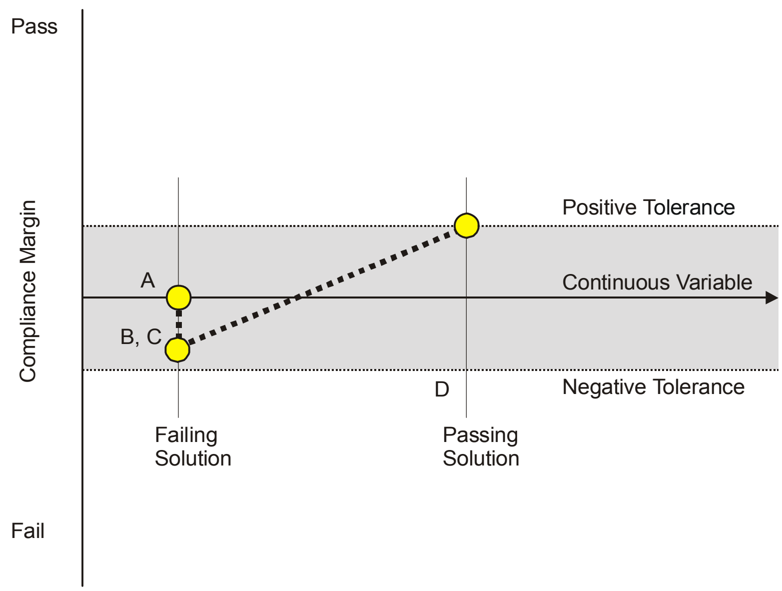


Figure R4-4 – Testing Concept – Discrete Modifications Produce Negative But Small Compliance Margin
The discrete modifications produce a negative compliance margin that is within the negative. The failing solution for the continuous variable is equal to the basecase; the passing solution is determined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

Acceptance Criteria

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

4.1.2 Standard Design Tests

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

Standard Design Equivalent Tests

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

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

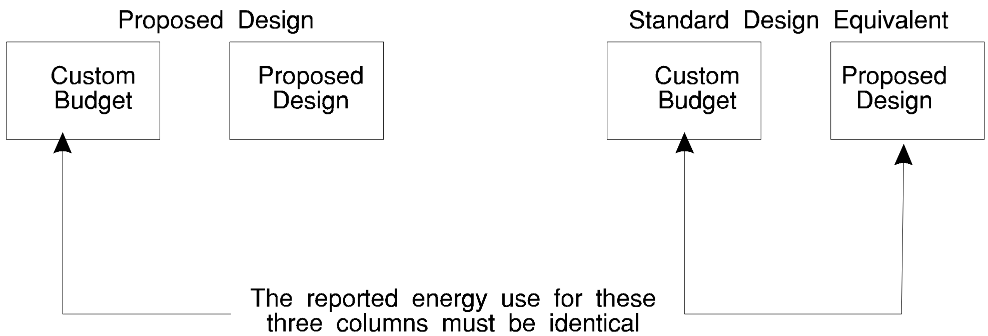


Figure R4-5 – Custom Budget Tests

Neutral Variable Tests

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

4.1.3 Labeling Tests and Computer Simulations

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

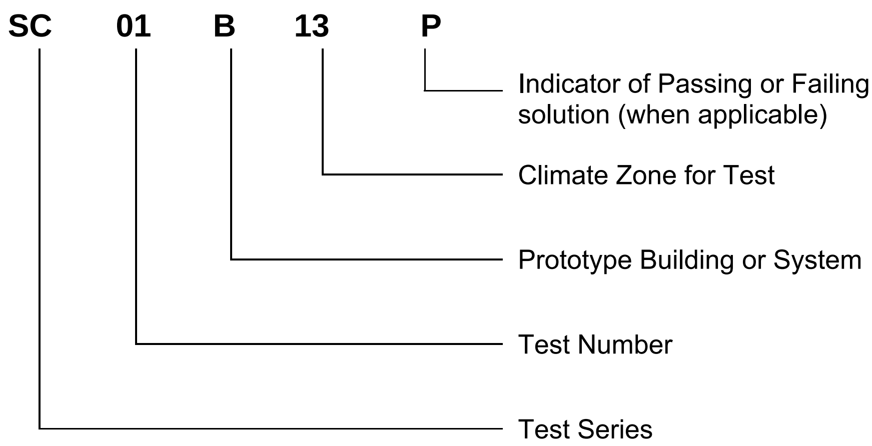


Figure R4-6 – Labeling of Computer Simulations

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

4.1.4 Documentation

The ACM vendor shall record the results of the tests on the forms provided in Appendix RA-2005 and provide electronic copies of the input files to the Energy Commission. The filenames shall include the test label (see below) with a “P” or “F” concatenated to the file name to indicate if the file represents the passing solution or the failing solution. The form (Appendix RA-2005) includes an entry for the TDV energy for the passing solution and the failing solution. The forms also include the continuous variable values for the passing and failing solutions as well as the ACM filenames for the passing and failing cases.

4.2 Space Conditioning Tests

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

4.2.1 Accuracy Tests (SC)

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

Prototype Buildings

The space conditioning accuracy tests are performed with two prototype buildings. The geometry of the prototype buildings and other features are described below and illustrated in Figure R4-7. The attic is not shown in Figure R4-7 ~~since the ACM modeling rules do not require the attic to be explicitly modeled as a separate thermal zone~~ since the dimensions and configuration of the attic are determined by the ceiling area.

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

A Prototype A has a slab-on-grade.

B Prototype B has raised floor construction.

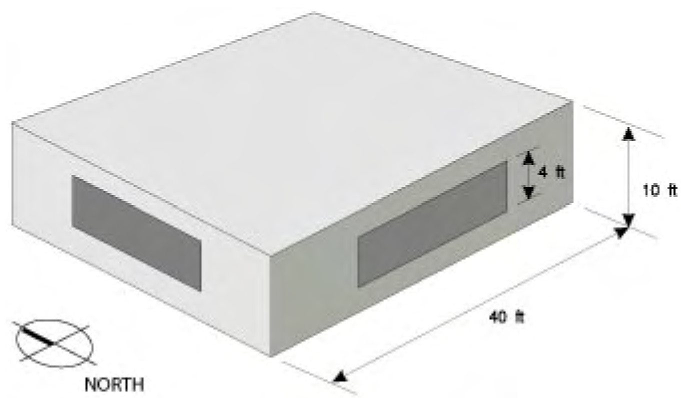


Figure R4-7 – Prototype Buildings A and B

Test Descriptions

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

Table R4-51 – Summary of the Space Conditioning Tests

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
SC	0	A, B	All	None	None
SC	1	A	3, 9, 12, 14, 16	**SEER**. Increase the cooling equipment efficiency (SEER) from the basecase condition of 12.0 to 14.0.. Use the default EER for both the SEER 12.0 and SEER 14.0 cases. Make no changes to the air distribution system or other HVAC system components. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	2	A	3, 9, 12, 14, 16	**Ceiling U-factor**. Reduce the ceiling U-factor from the basecase condition to R-60. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	3	A	3, 9, 12, 14, 16	**Wall U-factor**. Increase wall insulation to the equivalent of R-22 in a 2x6 wood framed cavity with R-14 continuous insulation. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a positive compliance margin.	**West Glass Area**. Increase west glass area to find the Passing Solution and the Failing Solution.
SC	4	A	12, 14, 16	**Slab F-factor**. Add R-7 slab insulation for climate zones 12 and 14. In climate zone 16, increase slab edge insulation from the basecase R-7 to R-21. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	5	A	3, 9, 12, 14, 16	**Fenestration Type**. Replace the basecase fenestration with a super high performance product with a U-factor of 0.25 and a SHGC of 0.40. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	6	A	3, 9, 12, 14, 16	**Fenestration Type**. Replace the basecase fenestration with a product that fails to comply with the package D requirements. The replacement product shall have a U-factor of 0.90 and an SHGC of 0.70. Produces a negative compliance margin.	**AFUE**. Increase or reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	7	A	12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	8	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**West Glass Area**. Increase west glass area to find the Passing Solution and the Failing Solution.
SC	9	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	10	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**East Glass Area**. Increase east glass area to find the Passing Solution and the Failing Solution.
SC	11	A	3, 9, 12, 14, 16	**South Overhangs**. Add a two foot projection from the surface of the south glass. Its bottom edge is located six inches above the top of the window. The window is assumed to be 6 ft 6 in. high and the overhang is assumed to extend an infinite distance beyond the sides of the windows (see Figure R4-8). Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	12	A	3, 9, 12, 14, 16	**Building Envelope Sealing**. Reduce the building (SLA) from 4.9 to 2.9 through diagnostic testing and sealing. Produces a positive compliance margin.	**Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution.

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
SC	13	A	3, 9, 12, 14, 16	**Building Envelope Sealing and Mechanical Ventilation**. The building leakage (SLA) is reduced from 4.9 to 2.9 through diagnostic testing and sealing. In addition, mechanical ventilation is added that provides 80 cfm (0.375 air changes per hour) of continuous ventilation and consumes 20 watts of power continuously. Produces a positive compliance margin.	**Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution.
SC	14	A	3, 9, 12, 14, 16	**Construction Quality**. Assume that the proposed design has been field verified to have quality wall and ceiling insulation quality. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	15	A	9, 12, 14	**Cool Roofs / Radiant Barrier**. Remove the radiant barrier (or equivalent cool roof) from the proposed design. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	16	A	9, 12, 14	**Natural Ventilation**. Change the window types to increase the free ventilation area from the default of 10% of the total window area to 20% of the window area, and assume a 10 ft elevation difference between the air inlet and the outlet. Produces a positive compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	17	A	3, 9, 12, 14, 16	**Duct Leakage**. Do not seal the ducts as required by the prescriptive standards. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	18	A	3, 9, 12, 14, 16	**Duct Surface Area.** Through diagnostic verification, reduce duct surface area from the default of 27% of the floor area to 10% of the floor area. Produces a positive compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	19	B	9, 12, 14	**Duct Location.** Move the HVAC ducts from the crawlspace (the default for one story, raised floor buildings) to the attic. Produces a negative compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	20	A	9, 12, 14	**Duct Insulation.** Reduce the duct R-value from the R-8 prescriptive requirement to R-4.2. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	21	A	9, 12, 14	**Energy Efficiency Ratio (EER)**. Instead of using the default EER of 10.415 for the default SEER 12 assume an EER of 11.5 with the same SEER of 12). Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	22	A	9, 12, 14	**TXV / Charge Testing**. Do not install a TXV and do not field verify that the split system has the correct refrigerant charge. Produces a negative compliance margin.	**SHGC**. Reduce the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	23	A	9, 12, 14	**Airflow Across Evaporator Coil**. Verify through field verification that there is adequate airflow for compliance credit (400 cfm/ton for a wet coil) across the evaporator coil. Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	24	A	9, 12, 14	**Air Conditioner Fan Power**. Reduce fan power through field verification. The default is 0.51 W/cfm. Reduce this to 0.20 W/cfm. Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	25	A	3, 9, 12, 14, 16	**Electric Heat**. Replace the gas furnace and air distribution system in the basecase with electric resistance baseboards (no air distribution or duct losses). In addition, increase the ceiling insulation to R-60. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a negative compliance margin.	**Fenestration U-factor**. Reduce the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.

Series	Number	Prototypes	Climates	Discrete Modification(s)	Continuous Variable
SC	26	A	9, 12, 14	**Side Fins**. For this test side fins are added to the east and west facades of prototype A. The side fins extend 40 feet from the surface of a window that is assumed to be 10 feet wide. The fins are 5 feet from the edge of the window. The top of the side fins are 20 feet above the top of the window. See Figure R4-9. Sidefins are expected to produce a positive compliance margin.	**SEER**. Vary the SEER (keep EER at the default) to find the passing solution and fail the failing solution.

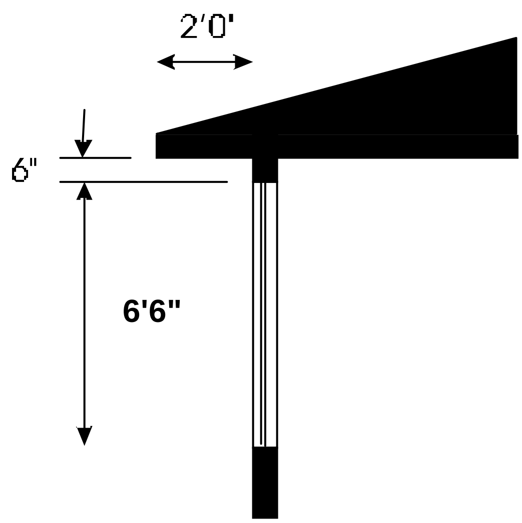


Figure R4-8 – Overhang Characteristics

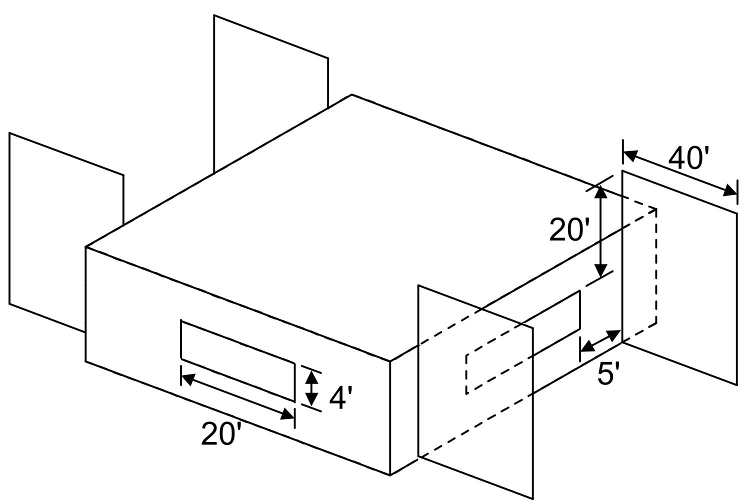


Figure R4-9 – Side Fins for Optional Capabilities Test

The north and south façades are the ones that do not have the sidefins.

Acceptance Criteria

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

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

4.2.2 Standard Design Generator Tests (*SD*)

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

Prototypes Buildings

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

C Prototype C is a ~~1,761~~2,100 ft² , one ~~and two~~-story, single-family detached home~~ which is widely used to analyze the impact of the standards and the cost effectiveness of measures~~. Two versions of this prototype are used in the tests. One has a slab floor and one has a raised floor. Details are available from the Energy Commission.

D Prototype D is a 2,700 ft², two-story detached home. ~~identical to prototype C, except that it is has a raised floor.~~ Details are available from the Energy Commission.

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

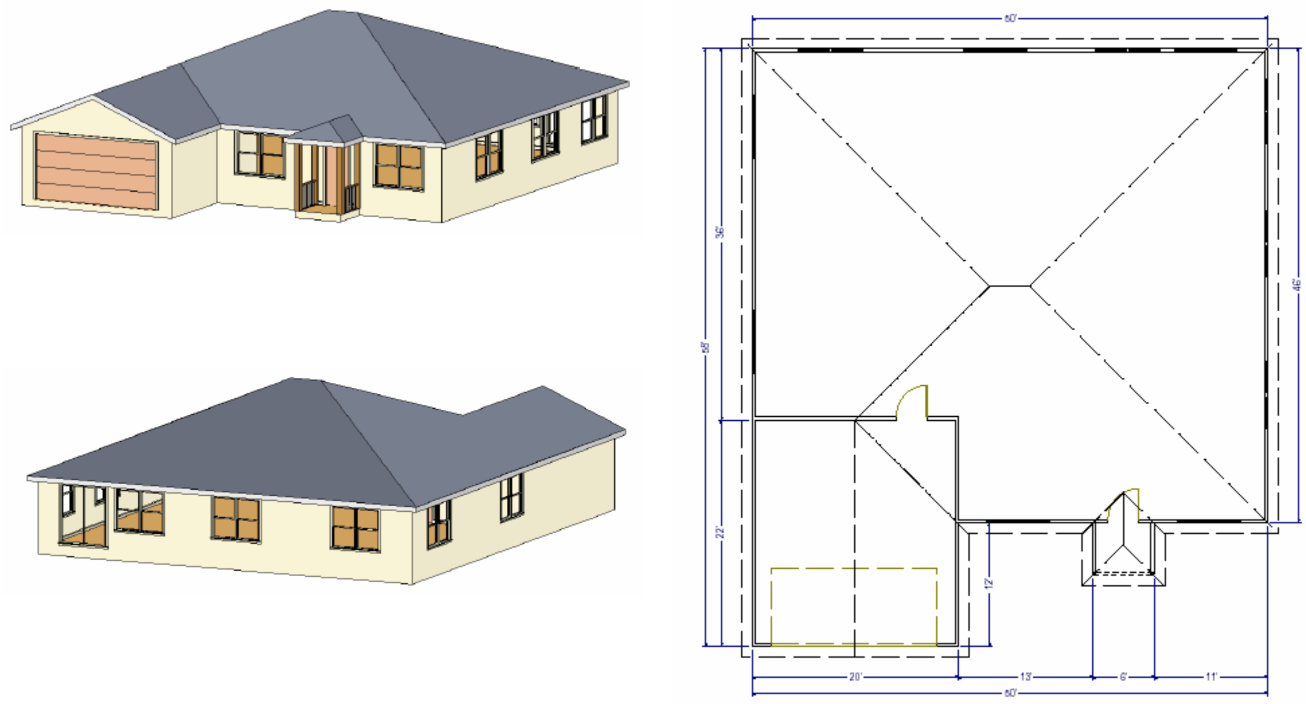


Figure R4-10 – Prototype C

Figure R4-11 – Prototype D

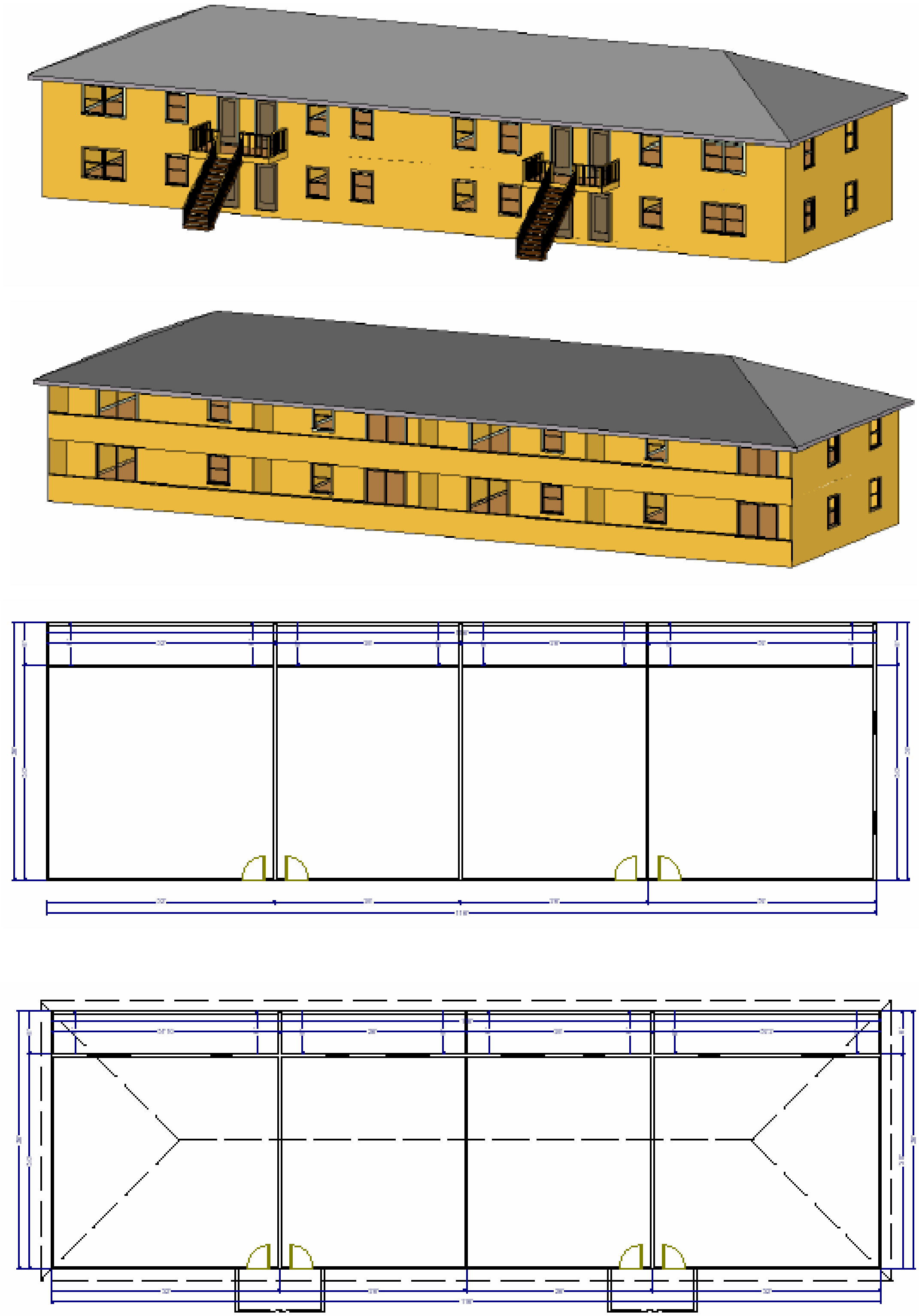


Figure R4-12 – Prototype E

Standard Design Equivalent Tests

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

Table R4-52 – Standard Design Tests

Series	Number	Prototypes	Climates	Description
SD	0	A, B	All	**Basecase Prototypes**. These tests were also performed in the SC series. For each of these tests, the standard design and proposed design TDV energy shall be equal. There is no proposed design case for these tests.
SD	1	C	All	**Slab-On-Grade**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using slab-on-grade designs. The “SC01C**” files are run in all 16 climate zones.
SD	2	D	All	**Raised Floor**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using raised floor buildings. The “SC01D**” files are run in all 16 climate zones.
SD	3	E	All	**Multi-Family.** The purpose of this test is to verify that the standard design generator correctly defines the standard design for multi-family buildings. The “SC01E**” files are run in all 16 climate zones.

Neutral Variable Tests

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

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

Series	Number	Prototypes	Climates	Description
SD	4	A	3, 9, 12, 14, 16	**Window Area**. Reduce window area from 20% of the floor area to 15% of the floor area. Reduce the size of the window on each façade to 60 ft². Do not change any other features.
SD	5	A	3, 9, 12, 14, 16	**Wall Area.** Increase the gross wall area on each façade from 400 ft² to 600 ft².

4.2.3 Additions and Alternations (AA)

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

Additions are treated as new buildings except that internal heat gains are allocated on a fractional dwelling unit basis. With the Addition + Existing + Alternation approach, energy credit may be taken for improvements to the existing building. This series of tests exercises the various default assumptions (see Table 3-11 in Section 3.8.4) based on the vintage of the existing building and the various reporting requirements for modeling an addition with an existing building. In addition, these tests verify the proper determination of the energy budget and compliance criteria for an addition with an improved existing building.

Prototype Buildings

The prototype used in these tests consists of an existing building and an addition. The existing building has the same physical configuration as Prototype A but the thermal performance of building envelope components is downgraded to be more typical of older existing buildings. Prototype E (Figure R5-10) has the thermal characteristics of 1977 construction practice and Prototype F has the thermal characteristics of 1989 construction practice. See the Additions and Alternations section of Chapter 3 for details on construction assemblies. Each window is 4 ft high and 20 ft wide centered on the façade. The addition is 12 ft deep by 40 ft long and 10 ft high and covers the whole west side of the existing building.

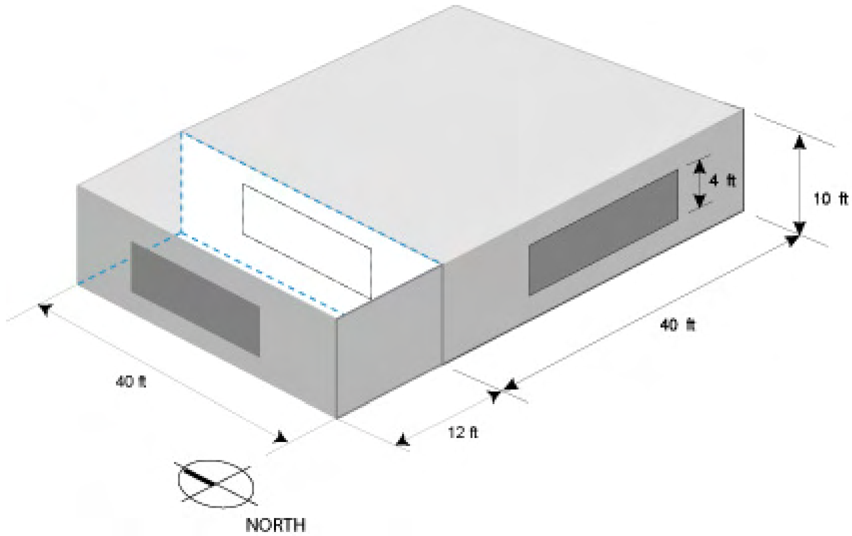


Figure R4-13 – Prototypes E and F

Test Descriptions

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

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

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
AA	1	E 1977	3, 9, 12, 14, 16	**Baseline**. The features of the addition shall all exactly meet the prescriptive requirements. The addition is served by an HVAC system in the existing house.	**None**. This is a standard design generator test.
AA	2	E 1977	3, 9, 12, 14, 16	**Increase Glass**. Increase fenestration area on the west side of the addition to 144 ft². This discrete change will fail compliance because the glass area exceeds 20% of the floor area.	**Fenestration Area U-factor**. Reduce the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.
AA	3	F 1989	3, 9, 12, 14, 16	**New HVAC**. Install a separate HVAC split system gas/electric system for the addition that has an SEER of 14 and an EER of 13. This will create a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.

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

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

Acceptance Criteria

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

4.3 Water Heating Tests (WH)

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

4.3.1 Prototype Systems

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

Table R4-56 – Base Case Water Heating Systems

Prototype	Prototype C	Prototype E
Building Information		
Dwelling Units	1	16
Total Building Area	~~1,761~~2,100 ft²	~~11,616~~6,960 ft²
Average Dwelling Unit Size	2,100~~1,761~~ ft²	~~726~~ 870 ft²
Water Heating Equipment		
Number of Water Heaters	1	4
Water Heater Type	Storage Gas (SG)	Storage Gas (SG)
Energy Factor	0.575	0.480
Tank Size	50	4 @ 100
Distribution System	Standard (PIK)	Recirculation with timer controls
Multi-Family Recirculation System		
Linear Feet of Pipe (Note 1)	n.a.	200
PF Outdoor Air	n.a.	0.10
PF Ground	n.a.	0.20
PF Conditioned or semi-conditioned air within the building envelope	n.a.	0.70
Pipe Diameter for Recirculation System	n.a.	1.5 in.
Recirculation Pipe Insulation	n.a.	1.0 in.
Pump Size (brake horsepower)	n.a.	½ hp
Pump Motor Efficiency	n.a.	0.85
Note 1. Total Linear feet used for recirculation between dwelling units (input to Section 3.5). PF is the fraction of the total linear feet that is used either outside, in the ground, or in the conditioned or semi-conditioned air within the building envelope, as defined in Section RG3.5.		

4.3.2 Accuracy Tests (WH)

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

Table R4-57 – Accuracy Tests – Water Heating

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
WH	0	C, E	All	None	None
WH	1	C, E	3, 9, 12, 14, 16	**Electric Storage Water Heater.** Change the water heater type from Gas Storage to Electric Storage. Use an Energy Factor of 0.91 for prototype C and 0.87 for E. This produces a negative compliance margin.	**Solar Savings Fraction (SSF).** Increase the SSF to find the passing and failing solutions.
WH	2	C, E	3, 9, 12, 14, 16	**Electric Instantaneous Water Heater.** Change the water heater type from gas storage to electric Instantaneous and use a point of use (POU) distribution system. This produces a negative compliance margin.	**Solar Savings Fraction (SSF).** Increase the SSF to find the passing and failing solutions.
WH	32	C	3, 9, 12, 14, 16	**Distribution Type.** Change the distribution system from the default to pipe insulation on all lines (PIA) system. This produces a positive compliance margin.	**Energy Factor.** Reduce the EF for the proposed building until the passing and failing solutions are reached.
WH	4	E	3, 9, 12, 14, 16	**Recirculation Control.** Add temperature and timer controls (RTmTp) for the recirculating system. This produces a positive compliance margin.	**Energy Factor (EF).** Reduce the EF to find the passing and failing solutions.
WH	5	E	3, 9, 12, 14, 16	**Large Storage Water Heater.** Change water heater type to a 400 gallon large gas storage, SBL = 0.1, thermal (recovery) efficiency= 0.75.	**Thermal Efficiency.** Decrease or increase thermal efficiency (recovery efficiency or AFUE) until the passing and failing solutions are reached.
WH	6	E	3, 9, 12, 14, 16	**Recirculation Piping Insulation.** Increase recirculation piping insulation from 1 in. to 1.5 in. This produces a positive compliance margin.	**Energy Factor.** Reduce the energy factor to find passing and failing solutions.
WH	7	C	3, 9, 12, 14, 16	**Number of Water Heaters.** Use 2 water heaters for the single residence; both are the same size and performance as the basecase. This will produce a negative compliance margin	**Energy Factor.** Increase the energy factor of both water heaters together to find passing and failing solutions.
WH	8	E	3, 9, 12, 14, 16	**Pump Controls.** Baseline assumes timer pump controls. Change to no pump control. This produces a negative compliance margin.	**Energy Factor.** Increase the energy factor of both water heaters together to find passing and failing solutions.

4.3.3 Standard Design Tests (WD)

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

Standard Design Equivalent Tests

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

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

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
WD	0	C, E	All	None	None

Neutral Variable Tests

The neutral variable tests are shown in Table R4-59. For these tests, the compliance margin shall remain at zero, unchanged.

Table R4-59 – Neutral Variable Tests – Water Heating

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*
WD	1	C	3, 9, 12, 14, 16	**House Size**. Increase house size to 2,500 ft². TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	2	C	3, 9, 12, 14, 16	**House Size**. Increase house size to 3,500 ft². The TDV energy for both the *Standard Design* and the *Proposed Design* shall equal the TDV energy for test 1.
WD	3	D	3, 9, 12, 14, 16	**Pipe Length**. Increase recirculation piping length to 400 ft. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	4	D	3, 9, 12, 14, 16	**Pipe Location**. Move all the piping outdoors. PF ground and plenum become zero and PF outdoors becomes 1.00. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	5	D	3, 9, 12, 14, 16	**Individual Water Heaters.** Replace the central water heating system with individual water heaters in each dwelling unit, which meet the basecase specification for single-family homes (see Table R4-56)

5. Optional Capabilities Tests

5.1 Overview

This chapter of the Manual explains the tests that must be performed in order for residential ~~ACM~~compliance programs to be approved for optional capabilities. See the Overview section of Chapter 5 for details. There are two sets of optional capabilities. The first are for space conditioning and include hydronic heating systems, combined (with the water heater) hydronic heating, zonal control of space temperatures, sunspaces, side fins and exterior mass walls. The second set of capabilities relate to solar systems used for water heating applications. ~~At this time, photovoltaic systems are not an optional capability~~.

~~B.Optional Space Conditioning Capabilities~~

~~C.Summary of Tests~~

The optional capabilities tests for space conditioning are summarized in Table R5-1. These tests use the same labeling scheme, test procedures, and prototypes as the minimum modeling capabilities (see previous cChapter 5).

Table R5-1 – Summary of the Optional Space Conditioning Tests

Type	*Test*	*Prototypes*	*Climates*	*Optional Capability (Discrete Modification(s))*	*Continuous Variable*
OC	1	A	3, 9, 12, 14, 16	**Dedicated Hydronic.** Replace the gas furnace and air distribution system with a gas boiler with hydronic baseboards and fan coils. See detailed description below. Produces a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.
OC	2	A	3, 9, 12, 14, 16	**Combined Hydronic, Gas Water Heater**. A 75 gallon storage gas water heater is used for both space conditioning and water heating. Hot water baseboards are used for heat distribution. Insulated pipes are used in unconditioned space.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	3	A	3, 9, 12, 14~~, 16~~	**Combined Hydronic, Electric Resistance Water Heater**. An electric water heater is used for both space conditioning and water heating and air is distributed through a fan coil system that delivers air to ducts located in an attic.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	4	A	3, 9, 12, 14, 16	**Combined Hydronic, Heat Pump Water Heater**. An electric heat pump is used for both space conditioning and water heating. Distribution is provided through hot water baseboards. All pipes are located within conditioned space.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	5	B	3, 9, 12, 14, 16	**Control Vent Crawlspace**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	6	A	3, 9, 12, 14, 16	**Zonal Control**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	7	A	3, 9, 12, 14, 16	**Attached Sunspace**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	8	A	3, 9, 12, 14, 16	**Exterior Mass Walls**. See detailed description below. Produces a negative compliance margin.	**Wall R-value**. Increase the interior wall R-value to find the Passing Solution and the Failing Solution.
OC	9	A	3, 9, 12, 14, 16	**Gas Absorption Cooling.** Replace the ~~basecase~~base case cooling system with an absorption gas cooling system with a COP of 3.3. Produces a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.
OC	10	A	6,9,12,14	**Evaporatively-cooled Condensing Unit.** Replace the base case cooling system with an evaporatively-cooled split system with an EER of 11. (Other inputs?) Produces a positive compliance margin.	**Fenestration U-factor.** Increase the fenestration U-factor on all orientations to find the Passing Solution and Failing Solution.
OC	11	A	9,12,14	**Ice Storage DX Air Conditioning Unit.** Replace the base case cooling system with an ice storage air conditioning unit. Specify inputs XXX,YYY. Produces a positive compliance margin.	**Fenestration U-factor.** Increase the fenestration U-factor on all orientations to find the Passing Solution and Failing Solution.

5.2 Dedicated Hydronic Systems

5.2.1 Measure Description

Dedicated hydronic systems have boilers or other heating devices which produce hot water that is distributed through the building for heating. The system is commonly used in other areas of the country. Its use in California is limited. Heat is transferred through the building by water instead of air. Terminal heating units include central fan coils (with ducts), local fan coils (without ducts), baseboards, radiators, radiant floors, or radiant ceilings. If large fan coils are used that distribute warm air through a conventional air distribution system, then the losses of the duct system must be accounted for in the same manner as gas furnaces.

5.2.2 Algorithms and Modeling Assumptions

Dedicated hydronic systems are modeled in a manner similar to a gas furnace, but the AFUE of the boiler is adjusted to account for pipes located outside the conditioned space. The ~~ACM~~compliance program vendor shall include inputs for pipes located in unconditioned spaces. Inputs shall include the pipe length, diameter and insulation, as described in Chapter 2.

Equation R6-1

$$AFUE_{eff} = AFUE - \frac{PL}{RI}$$

Where

$AFUE_{eff}$ = The effective AFUE of the gas boiler that is providing space heat (unitless).

AFUE = The rated AFUE of the boiler (unitless) or thermal efficiency.

PL = ~~Annual~~ Pipe losses (kBtu/h). This may be assumed to be zero when less than 10 feet of the piping (plan view) is located in unconditioned space. Pipe losses are calculated using the procedures described below.

RI = The rated input of the gas water heater (kBtu/h). This is available from the Energy Commission appliance directory and other sources.

If heat is distributed with a fan coil, then the energy of the fan shall be accounted for in the same manner as for furnaces. The default fan energy is 0.005 Wh/Btu of heat delivered by the fan coil (not the entire heating system).

Hydronic systems are permitted when the AFUE is known and can be entered. When water heaters are used in hydronic systems for space heating alone (a separate water heater for domestic service), the water heater functions as a boiler and is required by NAECA to have a minimum AFUE of 0.80. The AFUE of a water heater if tested as a boiler would be approximately equal to the average of the EF (energy factor) and the RE(recovery efficiency), and will generally not meet the minimum NAECA requirement. Water heaters proposed for use in hydronic systems for space heating only must be tested as a boiler using the DOE AFUE and appropriate safety standard test procedures.

5.2.3 Test Description

For prototype A, the base case heating system, consisting of a gas furnace and a forced air distribution system, is replaced with a dedicated hydronic system. The boiler has an AFUE of 85%. Twenty (20) ft of insulated pipe are located in unconditioned space. Heat is distributed with combination of fan coils (20 kBtu/h) and hydronic baseboards (40 kBtu/h). Water is circulated through the hydronic loop by a 1/8 hp pump. The pump motor meets the minimum efficiency requirements of the California appliance efficiency standards. Substituting this system will produce a positive compliance margin. The fenestration U-factor is then reduced to find the passing solution and the failing solution, according to the procedures described in Chapter 5. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The ~~ACM~~compliance program vendor must also demonstrate that the software correctly produces the standard design. This requires that the vendor create a standard design equivalent building that matches the standard design for the system described above. When the standard design equivalent building is entered into the candidate ~~ACM~~compliance program, the proposed design and standard design TDV energy must equal each other. The standard design equivalent energy must also equal the standard design energy for the test case.

5.3 Combined Hydronic Space/Water Heating

5.3.1 Measure Description

Combined hydronic space/water heating is a system whereby a water heater is used to provide both space heating and water heating. Dedicated hydronic space heating systems are also an optional capability covered in Section 5.2. Space heating terminals may include fan coils, baseboards, and radiant surfaces (floors, walls or ceilings).

5.3.2 Algorithms and Modeling Assumptions

For combined hydronic systems, the water heating portion is modeled in the normal manner. For space heating, an effective AFUE is calculated for gas water heaters. For electric water heaters or heat pumps, an effective HSPF is calculated. The procedures for calculating the effective AFUE or HSPF are described below.

When a fan coil is used to distribute heat, the fan energy and the heat contribution of the fan motor must be considered. The algorithms for fans used in combined hydronic systems are the same as those used for gas furnaces and are described in Chapter 4.

If a large fan coil is used and air distribution ducts are located in the attic, crawlspace or other unconditioned space, then the efficiency of the air distribution system must be determined using methods consistent with those described in Chapter 4. Duct efficiency is accounted for when the distribution type is "ducts."

Large Storage Gas Water Heater

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

Equation R6-2

$$AFUE_{eff} = RE - \frac{PL}{RI}$$

Where

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

RE = The recovery efficiency of the gas water heater. A default value of 0.76 may be assumed if the recovery efficiency is unknown. However, this value is generally available from the Energy Commission appliance directory.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space (see Equation R6-6).

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

Storage Electric Water Heater

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

Equation R6-3

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

Where:

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

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation R6-6).

kWI = The kilowatts of input to the water heater.

Heat Pump Water Heater

The HSPF of heat pump water heaters used for space heating in a combined hydronic system is given by the following equations. If the system has a fan coil, the $HSPF_{eff}$ is used. $HSPF_{w/o\_fan}$ is used if there is no fan coil.

Equation R6-4

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

where

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

CZ_{adj} = The climate zone adjustment (see Table RG-7).

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space (see Equation R6-6).

kWI = The kilowatts of input.

RE_{hp} = The recovery efficiency of the heat pump water heater. Equation R6-5 may be used as a default if the recovery efficiency is not known.

Equation R6-5

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

where

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

Pipe Losses

Pipe losses must be considered when pipes between the water heater storage tank and the fan coil or other heating element are located in unconditioned space. To simplify compliance, pipe losses can be ignored when no more than ten feet of pipe (in plan view) is located in unconditioned space. Hourly pipe loss rates (PLR) are given either from Equation R6-7 or from Table R5-2.

Equation R6-6

$$PL = \sum_{i=1}^{n} \frac{FT_i \times PLR_i}{8760}$$

PL = Hourly pipe loss (kBtu/h).

PLR_i = The annual pipe loss rate per foot of length for the i^{th} pipe (kBtu/y-ft).

FT_i = The length in feet of the i^{th} pipe located within unconditioned space. Can be assumed to be zero if less than ten feet in plan view.

n = The number of unique pipe size or insulation conditions.

The annual pipe loss rate per foot of length (PLRi) is calculated from the following equation

Equation R6-7

$$PLR_i = 8.76\left(\frac{T_s - T_a}{\frac{\ln\left(\frac{D_{io}}{D_{po}}\right)}{2\,\pi\,Ki} + \frac{1}{\pi\,ha\,D_{io}}}\right)$$

where

8.76 = Conversion factor from Btu/h to kBtu/y

T_s = Supply Temperature. This is assumed to be a constant 135 F.

T_a = Ambient Temperature. This is assumed to be 60.3 in all California climate zones.

D_{io} = Outside diameter of insulation. ft (actual not nominal).

D_{po} = Outside diameter of pipe, ft (actual not nominal).

Ki = Insulation conductivity, constant 0.023 Btu/h-ft-F

ha = Air film coefficient, constant 1.65 Btu/h-ft^2 -F

Table R5-2 – Annual Pipe Loss Rates (kBtu/y-ft)

	Insulation Thickness		
Nominal Pipe Size	1/2 inch	¾ inch	1 inch
1/2 inch	71.6	60.9	54.2
3/4 inch	91.1	75.8	66.6
1 inch	109.9	90.1	78.1
1 - 1/2 inch	146.7	117.5	100.3
2 inch	182.9	144.3	121.7

5.3.3 Test Description

The tests for combined hydronic systems are based on modifications to prototype A. Three different systems are added as discrete modifications. The test systems are described in Table R5-3

Table R5-3 – Combined Hydronic System Specifications

		Test Number		
		OC2A	OC3A	OC4A
Water Heater Type		SG	SE	HP
Recovery Efficiency	Unitless	0.76	n.a.	n.a.
Rated Input	Btu/h	60,000	n.a.	n.a.
Rated Input	KW	n.a.	5.00	n.a.
Wpump	W	n.a.	60.0	n.a.
EF	Unitless	n.a.	n.a.	2.00
Pipe Length in Unconditioned Space	Ft	100.0	n.a.	n.a.
Annual Pipe Loss Rate	kBtu/y-ft	71.6	n.a.	n.a.

For this series of tests, only the TDV energy for space conditioning is considered. The combined hydronic systems described above are added to the Prototype A building to replace the gas furnace. The ~~ACM~~compliance program vendor shall change the fenestration U-factor on all orientations of the prototype to find the passing solution and the failing solution. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

In addition, the ~~ACM~~compliance program vendor shall demonstrate that the software correctly defines the standard design for combined hydronic. This is achieved by creating and running the standard design equivalent building. For the standard design equivalent building, the TDV energy for the proposed design and the standard design must be equal. The standard design equivalent TDV energy must also equal the TDV energy for the standard design case of this test.

5.4 Controlled Ventilation Crawl Spaces (CVC)

5.4.1 Measure Description

A controlled ventilation crawlspace has insulation installed in the side walls of the crawlspace, instead of in the floor that separates conditioned space from the crawlspace. In addition, special dampers are used to provide the required ventilation for the crawlspace which open ~~in the summer~~when it is warm and close ~~in the winter~~when it is cold.

Eligibility criteria for this measure are presented in the residential standards appendix RA-4.

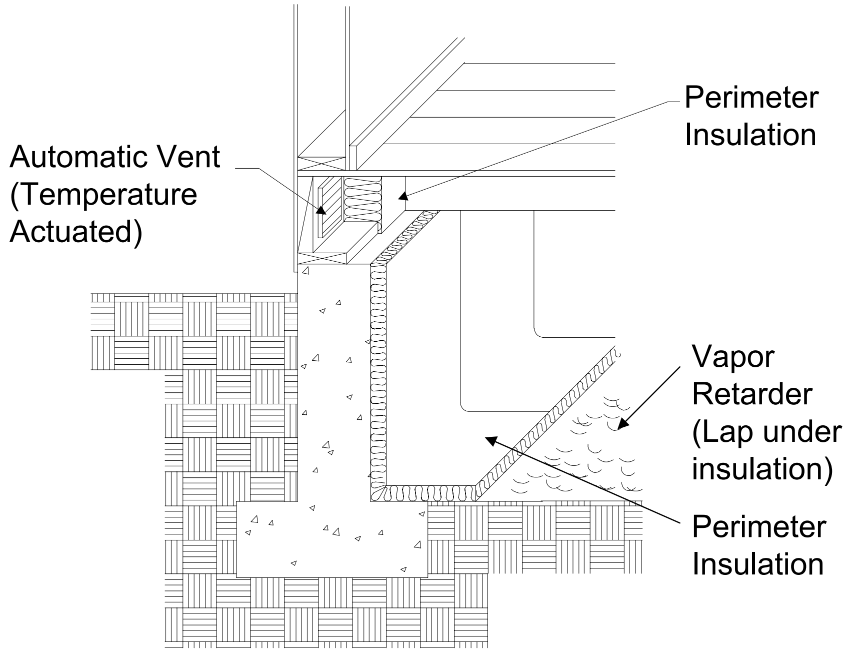


Figure R5-1 – Section at Crawlspace Perimeter

5.4.2 Algorithms and Modeling Assumptions

CVC requires that the ~~ACM~~compliance program have the capability of modeling two thermal zones. The house itself if modeled as a conditioned zone and the crawlspace is modeled as an unconditioned zone.

5.4.3 Test Description

To test this optional capability the ~~ACM~~compliance program vendor shall model prototype B in climate zones 3, 9, 12, 14, and 16. The CVC to be modeled shall have the following features:

- The CVC unconditioned zone has an exterior perimeter length and floor area (i.e., the ground area) equal to the prototype building B. Crawlspace volume is 3,467 ft^3.
- CVC infiltration is modeled using the air changes per hour method and uses 0.22 air changes per hour.
- The floor separating the crawl space from conditioned space is an inter-zone boundary~~. 400 ft² of this floor has~~ with a U-value of 0.~~342~~238, representing an uninsulated~~, uncarpeted~~ floorm (see Table ___ from Joint Appendix 4)~~, and the remainder has a U-value of 0.199, representing an uninsulated, carpeted floor~~.
- Insulation that meets the floor insulation requirements used for compliance is placed in the perimeter walls of the crawl space.
- The crawl space vents are modeled with automatic ~~seasonally~~ temperature operated louvers~~ to minimize ambient conditions within the crawl space~~. When the building is in a heating mode, the vents are assumed to be closed (inlet and outlet are zero). When the building is in a cooling mode, the vents are assumed to be open and the total vent area is 1/150 of the crawlspace floor area or 10.67 ft^2. Half of this is inlet and half outlet.
- The ventilation height difference between the inlets and the outlets is zero. Only wind effects apply. Wind speed is reduced to 25% of that on the weather tape to account for ground level conditions.
- Heat capacity in the crawlspace is 1.4 Btu/F-~~ft²~~ft² of crawlspace area.

This system is expected to produce a positive compliance margin. The heating equipment AFUE is then reduced to find the passing solution and the failing solution. The Energy Commission reference method must pass the passing solution and fail the failing solution. ~~Several eligibility criteria apply for CVC.~~

In addition, the vendor shall demonstrate that the ~~ACM~~compliance program correctly defines the standard design building and calculates the custom budget. The vendor shall create and run the standard design equivalent building for climate zone 12. The proposed design and standard design TDV energy for the be equal. The TDV energy from the standard design equivalent must also equal the standard design TDV energy for this test.

~~6.5Eligibility Criteria~~

~~6.6 **Drainage.** Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.~~

~~6.7 **Ground Water And Soils.** Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the building officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.~~

~~6.8 **Ventilation.** All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.~~

~~6.9 **Foam Plastic Insulating Materials.** Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:~~

~~6.10Fire Safety—UBC Section 1712(b)2. Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.~~

~~6.11Direct Earth Contact—Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slabedge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.~~

~~**6.12 Mineral Fiber Insulating Materials**~~

~~6.13Fire Safety—UBC Section 1713(c). "All insulation including facings, such as vapor barriers or breather papers installed within ... crawl spaces ... shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with UBC. Standard No. 42-1." In cases where the facing is also a vapor retarder, the facing shall be installed to the side that is warm in winter.~~

~~6.14Direct Earth Contact—Mineral fiber batts shall not be installed in direct earth contact unless protected by a vapor retarder/ground cover.~~

~~6.15 **Vapor Barrier (Ground Cover).** A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, shall be laid entirely over the ground area within crawl spaces.~~

~~6.16The vapor barrier shall be overlapped six inches minimum at joints and shall extend over the top of pier footings.~~

~~6.17The vapor barrier should be rated as 1.0 perm or less.~~

~~6.18The edges of the vapor barrier should be turned up a minimum of four inches at the stem wall.~~

~~6.19Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations.~~

~~6.20The vapor barrier must be shown on the plans and installed.~~

~~6.21 Studies show that moisture conditions found in crawl spaces that have minimal ventilation do not appear to be a significant problem for most building sites provided that the crawl-space floors are covered by an appropriate vapor barrier and other precautions are taken. The Energy Commission urges building officials to carefully evaluate each application of this insulating technique in conjunction with reduced ventilation because of the potential for adverse effects of surface water on crawl-space insulation that could negate the energy savings predicted by the procedure.~~

5.5 Zonal Control

5.5.1 Measure Description

Zonal control is one of the optional capabilities based on the ability of a~~n~~ ~~ACM~~compliance program to model more than one conditioned thermal zone at the same time. With zonal control, the sleeping and living areas are modeled separately, each with its own separate thermostat schedule and internal gain assumptions~~. The specifications for zonal control are detailed in Chapter 4~~. Key features are discussed below.

To use this compliance credit the measured air flow in CFM and the fan watt requirements defined in the residential Appendix RE must be met. The total non-closable opening area between zones cannot exceed 40 ft^2. Other eligibility criteria for this measure are presented in the residential standards appendix RA-4.

Algorithms and Modeling Assumptions

The thermostat schedules are in Chapter ~~4 Table R4-1~~3. An alternate set of internal gain schedules is used: one for the living areas of the house and one for the sleeping areas. Both standard schedules and schedules for zonal control are shown in Chapter 4. Internal gains in the living zone shall be 20,000 Btu/day plus 15 Btu/ft². Internal gains in the sleeping zone shall be 15 Btu/ft².

5.5.2 Test Description

For this test, prototype A is divided into living and sleeping zones as shown in Figure R5-2. The boundary between the zones consists of a wall with U-value of 0.29 and net area of 360 ft^2. The wall contains a non-closeable opening of 40 ft^2, modeled with a U-value of 20.0 Btu/h-ºF-ft².

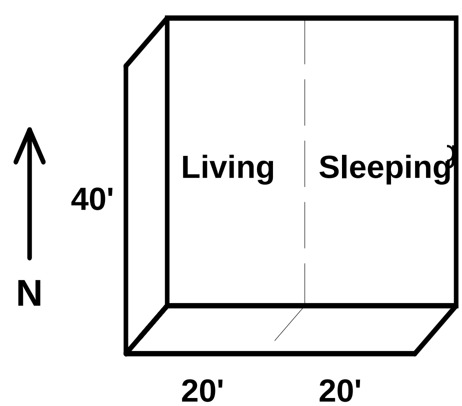


Figure R5-2 – Zoning the Prototype Building

Zonal control is added to prototype A as the discrete modification. The heating equipment AFUE is then reduced to find the passing solution and the failing solution as defined in Chapter 5. This test is performed in climate zones 3, 9, 12, 14, and 16. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The vendor shall also demonstrate that the ~~ACM~~compliance program correctly defines the standard design building and calculates the custom budget correctly. The vendor shall create and run a standard design equivalent building in climate zone 12. In the standard design equivalent building, the proposed design and standard design TDV energy must equal each other. The standard design equivalent TDV energy must also equal the standard design energy for this test.

5.6 Sunspaces

5.6.1 Measure Description

A sunspace is a passive solar system consisting of an unconditioned space facing south or near south. The sunspace has a great deal of fenestration that collects solar energy and stores the energy in thermal mass elements such as a slab floor. The ~~ACM~~compliance program must be capable of modeling two thermal zones in order for the sunspace feature to be approved.

Eligibility criteria for this measure are presented in the residential standards appendix RA-4.

~~6.23.2~~

5.6.2 Algorithms and Modeling Assumptions

Sunspaces shall be modeled as a separate, unconditioned thermal zone. An interzone vent separating the house from the sunspace is controlled to open only when temperature (T) conditions are $T_{house} < T_{desired}$ and $T_{sunspace} > T_{house}$ (in heating mode).

Assumptions for infiltration, heat capacity, solar gain targeting, and zone thermostat temperature settings vary from the conditioned zone. Internal gains in the sunspace are assumed to be zero. Sunspace zone infiltration is modeled using the air changes per hour method and the same infiltration of 0.50 air changes per hour. There are no restrictions on targeting solar gains that enter unconditioned spaces such as sunspaces.

5.6.3 Test Description

For this test, an unconditioned sunspace is added to the south side of Prototype A as illustrated in Figure R5-3 and Figure R5-4. The wall and window separating the sunspace and the house remain the same as in the base case, but the surfaces and vent openings of this wall are changed from exterior types to interzone types. The performance characteristics of sunspace envelope components are the same as for the ~~basecase~~base case prototype. Total vent area is assumed to be 40 ft^2 with an eight foot height difference

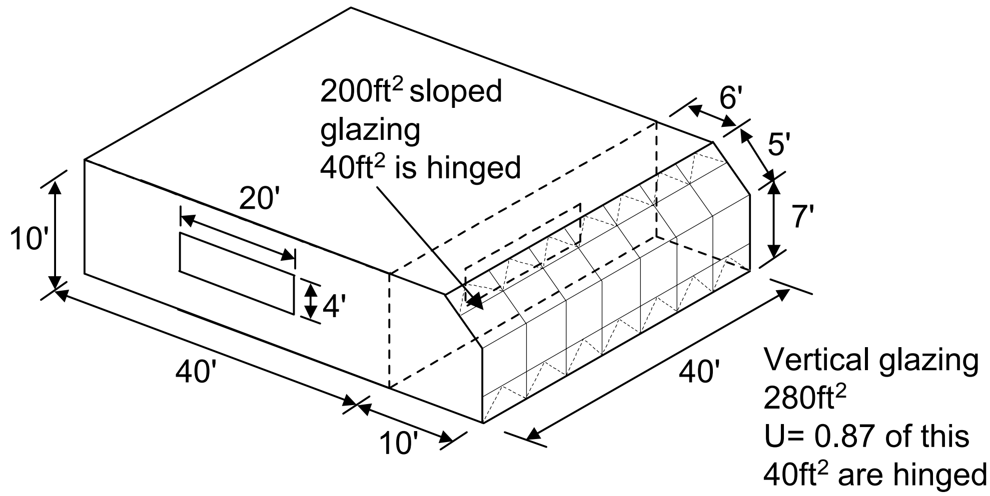


Figure R5-3 – Sunspace Prototype

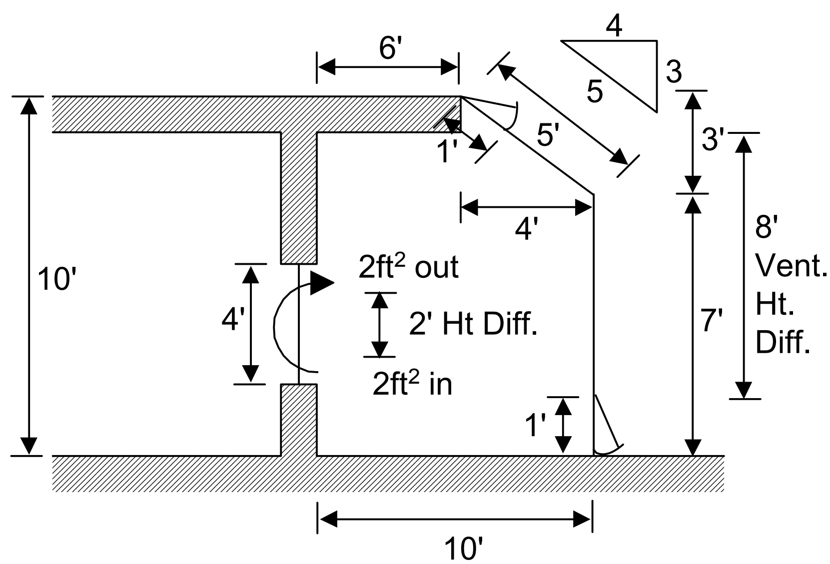


Figure R5-4 – Sunspace Section

The vendor must find the passing solution and failing solution in climates 3, 9, 12, 14, and 16 by varying the heating equipment AFUE. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

The vendor shall also demonstrate that the ~~ACM~~compliance program correctly defines the standard design building and calculates the space conditioning custom budget. The vendor shall create and run a standard design equivalent building for climate zone 12. The standard design equivalent proposed design TDV energy must equal the standard design equivalent standard design TDV energy. These values shall also equal the standard design TDV energy for this test.

5.7 Exterior Mass Walls

5.7.1 Measure Description

Exterior mass walls are walls that are built with a heavy material that absorbs heat as the sun strikes it and releases the heat into the conditioned space after a period of time. Thermal mass has the effect of both dampening and delaying heat transfer.

5.7.2 Algorithms and Modeling Assumptions

The ~~ACM~~compliance program must have the capability to model heat storage in exterior walls. The ~~ACM~~compliance program must accept inputs on the thermal storage capacity of walls. For the Energy Commission reference method, this input is heat capacity (HC) which is entered as Btu/ºF-ft^2. However, ~~ACM~~compliance programs may take the input in other ways acceptable to the Energy Commission.

5.7.3 Test Description

The test for exterior mass walls is made using prototype A in five climate zones: 3, 9, 12, 14, and 16. All of the exterior walls of the building are assumed to be of mass construction: The mass is assumed to be 12 inches thick with a volumetric heat capacity of 10 Btu/F-ft^3 and a conductivity of 1.064. The outside surface of the mass wall is modeled with a U-value of 2.63 (R = 0.38) to approximate the effect of an air film. Insulation is assumed to be on the inside surface of the wall. The ~~ACM~~compliance program vendor shall find the passing solution and the failing solution by varying the R-value of the interior insulation. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The ~~ACM~~compliance program vendor shall also demonstrate that the ~~ACM~~compliance program correctly defines the standard design building and calculates the custom budget. The ~~ACM~~compliance program vendor shall create and run a standard design equivalent building for climate zone 12. For the standard design equivalent building, the TDV energy for both the standard design and proposed design cases must be equal. They must also equal the TDV energy for the standard design case in this test.

5.8 Gas Cooling

5.8.1 Measure Description

Gas cooling provides an opportunity to reduce peak electric demand. With gas absorption, a chemical process is used to provide cooling.

As a minimum capability, ~~ACM~~compliance programs must be able to accept a COP input, and report the use of gas cooling in the *Special Features and Modeling Assumptions* section of the reports. The ~~ACM~~compliance program user shall also attach manufacturer's equipment specifications showing the COP95, CAP95 and PPC of the equipment.

5.8.2 Algorithms and Modeling Assumptions

See Chapter 3.

5.8.3 Test Description

To determine the accuracy of modeling cooling the ~~ACM~~compliance program vendor shall perform the test listed in Table R5-1. The passing and failing solutions are determined by varying the fenestration U-factor.

5.9 Solar Thermal Water Heating

D.Overview

This section describes the acceptable methods for calculating the solar savings multiplier (SSM). Two methods are provided here and ACMcompliance programs can become certified for one or both.

- The first method has limited scope. It may only be used for water heating systems serving individual dwelling units. In addition the solar system has to be rated by the Solar Rating and Certification Corporation (SRCC) with the OG 300 method.
- The second method is more general in scope and may be used for any active solar water heating systems in single family or multi-family buildings.

Energy benefits of solar water heating systems shall be calculated using the procedures described in ACM Appendix RGRE-20052008. When a credit is taken for nondepletable energy, the ACMcompliance program standard input reports must flag this and include a statement in the *Special Features and Modeling Assumptions* section of the reports. The ACMcompliance program user must also attach SRCC documentation for the system or collectors used and either Commission approved worksheets if the OG 300 method is used or an F-Chart computer run printout if the second method is used.

Integration in ACMcompliance Solar water heating calculation procedures may be integrated in residential ACMcompliance programs or they may be stand-alone calculation procedures. The descriptions, algorithms, and test procedures described in this section apply to either case. Contact the Energy Commission for information on how to obtain approval of a stand-alone solar water heating calculation procedure.

5.9.1 Individual Dwellings Rated with the OG 300 Procedure

Measure Description

Residential solar systems can include many types of systems. The simplest system is the integrated collector storage (ICS) system which is basically a dark colored tank mounted behind glazing. Thermosiphon systems have a storage tank mounted above the collectors so that the fluid (usually water) can circulate naturally as it is heated in the collectors. Forced circulation systems use a pump to circulate a fluid from the storage tank to the collector. For forced circulation systems, the collectors may be located remotely from the storage tank.

All of these residential scale solar systems are rated by the Solar Rating and Certification Corporation (SRCC). The SRCC OG 300 procedure tests a complete system put together by the manufacturer, including the collectors, the pumps, controls, storage tanks and backup system (SRCC refers to the backup system as the auxiliary system). The OG 300 procedure uses the TRNSYS computer program to calculate the rating for the system as a whole and produces a Solar Energy Factor (SEF). The SEF is a unitless term and is meant to be compared to the energy factor (EF) published for conventional water heaters. Since the rated system includes the backup water heater, the SEF depends on whether the system was rated with electric or gas backup. It also accounts for the efficiency of the backup system. The SRCC publishes data on all systems and collectors hat have been rated.

Algorithms and Modeling Assumptions

Modeling assumptions and algorithms are documented in ACM Appendix RG-20052008.

Eligibility Criteria

Eligibility criteria for solar water heating systems are in Residential Appendix RA-10

In order to use the OG-300 method, the system must satisfy the following eligibility criteria:

The collectors must face within 35 degrees of south and be tilted at a slope of at least 3:12

•The system must be installed in the exact configuration for which it was rated, e.g. the system must have the same collectors, pumps, controls, storage tank and backup water heater fuel type as the rated condition.

•The system must be installed according to manufacturer's instructions.

•The collectors shall be located in a position that is not shaded by adjacent buildings or trees between 9:00 AM and 3:00 PM (solar time) on December 21.

Test Description

To determine the accuracy of modeling solar systems using the OG 300 method the ACMcompliance program vendor shall perform the test listed in Table R6-4. The ACMcompliance program vendor modifies the gas water heating base case and reports the solar savings fraction (SSF) for both the proposed design and the standard design. The Energy Commission reference method shall predict SSF energy within 5% of the candidate ACMcompliance program.

Table R5-4 – OG-300 Solar Systems Tests

Type	*Test*	*Prototypes*	*Climates*	*Optional Capability (Discrete Modification(s))*
SS	1	A	3, 9, 12, 14, 16	**Solar System with Electric Backup.** Add a solar system with electric backup that has a SEF of 2.0.
SS	2	A	3, 9, 12, 14, 16	**Solar System with Gas Backup.** Add a solar system with gas backup that has a SEF of 1.0

5.9.2 Water heating Systems for Individual Dwellings or Multi-Family Buildings Based on Collector Tested Using the OG-100 Procedure

Measure Description

The solar thermal systems described in this section have general applicability for water heating applications. They may be used for multi-family or single family water heating systems. Any solar water heating system that uses forced circulation, and collectors rated under the SRCC OG-100 method can use this approach. Situations where this approach might be used are: a single family residences with large hot water demand, solar water heating systems for multi-family buildings, and where a single family system cannot meet the eligibility criteria for OG 300 rated systems. Minimum Reports.

A report shall be created that includes the parameters listed in Table R5-5 and Table R5-6.

Prototype

For this series of tests thermal loads and water heating budget shall be based on water heating prototype E (see chapter 5).

Table R5-5 – Prototype Solar System

Parameter	Value
Collector Slope	4:12
Collector Azimuth	180 º (due south)
Collector Area	Four collectors as described below.
Collector Performance (OG 100)	SRCC Certification Number 100-1998-0018 Yint = 0.530, Slope = -0.250 Btu/h-ft²-ºF, A = 32.9 ft²
Storage Tank Size	500 gallons
Pumping	¼ hp pump between collectors and storage tank
Freeze Control	Drain-down

Algorithms and Modeling Assumptions

The Energy Commission reference method is based on the F-Chart procedure, which is available from multiple sources. Modeling inputs and limits for the F-Chart reference method are defined in ~~ACM~~ Appendix RG-~~2005~~2008.

Test Description

To determine the accuracy of modeling solar systems using the SRCC OG100 method, the vendor of the integrated ~~ACM~~compliance program or stand-alone solar application shall perform the test listed in Table R5-6. The integrated ~~ACM~~compliance program or stand-alone solar application shall predict a solar savings fraction (SSF) for the cases in Table R5-6 within plus or minus 3% of the SSF predicted by the Energy Commission reference method.

Table R5-6 – OG 100 Solar System Tests

Type	*Test*	*Prototypes*	*Climates*	*Optional Capability (Discrete Modification(s))*
SS	3	ºF	All	**~~Basecase~~Base case.** The ~~basecase~~base case solar system with the schedule of loads shall be simulated in all climate zones.
SS	4	ºF	3, 9, 12, 14, 16	**Collector Orientation.** Vary the orientation of the collectors from due south (the ~~basecase~~base case) to 45 degrees east of south.
SS	5	ºF	3, 9, 12, 14, 16	**Collector Slope.** Change the collector slope from the 4:12 pitch in the ~~basecase~~base case to 12:12.
SS	6	ºF	3, 9, 12, 14, 16	**Collector Performance. Substitute the following collector.** SRCC Certification Number 100-1981-0085A Yint = 0.737, Slope = -0.805 Btu/h-ft²-ºF, A = 32.3 ft²
SS	7	ºF	3, 9, 12, 14, 16	**Collector Area.** Double the number of collectors
SS	8	ºF	3, 9, 12, 14, 16	**Storage Tank Size.** Reduce the storage tank size To 200 gallons.
SS	10	ºF	3, 9, 12, 14, 16	**Circulation Pump.** Increase the size of the circulation pump from ¼ hp to ½ hp.
SS	11	ºF	3, 9, 12, 14, 16	**Freeze Control.** Change the freeze control from drain-down to glycol.

~~Cooling System Energy (6.4)~~

5.10 Evaporatively Cooled Condensing Units

5.10.1 Measure Description

Evaporatively cooled condensers work by replacing the outdoor unit of a standard air cooled air conditioner with a water cooled unit. These are not swamp coolers and do not introduce any humidity to the conditioned space. From the outdoor unit to the air handler, these systems are the same as conventional air conditioners. Evaporatively cooled condensers take advantage of the fact that the wet bulb temperature is lower than the dry bulb temperature, reducing the energy consumption of the compressor. Compliance savings in cooling climates typically range around 40% of the cooling budget.

5.10.2 Algorithms and Modeling Assumptions

The calculation of the hourly cooling electricity consumption shall be determined using Equation R3-35 and Equation R3-37. Equation R6-10, Equation R6-8, and Equation R6-9 shown below shall replace Equation R3-38 and Equation R3-41, respectively. Equation 3-36, Equation R3-39, and Equation R3-42 do not apply to evaporatively cooled condensing units.

Equation R6-8
$$EERnfa = (1.0452 * EERa + 0.0115 * EERa^2 + 0.000251 * EERa^3) * Ftxv * Fair * Fsize$$

Equation R6-9
$$EERnfb = (1.0452 * EERb + 0.0115 * EERb^2 + 0.000251 * EERb^3) * Ftxv * Fair * Fsize$$

where

EERa = EER at 75o F wet bulb listed with ARI

EERb = EER at 65o F wet bulb published by the manufacturer in accordance with ARI guidelines

Ftxv = TXV factor (Default value of Ftxv is 0.96. If TXV installation is verified, Ftxv = 1.0)

Fair = Air flow factor (Default value of Fair is 0.925. If air flow is verified, Fair = 1.0)

Fsize = Sizing factor (Default value of Fsize is 0.95. If the equipment is sized using the method in Appendix RF, Fsize = 1.0)

Equation R6-10
$$CEt = EERnfa - ((EERnfa - EERnfb) * 7.5) + ((EERnfa - EERnfb)/10)xTwb$$

where

Twb = Outdoor wet bulb temperature taken from the Energy Commission weather file.

CEt = Energy efficiency ratio at a particular wet bulb temperature. EERnfa and EERnfb are calculated using equation R4-40(eca) and R4-40(ecb).

ACM developers must cause inputs to be linked between the credit for evaporatively cooled condensing units and duct sealing so that errors cannot be made by the program user. If the user chooses evaporatively cooled condensing units, the user must be notified that duct sealing is also required, and compliance results must not be determined until both measures are properly selected.

ACMs also must also automatically list “Evaporatively Cooled Condensing Unit” as a Special Feature and provide both the EERa (measured at outdoor wetbulb temperature of 75o F) and EERb (measured at outdoor wetbulb temperature of 65o F). ACMs also must automatically list “Evaporatively Cooled Condensing Unit” and

"Duct Sealing" on page 4 of the CF-1R in the list of "Special Features Requiring HERS Rater Verification when the user chooses to take compliance credit for evaporatively cooled condensing units.

5.10.3 Test Description

None

5.11 Ice Storage Air Conditioners (ISAC)

5.11.1 Measure Description

The ISAC system consists of a water tank containing refrigerant coils that cool the water and convert it into ice. To ensure good heat transfer, the ice tank coils are made of copper. These Helical copper coils can accommodate expansion and contraction resulting from the change in the water/ice tank temperature. The refrigerant is compressed in a compressor and then cooled in an air-cooled condenser. The liquid refrigerant then is directed through the coils in the water tank to make ice or to the air handler coils to cool the building. The compressor runs continuously as long as there is demand for cooling and/or demand for making ice. During peak periods, if there is enough ice capacity, the compressor remains turned off. At night, the compressor usually runs to make ice. However, if there is a cooling load on the building at night, which can occur in the hot central valley or inland regions and the deserts of Southern California, the compressor can alternate between ice making and cooling the building. A valve in the refrigeration management system is the only other moving part. The ice tank is insulated and this compliance option takes into account the energy losses from the tank surface. The tank is made of corrosion resistant material. Water quality in the ice tank does not change with the operation of the system.[7]

Eligibility criteria for this measure are presented in the residential standards appendix RA-4.

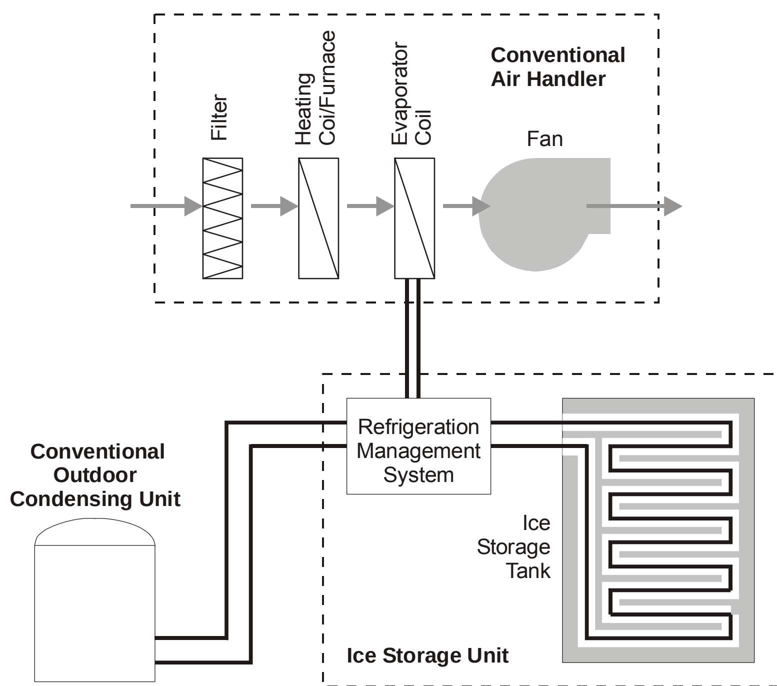


Figure R5-5 – Ice Storage Air Conditioners (ISAC)

5.11.2 Algorithms and Modeling Assumptions

The algorithms and modeling assumptions for low-rise residential buildings are located in Appendix C of "Ice Storage Air Conditioners, Compliance Options Application, Staff Report", May 2006, CEC-400-2006-006-SF.

Compliance software developers must cause inputs to be linked between the credit for ISAC systems and duct sealing and no credit for Thermostatic Expansion Valve so that errors can not be made by the program user. If the user chooses ISAC systems, the user must be notified that duct sealing is also required, and compliance results must not be determined until both measures are properly selected.

Compliance software also must automatically list "Ice Storage Air Conditioning Systems" as a Special Modeling Feature and shall automatically generate the CF-6R form. Samples of the modified forms are in Appendix A of "Ice Storage Air Conditioners, Compliance Options Application, Staff Report, May 2006, CEC-400-2006-006-SF.

Since the initial application, several modifications have been made to the residential model.

- The ability to specify the peak months and a peak melting start time has been added. The algorithm now reads and uses the peak month specifications (see PeakMonth to OpStMeltHour below) from the nonresidential portion of the description file to determine the melt start hour
- The model can now model a backup (second) compressor. If the variable IBBackup is set to true, the system is assumed to have a second compressor, allowing the primary compressor to provide the maximum possible ice make cycle.
- The model can now default to the compliance program SEER 13 model when there is no ice stored. If the variable IBSEER13 is set to true, the model uses the EER passed through from the compliance program algorithm for air conditioners for the zero ice stored case instead of the zero row case from the description file.
- Several changes were made to enable the algorithm to account for the tank losses when the tank is empty during the operating season and to remove the double counting of the 0.88 sensible heat multiplier on the gross cooling output that is already accounted for in the calling program.

The compliance program calculates the hourly cooling electricity consumption for ice storage air conditioning systems using Equation R6-8. This equation is of the same form as Equation R4-34 used to calculate the electricity consumption of standard air conditioners.

Equation R6-8 $$ACkWh = (FanWh + CompWh + PPCWh) / 1{,}000$$

Where

ACkWh = Air conditioning kWh of electricity consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

FanWh= Fan watt-hours for a particular hour of the simulation. This is calculated using Equation R4-38.

CompWh= Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R6-9.

PPCWh= Parasitic Power watt-hours for a particular hour of the simulation. This is calculated using Equation R6-10.

Test Description

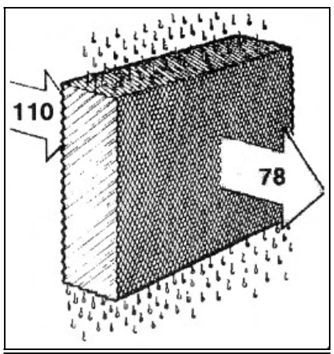
None.

5.12 Evaporative Coolers

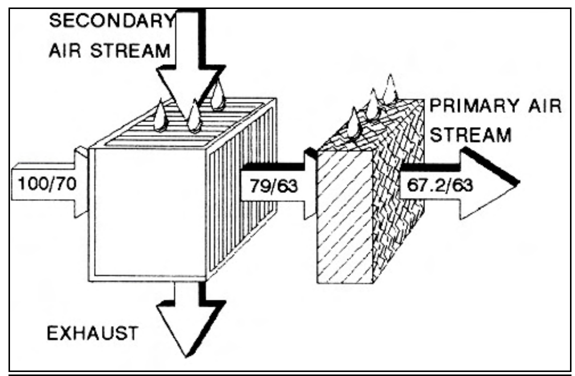
~~1.11.1~~5.12.1 Measure Description

Evaporative cooling offers significant energy and demand benefits over conventional vapor compression cooling by substituting blower(s) and pump(s) for energy intensive compressors and air handling components. The technology is best suited for dry climates where direct and/or indirect cooling of the supply air stream can occur without compromising indoor comfort. Evaporative cooling can fully eliminate air conditioning in mild climates or in intelligently designed homes in more severe cooling climates. The potential of evaporative cooling to play a key role in California's energy future is improving as newer homes increasingly incorporate measures reducing cooling loads, allowing evaporative coolers to meet the load.

The figures below render the direct evaporative cooling process and the indirect-direct process where an indirect heat exchanger pre-cools outdoor air prior to the direct evaporative stage. The indirect stage does not add moisture to the supply air stream. Due to indoor humidity concerns, evaporative cooler compliance credit is offered only for indirect and indirect-direct evaporative coolers.



Direct Evaporative Cooler



Indirect-Direct Evaporative Cooler

Figure R5-6 – Evaporative Coolers

~~1.11.2~~5.12.2 Algorithms and Modeling Assumptions

Evaporative coolers shall be modeled on an hourly basis using Title 20 performance data (effectiveness, airflow, and power) and the algorithms presented in this section. Indirect and indirect-direct evaporative cooler efficiencies should be fixed 13 "EER" and should not be degraded with changing outdoor or indoor conditions. The projected cooling savings (~30% for indirect and indirect-direct) are consistent with the privious Title 24 treatment of evaporative coolers.

The algorithms and modeling assumptions for evaporative coolers are documented in "Measure Information Template: Residential Evaporative Cooling", 2008 California Building Energy Efficiency Standards, Southern California Gas Company (SCG), May 8, 2006 (Revised August 16, 2007). This document shall be used for modeling of evaporative coolers.

The key performance descriptor is saturation effectiveness, ε, defined as:

Equation R6-11

$$\varepsilon = \frac{t_{db} - t_s}{t_{db} - t_{wb}}$$

where,

t_{db} and t_{wb} = outdoor dry and wet bulb temperatures, respectively, and

t_s = supply air temperature

A saturation effectiveness of 100% indicates the system is providing supply air at a temperature equivalent to the outdoor wet bulb temperature. Direct evaporative systems, which pass outdoor air through wetted media, typically achieve an effectiveness of 70-90%, while indirect-direct systems can achieve an effectiveness of 90-100%.

The required inputs for evaporative cooler modeling are the Title 20 parameters: system maximum airflow, effectiveness at full speed, and total system power. The algorithm to calculate hourly EC cooling capacity is shown in Equation R6-12.

Equation R6-12

$$ClgCap = 1.08 \times Q \times (Tin \ \ (Tdb - \varepsilon \times (Tdb - Twb))$$

where

Q = airflow (cfm)

Tin = indoor dry bulb temperature

Tdb = outdoor dry bulb temperature

ε = system effectiveness (fraction) expressed in terms of “media saturation efficiency” or “cooling efficiency”, depending upon equipment type, according to Title 20 appliance listing regulations

Twb = outdoor wet bulb temperature

There are two performance issues that the modeling methodology addresses. The first issue relates to rising indoor relative humidity during periods with extended EC operation. Since modeling of indoor air moisture levels is a complicated process beyond the capability of standard building simulation models, a simplified algorithm is used to prohibit evaporative cooler operation during hours when extended operation under unfavorable conditions is likely. The algorithm will filter, based on outdoor wet bulb temperature, and disallow EC operation when outdoor wet bulb temperatures exceed 70 F.

The second performance issue relates to evaporative cooler capacity limitations. Since evaporative coolers are 100% outdoor air systems with capacity limited by outdoor wet bulb temperature, they are more prone to experience diminished cooling capacity than a conventional vapor compression system. Each hour with calculated load, the algorithm will check both outdoor wet bulb temperature and verify that the cooling capacity (“ClgCap”) is greater than the calculated house cooling load. If either of these filters disallows EC operation, the program assumes that the hourly cooling load is met by a 13 SEER air conditioner (i.e. zero evaporative cooler credit for that hour). If the filters allow evaporative cooler operation, a fixed efficiency of 13 Btu/Wh (or EER) is applied to determine hourly energy use. This fixed EER approach is used to limit the potential evaporative cooler compliance credit. Calculated hourly energy use is then valued based on the TDV value for that hour. The flow chart shown below depicts the modeling approach.

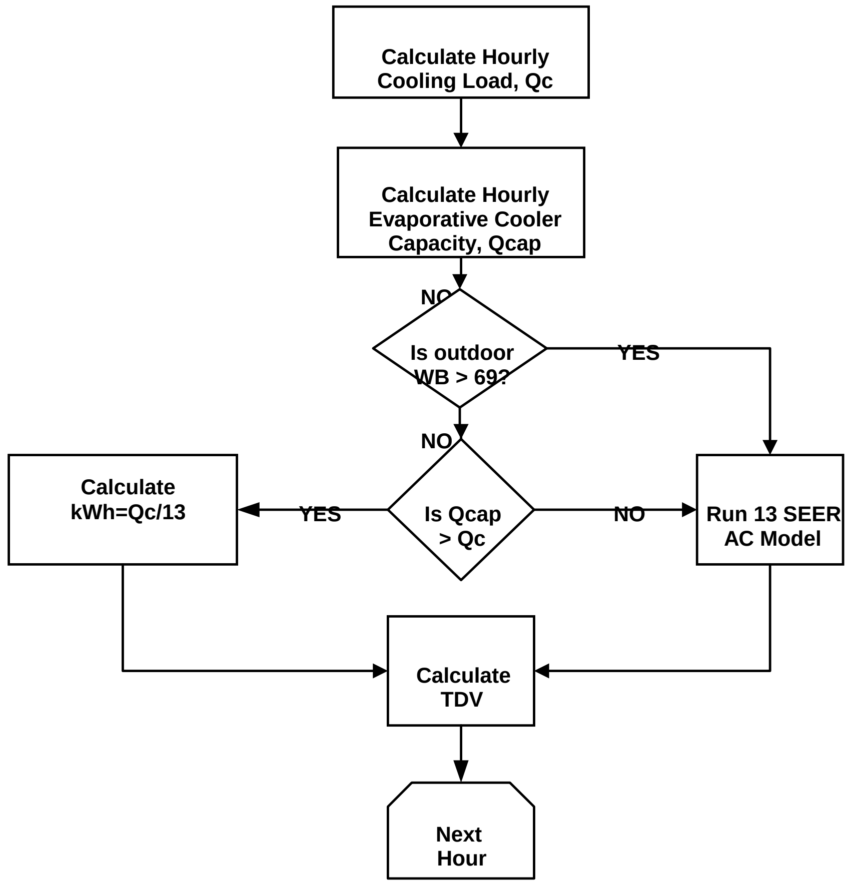


Figure R5-7 – Evaporative Cooler Calculation Flow Chart

The proposed modeling methodology deviates from current ACM modeling rules for conventional air conditioning by requiring the user to model a specific evaporative cooler unit for Title 24 compliance. If the specified equipment being modeled is significantly undersized, or of low evaporative efficiency, the compliance run results will demonstrate reduced compliance credit. The proposed methodology provides feedback insuring that the specified equipment is both adequately sized and of sufficient efficiency for the load.

5.12.3 Test Description

None

5.13 New Solar Home Partnership (NSHP) Compliance Option

This compliance option requires above code energy efficiency along with installation of photovoltaic systems. It aligns with the requirements of the NSHP program which provides expected performance based incentive for photovoltaic installations on new residential construction.

5.13.1 Energy Efficiency Requirements

Measure Description

The builder can choose to comply with either of two tiers of energy efficiency measures:

1) Tier I – 15 percent reduction in the residential building's combined space heating, cooling and water heating energy compared to the current *Title 24 Standards*;

2) Tier II – 35 percent reduction in the residential building's combined space heating, cooling and water heating energy and 40 percent in the residential building's air conditioning energy compared to the current *Title 24 Standards*.

A report shall be created that includes the Tier I or II achieved and a HERS verification notification will be printed for all measures used to achieve this level, irrespective of credit taken for any special HERS verification measures (as described in Chapter 2). Field verification of measures will be required to be consistent with current Title 24 Standards field verification procedures and protocols. Solar water heating may be used to assist in meeting the energy efficiency requirements of either Tier I or Tier II. Only energy efficiency documentation completed by persons who are Certified Energy Plans Examiners (CEPE) by the California Association of Building Energy Consultants (CABEC) will be accepted.

Algorithms and Modeling Assumptions

The modeling assumptions and results will be consistent with the current Title 24 standards.

5.13.2 Photovoltaic Performance Calculation

Measure Description

Under the NSHP compliance option the expected performance of PV systems will be reported. To qualify under this measure the PV systems will be at least 1 KW AC capacity and installed in conjunction with higher energy efficiency requirements as stated above. The equipment used will need to be certified and tested under the standards as specified in the NSHP Guidebook Appendix 3 and listed with the Energy Commission as eligible equipment. The annual production calculated is weighted with TDV multipliers on an hourly basis to encourage systems which are installed to address the peak load mitigation. Additionally, third-party field verification will be conducted to assess whether systems have been installed consistent with the characteristics used to determine estimated performance. An expected performance table is generated for each system specifically which is used to ensure minimum performance at given conditions.

Prototype

No tests for this measure, just the review of appropriate incorporation of the PV calculator.

Algorithms and Modeling Assumptions

The Energy Commission reference method is based on the CECPV engine, which is available from the commission upon request. Modeling inputs and limits for the PV calculator are defined in Appendix RB-2008.

6. Compliance Supplement

Each ~~ACM~~Compliance Software vendor is required to publish a Compliance Supplement to the normal ~~program~~software users manual. This requirement may be met with a help manual incorporated into the software, however, a printed version of the help manual which include all help items must be submitted with the application. The Compliance Supplement serves two major purposes. First, it helps building permit applicants to use the ~~ACM~~Compliance Software correctly and to prepare complete documentation of their analyses. Second, it helps building officials to check permit applications for compliance with the low-rise residential Building Energy Efficiency Standards. As a result, it helps to assure that both the performance standards and the ~~ACM~~Compliance Software are used properly.

The Compliance Supplement shall describe the specific procedures for using the ~~ACM~~Compliance Software for compliance with the Building Energy Efficiency Standards. The supplement shall provide instructions for preparing the building input, using the correct fixed and restricted inputs, and for using each of the optional capabilities for which the ~~ACM~~Compliance Software is approved. Also included are procedures for generating the standard reports and documenting the analysis. A sample of a properly documented building analysis shall be included.

All Compliance Supplements shall be written in a clear and concise manner and with an ~~common~~ organization and format that will allow users to quickly locate the topic and understand the instructions. ~~Variations in format may be approved by the Energy Commission, however, to allow for the differences between ACMs. This will assure consistency between the compliance supplements of different ACMs, simplifying the enforcement task of building officials.~~ Also, vendors of approved ~~ACM~~Compliance Software are required to make copies of their compliance supplement available to all building departments in California.

The following sections describe the information that shall be included in all compliance supplements. It also presents the required organization for that information.

6.1 Energy Commission Approval

This section includes a copy of the official Energy Commission notice of approval of the ~~ACM~~Compliance Software. The notice may include restrictions or limitations on the use of the ~~ACM~~Compliance Software. It will also include the date of approval, and may include an expiration date for approval as well. The notice will indicate which optional capabilities the ~~ACM~~Compliance Software is approved for and other restrictions on its use for compliance. The Energy Commission will provide this notice upon completion of evaluation of the ~~ACM~~Compliance Software application.

6.2 Software Capabilities

This section discusses the program capabilities, with supporting written material explaining, as necessary, how the ~~ACM~~Compliance Software treats each one. Reference may be made to non-compliance sections of the ~~ACM~~Compliance Software Users Manual for more complete descriptions, if they exist.

6.3 Standard Input/Output Report

Inputs files shall be organized so that data is presented in the same order as that used by the required output reports.~~This section explains how to use the program to prepare the standard input/output reports.~~

6.4 Fixed and Restricted Inputs

Approved ACMCompliance sSoftware shall automatically use the standard fixed and restricted inputs for the standard design run. It shall also default to the standard assumptions for the proposed design run. When the alternative fixed and restricted inputs are used for the proposed design run, the ACMCompliance Software shall report this in the *Special Features and Modeling Assumptions* sections of the standard reports.

This section of the Compliance Supplement explains the fixed and restricted inputs and how they are invoked in the ACMCompliance Software. This is especially important if the ACMCompliance Software offers the possibility of non-compliance runs which can deviate from the fixed and restricted inputs.

6.5 Preparing Basic Input

This section covers the basic use of the ACMCompliance Software for compliance. Optional capabilities are described in greater detail. Reference may be made to the users manual, but this section should include a complete summary of all inputs and/or commands necessary for compliance.

6.6 Optional Capabilities

This section explains the procedures for using each of the optional capabilities of the ACMCompliance Software. It is a parallel section to the basic inputs section above. The section for each optional capability should explain how to prepare inputs, how to document assumptions, and what the limitations are of each analysis capability.

6.7 Special Features and Modeling Assumptions

This section explains the use of the Special Features and Modeling Assumptions listing to highlight the importance of verifying the special features and the aspects of those features that were modeled to achieve compliance.

6.8 Field Verification

This section explains the use of the Field Verification and Diagnostic Testing listing to highlight the special features that require diagnostic testing by a certified home energy rater under the supervision of an Energy Commission approved HERS provider to assure proper installation and verification. This section may rely on the information provided in Chapter 7Reference Appendix RA2, other sections of this manual, or may refer to other Commission documents.

6.9 Checklist for Compliance Submittal

This section should contain a concise checklist of all items that shall be included in a compliance submittal to a building official using the ACMCompliance Software.

6.10 Sample Compliance Documentation

This section should include a complete set of compliance documentation for a sample building. The building need not be overly complex, nor need it include every programsoftware capability. The example should, however, include all documentation and standard reports that would normally be submitted. This example will serve as a model to ACMCompliance Software users and building officials of what a proper compliance submittal should look like.

6.11 Compliance Statement

The following statement shall appear within the first several pages of the Supplement:

[~~ACM~~Compliance Software Name] may be used to show compliance with California's Residential Building Energy Efficiency Standards.

6.12 Related Publications

The Compliance Supplement should refer users to the following related Energy Commission publications and where to obtain them:

- ~~2005~~2008 *Building Energy Efficiency Standards* (P400-07~~3~~-001F)
- ~~2005~~2008 *Residential Manual* (publication number unknown at time of printing)

Both publications are available from:

California Energy Commission
Publications Unit
1516 Ninth Street
Sacramento CA 95814
(916) 654-5200

End Notes

These notes are an explanation of the changes that have been made to the Standards. They are informational only and are not part of the Standard.

1 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

2 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

3 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

4 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

5 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

6 From Wilcox, Residential Indoor Air Quality Ventilation New Mandatory Requirements for Indoor Air Quality Ventilation in Low Rise Residential Buildings. Posted: July 31, 2006. (PDF file, 22 pgs, 608 kb)

7 Description is taken from Ice Storage Air Conditioners, Compliance Options Application, Staff Report, May 2006, CEC-400-2006-006-SF

Residential ACM Appendix A – 2008

RACM Appendix A – Certification of Alternative Calculation Method

Energy Efficiency Standards for Residential Buildings, Sections 150 to 152

I, _______________________________________ (name), certify that this alternative calculation method (compliance program), _______________________________________ (name of ~~ACM~~compliance program), version number ____________, dated ____________________, developed by, _______________________________ (personnel or company), _______________________________ (address) _______________________________ (city, state) ________ (zip), passes all of the ACM tests and gives results that are reliable and accurate when used for calculating custom budgets and annual energy use estimates to comply with CEC (California Energy Commission) regulations, subject to the fixed and restricted assumptions specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2008 Energy Efficiency Standards for Residential Buildings*, and the fixed and restricted inputs specified in the manuals describing the use of this method (Users Manual and Compliance Supplement thereto). I certify that the calculation of energy use in buildings, following the instructions in the manuals, and using accurate and complete plans and specifications for a building will achieve reliable and accurate energy analysis results with this ~~ACM~~compliance program. Moreover, the calculations are verifiable when modeling the same building and accurately applying the fixed and restricted assumptions and inputs mentioned above. I further certify that all variables used by the program that are not subject to ready verification in the plans and specifications or that are subject to occupant use are either fixed, carefully restricted, or defaulted in this ~~ACM~~compliance program.

I also certify that the inputs, default values, and assumptions specified for compliance runs in the manuals, and used in the accompanying application for the CEC residential ~~ACM~~compliance program approval, are consistent with the inputs, default values, and assumptions specified by the CEC in the *Alternative Calculation Method (ACM) Approval Manual for the 2008 Energy Efficiency Standards for Residential Buildings* for use when generating standard design budgets and annual energy use estimates. I also certify that all specific inputs, variables, and assumptions needed to achieve the accuracy required to pass the capability tests in the *ACM Approval Manual* are either not subject to user variation, are defaulted to the values used for compliance, or are clearly specified as restricted or required inputs in the manuals for the ~~ACM~~compliance program. In addition, the manuals clearly indicates that an easily verified list of the actual values of any such variables used for performance approach compliance which are subject to programmatic or user variation are to be included with the compliance documentation supplied by a building permit applicant to the enforcement agency. In summary, I also certify that the results of this alternative calculation method as specified in the manuals for the ~~ACM~~compliance program in conjunction with an accurate and adequate set of plans and specifications for a building are not subject to significant variation by the manipulation of unrestricted user specified inputs that are difficult or impossible to verify.

In certifying the reliability and accuracy of this ~~ACM~~compliance program, I certify that the results of this ~~ACM~~compliance program 's calculations, algorithms and assumptions are open to inspection by any individual or State entity, that this ~~ACM~~compliance program may be challenged for its validity and accuracy as specified by the ACM Approval Manual, and that if challenged, I will prepare an adequate response or face possible withdrawal of ~~ACM~~compliance program approval.

This certification is based upon the tests and requirements specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2008 Energy Efficiency Standards for Residential Buildings,* and upon personal knowledge and experience with the use of this alternative calculation method.

Signed Date Title

Space Conditioning Tests (SC)

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test SC00 – Basecase Simulations

Enter the TDV energy for the standard design and the proposed design – values should match.

Test Label	TDV Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SC00A01			
SC00A02			
SC00A03			
SC00A04			
SC00A05			
SC00A06			
SC00A07			
SC00A08			
SC00A09			
SC00A10			
SC00A11			
SC00A12			
SC00A13			
SC00A14			
SC00A15			
SC00A16			
SC00B01			
SC00B02			
SC00B03			
SC00B04			
SC00B05			
SC00B06			
SC00B07			
SC00B08			
SC00B09			
SC00B10			
SC00B11			
SC00B12			
SC00B13			
SC00B14			
SC00B15			
SC00B16			

Test SC01 – SEER vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC01A03						
SC01A09						
SC01A12						
SC01A14						
SC01A16						

Test SC02 – Ceiling U-factor vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC02A03						
SC02A09						
SC02A12						
SC02A14						
SC02A16						

Test SC03 – Wall U-factor vs. West Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC03A03						
SC03A09						
SC03A12						
SC03A14						
SC03A16						

Test SC04 – Slab F-factor vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC04A12						
SC04A14						
SC04A16						

Test SC05 – Fenestration Type vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC05A03						
SC05A09						
SC05A12						
SC05A14						
SC05A16						

Test SC06 – Fenestration Type vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC06A03						
SC06A09						
SC06A12						
SC06A14						
SC06A16						

Test SC07 – Exposed Thermal Mass vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC07A12						
SC07A14						
SC07A16						

Test SC08 – Exposed Thermal Mass vs. West Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		~~ACM~~compliance program Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC08A03						
SC08A09						
SC08A12						
SC08A14						
SC08A16						

Test SC09 – Exposed Thermal Mass vs. North Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		~~ACM~~compliance program Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC09A03						
SC09A09						
SC09A12						
SC09A14						
SC09A16						

Test SC10 – Exposed Thermal Mass vs. East Glass Area

	Space Conditioning TDV Energy (kBtu/ft²/y)		East Glass Solution (ft²)		~~ACM~~compliance program Filenames	
Label	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC10A03						
SC10A09						
SC10A12						
SC10A14						
SC10A16						

Test SC11 – South Overhangs vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC11A03						
SC11A09						
SC11A12						
SC11A14						
SC11A16						

Test SC12 – Building Envelope Sealing vs. Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC12A03						
SC12A09						
SC12A12						
SC12A14						
SC12A16						

Test SC13 – Building Envelope Sealing and Mechanical Ventilation vs. Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC13A03						
SC13A09						
SC13A12						
SC13A14						
SC13A16						

Test SC14 – Construction Quality vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC14A03						
SC14A09						
SC14A12						
SC14A14						
SC14A16						

Test SC15 – Cool Roofs/Radiant Barrier vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC15A09						
SC15A12						
SC15A14						

Test SC16 – Natural Ventilation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC16A09						
SC16A12						
SC16A14						

Test SC17 – Duct Leakage vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC17A03						
SC17A09						
SC17A12						
SC17A14						
SC17A16						

Test SC18 – Duct Surface Area vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC18A03						
SC18A09						
SC18A12						
SC18A14						
SC18A16						

Test SC19 – Duct Location vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC19B09						
SC19B12						
SC19B14						

Test SC20 – Duct Insulation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC20A09						
SC20A12						
SC20A14						

Test SC21 – Energy Efficiency Ratio vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC21A09						
SC21A12						
SC21A14						

Test SC22 – TXV/Charge Testing vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC22A09						
SC22A12						
SC22A14						

Test SC23 – Airflow Across Evaporator Coil vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC23A09						
SC23A12						
SC23A14						

Test SC24 – Air Conditioner Fan Power vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC24A09						
SC24A12						
SC24A14						

Test SC25 – Electric Heat vs. Fenestration U-Factor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC25A03						
SC25A09						
SC25A12						
SC25A14						
SC25A16						

Test SC26 – Side Fins

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC26A09						
SC26A12						
SC26A14						

A1. Standard Design Tests (SD)

Test SD00 – Basecase Prototypes

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD00A01					
SD00A02					
SD00A03					
SD00A04					
SD00A05					
SD00A06					
SD00A07					
SD00A08					
SD00A09					
SD00A10					
SD00A11					
SD00A12					
SD00A13					
SD00A14					
SD00A15					
SD00A16					
SD00B01					
SD00B02					
SD00B03					
SD00B04					
SD00B05					
SD00B06					
SD00B07					
SD00B08					
SD00B09					

SD00B10					
SD00B11					
SD00B12					
SD00B13					
SD00B14					
SD00B15					
SD00B16					
SD00B16					

Test SD01 – Single-Family Slab-on-Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD01C01					
SD01C02					
SD01C03					
SD01C04					
SD01C05					
SD01C06					
SD01C07					
SD01C08					
SD01C09					
SD01C10					
SD01C11					
SD01C12					
SD01C13					
SD01C14					
SD01C15					
SD01C16					

Test SD02 – Single-Family Raised Floor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD02D01					
SD02D02					
SD02D03					
SD02D04					
SD02D05					
SD02D06					
SD02D07					
SD02D08					
SD02D09					
SD02D10					
SD02D11					
SD02D12					
SD02D13					
SD02D14					
SD02D15					
SD02D16					

Test SD03 – Multi-Family Slab on Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD03E01					
SD03E02					
SD03E03					
SD03E04					
SD03E05					
SD03E06					
SD03E07					
SD03E08					
SD03E09					
SD03E10					
SD03E11					
SD03E12					
SD03E13					
SD03E14					
SD03E15					
SD03E16					

Test SD04 – Neutral Variable Test: Window Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD04A03					
SD04A09					
SD04A12					
SD04A14					
SD04A16					

Test SD05 – Neutral Variable Test: Wall Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD05A03					
SD05A09					
SD05A12					
SD05A14					
SD05A16					

RA.2 Standard Design Tests (SD)

Test SD01 – Single-Family Slab-on-Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD01C01					
SD01C02					
SD01C03					
SD01C04					
SD01C05					
SD01C06					
SD01C07					
SD01C08					
SD01C09					
SD01C10					
SD01C11					
SD01C12					
SD01C13					
SD01C14					
SD01C15					
SD01C16					

~~Test SD02 – Single-Family Raised Floor~~

	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
~~Label~~	~~Proposed Design Custom Budget~~	~~Standard Design Equivalent Custom Budget~~	~~Standard Design Equivalent Proposed Design~~	~~Proposed Design~~	~~Standard Design Equivalent~~
~~SD02D01~~					
~~SD02D02~~					
~~SD02D03~~					
~~SD02D04~~					
~~SD02D05~~					
~~SD02D06~~					
~~SD02D07~~					
~~SD02D08~~					
~~SD02D09~~					
~~SD02D10~~					
~~SD02D11~~					
~~SD02D12~~					
~~SD02D13~~					
~~SD02D14~~					
~~SD02D15~~					
~~SD02D16~~					

~~Test SD03 – Multi-Family Slab on Grade~~

~~Label~~	~~Space Conditioning TDV Energy (kBtu/ft²/y)~~			~~ACM Filenames~~	
	~~Proposed Design Custom Budget~~	~~Standard Design Equivalent Custom Budget~~	~~Standard Design Equivalent Proposed Design~~	~~Proposed Design~~	~~Standard Design Equivalent~~
~~SD03E01~~					
~~SD03E02~~					
~~SD03E03~~					
~~SD03E04~~					
~~SD03E05~~					
~~SD03E06~~					
~~SD03E07~~					
~~SD03E08~~					
~~SD03E09~~					
~~SD03E10~~					
~~SD03E11~~					
~~SD03E12~~					
~~SD03E13~~					
~~SD03E14~~					
~~SD03E15~~					
~~SD03E16~~					

~~Test SD04 – Neutral Variable Test: Window Area~~

~~Label~~	~~Space Conditioning TDV Energy (kBtu/ft²/y)~~			~~ACM Filenames~~	
	~~Proposed Design Custom Budget~~	~~Standard Design Equivalent Custom Budget~~	~~Standard Design Equivalent Proposed Design~~	~~Proposed Design~~	~~Standard Design Equivalent~~
~~SD04A03~~					
~~SD04A09~~					
~~SD04A12~~					
~~SD04A14~~					
~~SD04A16~~					

A2. Additions and Alterations Tests

Test AA01 – Baseline Simulations

Label	TDV Energy (kBtu/ft²/y)		~~ACM~~compliance program Filenames
	Standard Design	Proposed Design	
AA01E03			
AA01E09			
AA01E12			
AA01E14			
AA01E16			

Test AA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
AA02E03						
AA02E09						
AA02E12						
AA02E14						
AA02E16						

Test AA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
~~AA02E03~~AA03F03						
~~AA02E09~~AA03F09						
~~AA02E12~~AA03F12						
~~AA02E14~~AA03F14						
~~AA02E16~~AA03F16						

Test EA01 – Baseline

Label	TDV Energy (kBtu/ft²/y)		~~ACM~~compliance program Filenames
	Standard Design	Proposed Design	
EA01E03			
EA01E09			
EA01E12			
EA01E14			
EA01E16			

Test EA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA02E03						
EA02E09						
EA02E12						
EA02E14						
EA02E16						

Test EA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA03F~~2E~~03						
EA03F~~2E~~09						
EA03F~~2E~~12						
EA03F~~2E~~14						
EA03F~~2E~~16						

A3. Water Heating Tests

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test WH00 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
WH00C01			
WH00C02			
WH00C03			
WH00C04			
WH00C05			
WH00C06			
WH00C07			
WH00C08			
WH00C09			
WH00C10			
WH00C11			
WH00C12			
WH00C13			
WH00C14			
WH00C15			
WH00C16			
WH00E01			
WH00E02			
WH00E03			
WH00E04			
WH00E05			
WH00E06			
WH00E07			
WH00E08			
WH00E09			
WH00E10			
WH00E11			
WH00E12			
WH00E13			
WH00E14			
WH00E15			
WH00E16			

Test WH01 – Gas Storage vs. Electric Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH01C03						
WH01C09						
WH01C12						
WH01C14						
WH01C16						
WH01E03						
WH01E09						
WH01E12						
WH01E14						
WH01E16						

Test WH02 – Gas Storage vs. Electric Instantaneous Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH02C03						
WH02C09						
WH02C12						
WH02C14						
WH02C16						
WH02E03						
WH02E09						
WH02E12						
WH02E14						
WH02E16						

Test WH03 – Pipe Insulation on All Lines

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH03C03						
WH03C09						
WH03C12						
WH03C14						
WH03C16						

Test WH04 – Recirculation Control

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH04E03						
WH04E09						
WH04E12						
WH04E14						
WH04E16						

Test WH05 –Large Gas Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH05E03						
WH05E09						
WH05E12						
WH05E14						
WH05E16						

Test WH06 – Recirculation Piping Insulation

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH06E03						
WH06E09						
WH06E12						
WH06E14						
WH06E16						

Test WH07 – Number of Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH07C03						
WH07C09						
WH07C12						
WH07C14						
WH07C16						

Test WH08 – Pump Controls

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH08E03						
WH08E09						
WH08E12						
WH08E14						
WH08E16						

A4. Water Heating Neutral Variable Tests (WD)

Test WD00 – Basecase

Label	Water Heating TDV Energy (kBtu/ft²/y)			compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD00C01					
WD00C02					
WD00C03					
WD00C04					
WD00C05					
WD00C06					
WD00C07					
WD00C08					
WD00C09					
WD00C10					
WD00C11					
WD00C13					
WD00C14					
WD00C15					
WD00C16					
WD00E01					
WD00E02					
WD00E03					
WD00E04					
WD00E05					
WD00E06					
WD00E07					
WD00E08					
WD00E09					
WD00E10					
WD00E11					
WD00E12					
WD00E13					
WD00E14					
WD00E15					
WD00E16					

Test WD01 – Increase House Size to 2500ft^2

Label	Water Heating TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD01C03					
WD01C09					
WD01C12					
WD01C14					
WD01C16					

Test WD02 – Increase House Size to 3500ft^2

Label	Water Heating TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD02C03					
WD02C09					
WD02C12					
WD02C14					
WD02C16					

Test WD03 – Increase Recirculation Piping Length

Label	Water Heating TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD03D03					
WD03D09					
WD03D12					
WD03D14					
WD03D16					

Test WD04 – Change Recirculation Pipe Location

Label	Water Heating TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD04D03					
WD04D09					
WD04D12					
WD04D14					
WD04D16					

Test WD05 – Change to Individual Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)			~~ACM~~compliance program Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD05D03					
WD05D09					
WD05D12					
WD05D14					
WD05D16					

A5. Optional Capabilities Tests (OC)

Test OC01 – Dedicated Hydronic Heating

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC01A03						
OC01A09						
OC01A12						
OC01A14						
OC01A16						

Test OC02 – Combined Hydronic, Gas Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~<u>compliance program</u> Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC02A03						
OC02A09						
OC02A12						
OC02A14						
OC02A16						

Test OC03 – Combined Hydronic, Electric Resistance Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~<u>compliance program</u> Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC03A03						
OC03A09						
OC03A12						
OC03A14						
OC03A16						

Test OC04 – Combined Hydronic, Heat Pump Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~<u>compliance program</u> Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC04A03						
OC04A09						
OC04A12						
OC04A14						
OC04A16						

Test OC05 – Control Vent Crawlspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC05B03						
OC05B 09						
OC05B 12						
OC05B 14						
OC05B 16						

Test OC06 – Zonal Control

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC06A03						
OC06A09						
OC06A12						
OC06A14						
OC06A16						

Test OC07 – Attached Sunspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC07A03						
OC07A09						
OC07A12						
OC07A14						
OC07A16						

Test OC08 – Exterior Mass Walls

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Wall R-Value Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC08A03						
OC08A09						
OC08A12						
OC08A14						
OC08A16						

Test OC9 – Gas Absorption Cooling

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		~~ACM~~compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC09A03						
OC09A09						
OC09A12						
OC09A14						
OC09A16						

Test OC10 – Evapoartively-cooled Condensing Unit

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC10A06						
OC10A09						
OC10A12						
OC10A14						

Test OC11 – Ice Storage DX Air Conditioning Unit

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		compliance program Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC10A09						
OC10A12						
OC10A14						

A6. Solar Systems Tests (SS)

Test SS01 – Solar System with Electric Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS01A03			
SS01A09			
SS01A12			
SS01A14			
SS01A16			

Test SS02 – Solar System with Gas Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS02A03			
SS02A09			
SS02A12			
SS02A14			
SS02A16			

Test SS03 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS03F01			
SS03F02			
SS03F03			
SS03F04			
SS03F05			
SS03F06			
SS03F07			
SS03F08			
SS03F09			
SS03F10			
SS03F11			
SS03F12			
SS03F13			
SS03F14			
SS03F15			
SS03F16			

Test SS04– Collector Orientation

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS04F03			
SS04F09			
SS04F12			
SS04F14			
SS04F16			

Test SS05– Collector Slope

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS05F03			
SS05F09			
SS05F12			
SS05F14			
SS05F16			

Test SS06– Collector Performance

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS06F03			
SS06F09			
SS06F12			
SS06F14			
SS06F16			

Test SS07– Collector Area

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS07F03			
SS07F09			
SS07F12			
SS07F14			
SS07F16			

Test SS08– Storage Tank Size

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS08F03			
SS08F09			
SS08F12			
SS08F14			
SS08F16			

Test SS10– Circulation Pump

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS10F03			
SS10F09			
SS10F12			
SS10F14			
SS10F16			

Test SS11– Freeze Control

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		~~ACM~~compliance program Filename
	Standard Design	Proposed Design	
SS11F03			
SS11F09			
SS11F12			
SS11F14			
SS11F16			

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Residential ACM Appendix B – 2008

RACM Appendix B – Algorithms and Procedures for Calculating PV Production

B1 Purpose and Scope

ACM RB documents the methods and assumptions used for simulating the hourly electricity production for residential photovoltaic systems. The documented method is used to qualify for the New Solar Homes Partnership (NSHP) compliance option. The NSHP compliance option requires time dependent valued (TDV) energy production of PV systems, which is based on system performance as a whole, rather than on installed capacity. The calculation procedure described in this document accounts for the rated performance of the PV modules and the inverter. It also accounts for climate, number of PV modules, wiring configuration, tilt, azimuth, and shading conditions.

The calculation procedure uses publicly available algorithms to estimate PV system output at each hour of the year[1]. Inverter performance data is used to determine electrical AC output. These algorithms are implemented in a software module that can be licensed at no cost from the Energy Commission. The algorithms incorporated in the software module were developed by the Solar Energy Laboratory at the University of Wisconsin and are referred to as the Five Parameter Model. The software module was written by Dr. William Beckman. The calculation procedure is a simulation whereby energy production is calculated for each hour of the year and summed. An hourly simulation is needed since time dependent valued TDV weights must be applied for each hour of the year.

The software module accepts a text file as input and produces a text file as output. The format of both the input and output text files is described in this document to enable software developers to interface with the software module. The software module does not produce reports, although standard reports are required in order to qualify for the NSHP compliance option. The Residential Compliance Manual documents the reports required for the NSHP compliance option.

These calculation procedures apply only to grid-tied systems with fixed tilt and orientation. Tracking systems are not handled in these calculation procedures at this time.

B2 Calculation Proceduress

The software module (referred to as the “calculation engine” in this document) determines hourly system production from inputs of PV module and inverter information and site-specific installation details. The Compliance Software must perform both pre-processing of the inputs and post-processing of the inoutputs to determine annual TDV output of the system.

The calculation engine also contains databases with performance data for both PV modules and inverters. The Compliance Software passes the PV module name and inverter name to the calculation engine, which matches the PV module and inverter names passed in the input file to names in its internal database. The location and source of data is shown in the table below.

1 From DeSoto, W., Klein S. and Beckman, W, Improvement and Validation of a Model for Photovoltaic Array Performance, *Solar Energy*, Volume 80, Issue 1, January 2006, pp. 78-88.

Table RB-1 – Data Location for PV Simulation Runs

Data	Location	Source
PV Module Name	Both	PVDROPDOWN.TXT file provided by CEC
PV Performance Data	Calculation Engine	PVMODULES.LKT file provided by CEC
Inverter Name	Both	INVERTERDROPDOWN.TXT file provided by CEC
Inverter Efficiency Data	Calculation Engine	INVERTERDATAFILE.LKT file provided by CEC
City Latitude and Longitude Data	Compliance Software	2008 Joint Appendix 2
Representative City Data for CEC Climate Zones	Compliance Software	2008 Joint Appendix 2
Time Dependent Valuation Multipliers	Compliance Software	http://www.energy.ca.gov/title24/2008standards/documents/E3/index.html
TDV Retail Rate Adjustment Adders	Compliance Software	http://www.energy.ca.gov/title24/2008standards/documents/E3/index.html

The PV calculation processsdure consists of the following steps:

1. The Compliance Software (CS) accepts required inputs for PV module and inverter information, and site-specific details such as tilt, azimuth, mounting height and offset and location information.
2. The Compliance Software accepts optional inputs describing shading objects, which include trees, adjacent buildings, and roof obstructions.
3. The Compliance Software follows preprocessing rules to determine the climate zone and other inputs.
4. The Compliance Software writes a text input file (described later in this document).
5. The Compliance Software runs an executable command and designates the names of two output files (in comma-separated value format) to be used for post-processing.
6. The Compliance Software performs post--processing to apply TDV valuation and shading rules to determine annual array TDV production.

Additional information related to the New Solar Homes Partnership can be found in the New Solar Homes Partnership guidebook[2].

B3 Model Required Inputs

PV module and inverter performance data is stored in libraries along with the calculation engine. The Compliance Software accepts several user inputs and passes them to the calculation engine through a text input file. The Compliance Software also shall assume fixed values for several of the inputs.

B3.1 User Inputs

The Compliance Software shall allow for the following user inputs:

1. PV Module Name – the name must match a listed name in the CEC database. A list of PV module names is available in a text file, PVDROPDOWN.TXT which is provided along with the calculatorion engine and periodically updated to include new PV modules as they become eligible. The text file also contains a flag for each PV module that indicates whether or not the PV module is a building -integrated photovoltaic (BIPV). Each entry in the text file has the format:

'Module ABC,Y'

In this example, “Module ABC” is the name of the PV module and “Y” indicates that it is a BIPV.

[2] NSHP Guidebook is available at http://www.gosolarcalifornia.ca.gov/documents/index.html

2. Inverter Name – the inverter make and model, which must match an inverter name in the CEC database. A list of inverters in the CEC database is also available in a text file, INVERTERDROPDOWN.TXT which is provided along with the calculatorion engine and periodically updated.

3. City – the Compliance Software shall allow selection of a City based on cities listed in JA2 of the 2008 Standards. The city selection determines the climate zone weather file that is used as an input for the calculation engine.

4. Number of series modules in each string – the number of PV modules connected in series in each string.

5. Number of strings in parallel – the number of strings of PV modules that are connected in parallel.

6. Installation Option – the Compliance Software shall allow the user to choose an installation option from the following choices: California Flexible Installation, Detailed Input.

a) For the *California Flexible Installation* option, the tilt shall be fixed at 22.6 degrees (5:12 tilt) and azimuth shall be fixed at 170 degrees in the background as inputs for the simulation runs. But this implies that the user is allowed greater flexibility in actual installation with range of azimuth from (150 degrees to 270 degrees) and tilt from 41:12 to 7:12. This option also assumes the wind factor is set at 0.61 (at 22 feet or greater). For this option, shading is required to be minimal.

b) For the *detailed input* option, the Compliance Software shall allow user inputs for tilt, azimuth and mounting height. This option can allow for entry of user defined detailed shading input.

7. Mounting standoff distance – the Compliance Software shall allow the following entries for standoff for PV modules that are not BIPV:

Roof mounted (min 3.5 in. from roof)

Roof mounted (2.5 in. to 3.5 in. from roof)

Roof mounted (1.5 in. to 2.5 in. from roof)

Roof mounted (0.5 in. to 1.5 in. from roof)

Roof mounted (within 0.5 in. from roof)

Roof mounted (Ground / rack mounted)

For PV modules that are BIPV, the compliance software shall not allow a user selection for standoff height.

8. Tilt – the tilt in degrees of the PV array. The Compliance Software can allow this input defined as a rise over run pitch, but would need to convert to degrees for creating the input file (e.g. 5:12 pitch would be 22.6 deg).

9. Azimuth – the azimuth of the PV array in degrees (180 is South, 0 is North, 90 is East and 270 is West).

B3.2 Fixed Inputs

The calculation engine requires several additional inputs that are "hardcoded" to the input file. For the annual simulation run, the input file requires the following inputs:

1. RowStart – the starting hour of the simulation. Value is "1" to indicate the first hour of the year.

2. RowEnd – the ending hour of the simulation. Value is "8760" to indicate the last hour of the year.

3. Tracking – tracking option, defaults to 1 for fixed (no tracking).

4. eta_MPPT – maximum power point tracking efficiency. Value is fixed at "0.88" to account for losses due to dirt and mismatched wiring.

For the FVT simulation run, the input file requires the following entries:

1. Month – this is fixed at "3" (for March) as representative of typical solar angles.

2. RowStart – fixed at "1".

3. RowEnd – fixed at "37" (for 37 rows in the field verification output table).

4. eta_MPPT – this value is fixed at "0.792" to account for losses due to dirt, mismatched wiring and an additional tolerance for capturing field verification related measurements.

5. Tracking$ - fixed at " 'Fixed' " (no tracking).

B3.3 Multiple Orientations Arrays

A system may have arrays in multiple orientations connected to the same inverter. In this case, a separate hourly simulation run is performed for arrays in each orientation, and the hourly results can be summed to determine the total annual TDV Output. Separate field verification tables are required for each orientation and solar irradiance must be measured separately in a plane parallel to each array that has a different azimuth or tilt. The expected output AC power is determined separately for each condition and the sum is used for field verification purposes.

B4 Shading

Shading can significantly affect the output of a PV system. The Compliance Software shall assume that if any part of the array is shaded, PV production will drop to zero. An array will meet the "minimal shading" criterion if anything higher than the PV array is located a distance from the array at least two times the height difference. When an array does not meet this criteria, it will be considered shaded and production will drop to zero for the specific hour in which the solar access is obstructed.

Mature tree heights are defined as follows: small trees are assumed to be 20 feet in height, medium trees 35 feet in height and large trees 50 feet in height. The Reference Residential Appendix R9A3.6 contains reference to information on classification of tree species into the three categories for input and field verification purposes.

Utility poles are an exception to the 'no shading' criterion provided they are located at least 30 feet from the array. The shading analysis must also consider the expected mature height of any nearby trees. Shading does not disqualify homeowner from receiving PV incentives, as electricity production is only ignored during hours of the year when shading occurs.

If the Detailed Input with Shading input is selected, the Compliance Software shall allow the user to define and describe a number of shading obstructions. A sample interface accepting such inputs is shown below.

Orientation	Obstruction Type	Height of Shading Obstruction	Horizontal Distance to Shading Obstruction	Shading Angle
SE (Azimuth >123.75 to 146.25)	Medium Tree (existing - mature)		15	
WSW (Azimuth >236.25 to 258.75)	**Neighboring Structure (Enter Distance and Height)**	15	10	
WNW (Azimuth >281.25 to 305)	On Roof Obstruction (Enter Distance and Height)	10	10	
S (Azimuth >168.75 to 191.25)	Neighboring Structure (Measured Angle)			32.0

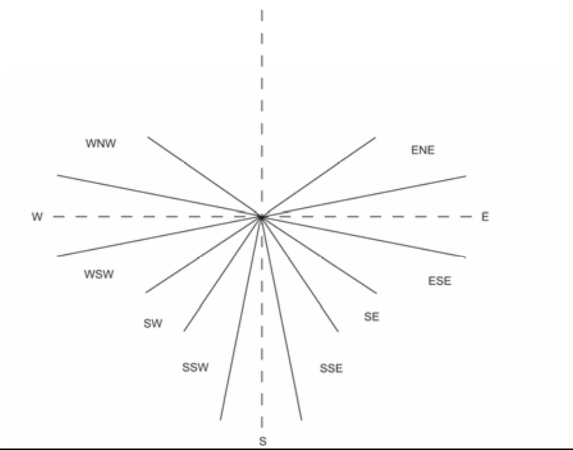


Figure RB-1 – Sample Shading Interface

For each shading obstruction, the following information is required:

1. Azimuth. The azimuth of the obstruction relative to the ~~module~~array shall be selected from a list of direction segments. Each direction segment spans an azimuth range of 22.5 degrees, except for WNW and ENE directions, since the azimuth angles between 305 degrees and 55 degrees are exempt from shading obstruction input.

   For each shading obstruction, the user should choose from the following direction segments:

   ENE (Azimuth >55 to 78.75)

   E (Azimuth >78.75 to 101.25)

   ESE (Azimuth >101.25 to 123.75)

   SE (Azimuth >123.75 to 146.25)

   SSE (Azimuth >146.25 to 168.75)

   S (Azimuth >168.75 to 191.25)

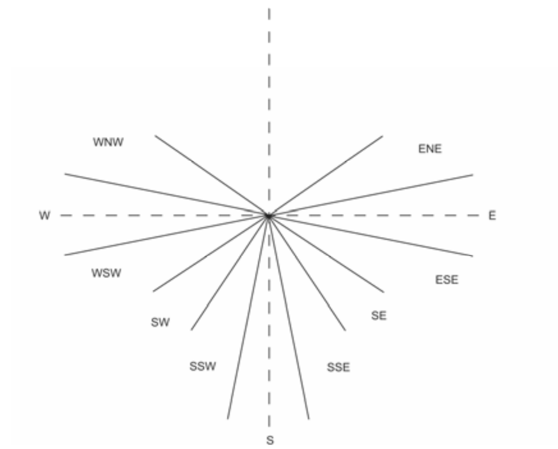
   SSW (Azimuth >191.25 to 213.75)

   SW (Azimuth >213.75 to 236.25)

   WSW (Azimuth >236.25 to 258.75)

   W (Azimuth >258.75 to 281.25)

   WNW (Azimuth >281.25 to 305)



2. Obstruction Type – the user chooses the obstruction type from the following:

Table RB-2 – Obstruction Types for Shading Calculation

Obstruction Type	**Required Inputs**
Small Tree (existing - mature)	Distance from Obstruction
Small Tree (existing - not mature)	Distance from Obstruction
Small Tree (planned)	Distance from obstruction
Medium Tree (existing - mature)	Distance from Obstruction
Medium Tree (existing - not mature)	Distance from Obstruction
Medium Tree (planned)	Distance from Obstruction
Large Tree (existing - mature)	Distance from Obstruction
Large Tree (existing - not mature)	Distance from Obstruction
Large Tree (planned)	Distance from Obstruction
On Roof Obstruction (Enter Distance and Height)	Distance from Obstruction, Height of Obstruction
On Roof Obstruction (Measured Angle)	Altitude Angle
Neighboring Structure (Enter Distance and Height)	Distance from Obstruction, Height of Obstruction
Neighboring Structure (Measured Angle)	Altitude Angle

The ***distance from obstruction*** is the horizontal distance to the obstruction from the closest edge of the array with worst shading impact.

The ***height of obstruction*** is the vertical height of the obstruction. For on-roof obstructions, the height is measured relative to the mounting height of the array; for neighboring structures, the height is measured relative to the ground.

The ***altitude angle*** is the angle from the worst shaded point on the PV array to the highest point on the shading obstruction in each direction segment. The greatest altitude angle for a given direction segment determines the shading angle.

The Compliance Software shall determine the greatest shading angle for each of the 11 direction segments, and uses this angle to adjust hourly system production. The Compliance Software shall assume that there is minimal shading for any direction segment that has a shading angle equal or less than 26.5 degrees (corresponding to a distance to height ratio of 2:1). If this minimal shading criterion is met, shading effects shall be ignored for the corresponding direction segment.

The calculation engine produces hourly output that includes solar altitude angle and solar azimuth. Whenever the solar azimuth for the current hour ~~is~~falls within a direction segment whose shading angle is greater than the solar altitude angle for that hour, the electricity production of the system (in W) is assumed to be zero (0) for that hour.

B5 Input Processing

The Compliance Software must perform preprocessing of some user inputs prior to writing the input file.

1. **Determine CEC climate zone from city entry.** In order for PV production to be calculated, a city in California must first be chosen. The city location will correspond with 1 of 16 climate zones, each having a unique weather file. These weather files, as defined in Joint Appendix 2, will provide data necessary to perform the production calculation, such as radiation on a horizontal surface, beam normal radiation, diffuse radiation, and ambient temperature for each hour of the year.

2. **Determine normal operating cell temperature (NOCT) adjustment** (DELTANOCT in input file) from mounting standoff height according to the table below[3].

Table RB-3 – NOCT Adjustment from Mounting Standoff

Mounting Standoff Height	**Input for NOCT adjustment**
Building Integrated	DELTANOCT=0
Roof mounted (Ground / rack mounted)	DELTANOCT=0
Roof mounted (min 3.5 in. from roof)	DELTANOCT=0
Roof mounted (2.5 in. to 3.5 in. from roof)	DELTANOCT=2
Roof mounted (1.5 in. to 2.5 in. from roof)	DELTANOCT=6
Roof mounted (0.5 in. to 1.5 in. from roof)	DELTANOCT=11
Roof mounted (within 0.5 in. from roof)	DELTANOCT=18

3. **Determination of wind adjustment factor** from mounting height (one-story or two-story):

The user may select the mounting height of the array, which is the height of the lowest point of the array relative to the ground. The user may choose between *one-story*, *two-story*, or a user-defined height. The mounting height is used to determine the wind adjustment factor, and is used for shading calculations. The wind adjustment factor is defined by the following rule: for a mounting height below 22 feet or for a one-story building, the wind adjustment factor is 0.51. For a mounting height at 22 feet or above or for a two-story building, the wind adjustment factor is 0.61.

4. **Determination of latitude and longitude** for annual simulation run: the latitude and longitude for the annual simulation are the latitude and longitude of the reference city in the city's climate zone. Representative cities are shown in the table below. For instance, in climate zone 4, the reference city is Sunnyvale, so latitude and longitude data from this city are used in the annual simulation run. For the FVT simulation run, the latitude and longitude of the reference city in the city's climate zone are used in the FVT simulation run.

[3] Data interpolated from Fuentes, M., "A Simplified Thermal Model of Flat-plate Photovoltaic Arrays," Sandia, 1987.

Table RB-4 – Reference City Data by Climate Zone

Zone	City	Latitude	Longitude
1	Arcata	40.8	124.2
2	Santa Rosa	38.4	122.7
3	Oakland AP	37.7	122.2
4	Sunnyvale	37.4	122.4
5	Santa Maria AP	34.9	120.4
6	Los Angeles AP	33.9	118.5
7	San Diego AP	32.7	117.2
8	El Toro MCAS	33.6	117.7
9	Burbank AP	34.2	118.4
10	Riverside FS 3	33.9	117.2
11	Red Bluff AP	40.2	122.2
12	Sacramento AP	38.5	121.5
13	Fresno AP	36.8	119.7
14	China Lake	35.7	117.7
15	El Centro	32.8	115.6
16	Mount Shasta	41.3	122.3

B6 CECPV Input File

A sample input file to the CECPV Calculatorcalculation engine is shown below, with comments after each entry prefaced by "//". The input file is to be written in text format. The default filename for the input file is CECPV.emf

```
//This input file is run with the Title 24 PV EES Application
Load #1                                // Fixed command to EXE
PVModule$='Example Module,Y'  // Module Name – must match list in PVDROPDOWN.TXT
LatitudeX=37.3                // Latitude of City (same value as Latitude)
LongitudeX=122                // Longitude of City (same value as Longitude)
City$='San Jose'                       // City Name –determines used to determine the CZ based on
                                       JA2 Table 2.2
Zone=4                                 // CEC Climate Zone – ACMCompliance Software shall determine from
                                       city
Latitude=37.4                 // Latitude defaulted from reference city in CZ
Longitude=122.4                        // Longitude defaulted from reference city in CZ
slope=22.6                             // Tilt of the collector, in degrees
N_Parallel=1                  // Number of strings connected in parallel
N_series=48                            // Number of PV modules in each series string
RowStart=1                             // Fixed Entry - Starting hour of annual simulation-
RowEnd=8760                            // Fixed Entry - Ending hour of annual simulation-
CEC_inverter$='SMA America     SWR2500U (240V)'      // Inverter name – must match list
                                       in INVERTERDROPDOWN.TXT
AZ_CEC=180                             // Solar azimuth
eta_MPPT=0.88                 // Placeholder for MPPT of inverter, but for now
                                       used as overall derating factor accounting for dirt, dust and
                                       mismatched wiring in a system for now, and fixed
                                       at 0.88
FFV_wind=0.51                 // Wind adjustment factor – 0.51 for one-story,
                                       0.61 for two-story
Output$='CECPV_output.csv'    // Name of output file
DELTANOCT=0                            // NOCT adjustment based on cellarray mounting height
Tracking=1                             // Tracking option - fixed
Solve                                  // Fixed command to EXE
//The following entries are required for generation of a field verification table
Load #2                       // Fixed command to EXE
Month=3                       // Fixed representative month for calculation
PVModule$='Example Module,Y'  // Module name – must match list in PVDROPDOWN.TXT
City$='San Jose'                       // City name –– used to determines the CZ based on
                                       JA2 Table 2-2
Zone=4                        // CEC cClimate zZone for city- Compliance Software shall
```

```
                                      determine from city
Latitude=37.4                  // Latitude defaulted from reference city in CZ
Longitude=121.9                       // Longitude defaulted from reference city in CZ
slope=22.6                            // Tilt of the collector, in degrees
N_Parallel=1                   // Number of strings connected in parallel
N_series=48                           // Number of PV modules in each series string
RowStart=1                            // Fixed entry - Starting row of FVT output table
RowEnd=37                             // Fixed entry – Ending row of FVT output table
CEC_inverter$='SMA America     SWR2500U (240V)'     // Inverter name – must match list
                                      in INVERTERDROPDOWN.TXT
AZ_CEC=180                            // Solar azimuth
eta_MPPT=0.792                 // Placeholder for MPPT of inverter, but for now
                                      used as overall derating factor accounting for dirt, dust,
                                      mismatched wiring in a system, and additional tolerance for FVT,
                                      and fixed at 0.
FFV_wind=0.51                  // Wind adjustment factor – 0.51 for one-story,
                                      0.61 for two-story
Output$='FVT.csv'                     // Name of output file
DELTANOCT=0                           // NOCT adjustment based on array mounting height
Tracking$='Fixed'                     // Tracking option – fixed
solveTable 'FVT'                      // Fixed command to EXE
Quit                                  // Fixed command to EXE
```

B7 Execute Simulation

After the input file is written, the Compliance Software runs the calculation engine executable as a background process. Execution of the command follows the following format:

c:\ Software\CECPV.exe c:\Software\CECPV.emf

The input file name is specified as an argument in the command line. This input file name contains the file names for the two output files that are generated from the simulation runs. This command runs the calculation engine in the background. Note that the simulation may take as long as 90 seconds to run, depending upon the performance of the system.

B8 Post-Process Results

B8.1 Calculation Engine Output Files

The calculation engine produces two output files: an hourly table of electricity production, and a field verification table, each in comma-separated value (.csv) format. The hourly electricity production table has the following data:

Table RB-5 – ~~PV~~Calculation Engine Output File Details

Column	Field	Units	Notes
A	hr of year	--	Hour of year (1-8760)
B	month	--	Month for the current hour
C	day	--	Day for the current hour
D	T_amb	°C	Ambient (outdoor) temperature from weather file
E	I_T	W/m^2	Horizontal Incident Solar Radiation from weather file
F	T_c	°C	Cell Temperature
G	I_mp	A	Maximum power point current for the current hour
H	V_mp	V	Maximum power point voltage for the current hour
I	eta_mp	Unitless	Conversion efficiency of solar to DC power
J	eta_inverter	Unitless	Inverter Efficiency for the current hour
K	P_del	Watts	AC Power delivered
L	gamma_s	Degrees	Solar azimuth angle
M	alpha_s	Degrees	Solar altitude angle
N	hr of Day	--	Hour of day (1-24)

The data that is used for post-processing is the power delivered (column K) and the solar azimuth and altitude angles (columns L and M). The power delivered is the AC power for the current hour of the simulation. If the system is not shaded for that hour, the power is added to the annual total. The solar azimuth and altitude angles are used with the shading angle for each orientation, determined from pre-processing of shading inputs, to determine whether or not the system is shaded.

B8.2 TDV Calculation

The state of California places greater value on electricity during periods of higher demand as defined in Joint Appendix 3. This time-dependent valuation of energy will be considered in calculating PV production by assigning a TDV multiplier to electricity production for each hour of the year.

The Compliance Software sums the hourly system AC production, excluding electricity production for all hours when the solar azimuth falls within a direction segment whose shading angle is greater than the solar altitude angle for that hour. Output is expressed in Wh; the hourly output is multiplied by a TDV multiplier, and then summed to determine annual TDV output. The TDV multiplier used in this calculation excludes a retail rate adjustment adder that is used in compliance calculations. This retail rate adjustment, which is constant for a given climate zone, is subtracted from the TDV multiplier to determine the TDV multiplier for the PV performance calculation. A listing of TDV values may be found at: http://www.energy.ca.gov/title24/2008standards/documents/E3/index.html

Table RB-6 – Retail Rate Adder

Climate Zone	Retail Rate Adder (kBtu/kWh)
1	3.12
2	3.21
3	3.45
4	3.34
5	3.34
6	3.24
7	6.19
8	3.23
9	3.17
10	3.11
11	3.07
12	3.17
13	3.42
14	3.10
15	3.09
16	3.02

B8.3 Field Verification Table

The calculation engine also produces an output file with a field verification table, which lists expected system AC power output (in W) for different solar irradiance levels and ambient temperatures. This table is used for field verification purposes to verify proper installation and operation of the PV system. The table shows expected PV system output for solar irradiance levels in 25 W/m^2 increments and for ambient temperatures in 5°F increments. Table RB-7 shows a sample of the output.

Table RB-7 - Example of Field Verification Table

(W/m²)	T=15	T=20	T=25	T=30	T=35	T=40	T=45	T=50	T=55	T=60	T=65	T=70	T=75	T=80	T=85	T=90	T=95	T=100	T=105	T=110	T=115	T=120
300	614	606	599	591	584	576	568	560	553	544	536	528	520	512	504	496	487	479	471	463	454	446
325	665	657	648	640	632	623	615	607	598	590	581	572	564	555	546	537	528	519	510	501	492	483
350	716	707	698	689	680	671	662	653	643	634	625	616	606	597	588	578	569	559	550	540	530	520
375	766	757	747	738	728	718	708	699	689	679	669	659	649	639	629	619	609	598	588	578	568	557
400	817	807	797	786	776	765	755	745	734	723	713	702	691	681	670	659	648	637	626	615	604	593
425	868	857	846	835	824	813	802	790	779	768	757	745	734	722	711	699	688	676	664	653	641	629
450	918	907	895	883	872	860	848	836	824	812	800	788	776	764	752	739	727	715	702	690	677	665
475	967	955	943	931	919	907	894	882	869	856	843	831	818	805	792	779	766	753	740	727	714	700
500	1016	1004	991	978	966	953	940	927	913	900	887	873	860	846	832	819	805	791	777	763	750	736
525	1065	1052	1038	1025	1012	998	984	971	957	943	929	915	901	887	872	858	843	829	814	800	785	770
550	1113	1099	1085	1071	1057	1043	1029	1014	1000	986	971	956	942	927	912	897	882	866	851	836	820	805
575	1161	1147	1132	1117	1102	1088	1073	1058	1043	1027	1012	997	982	966	951	935	919	903	887	871	855	839
600	1209	1194	1178	1163	1147	1132	1116	1100	1085	1069	1053	1037	1021	1005	989	972	956	940	923	906	890	873
625	1256	1240	1224	1208	1192	1176	1159	1143	1126	1110	1093	1077	1060	1043	1026	1009	992	975	958	941	924	906
650	1302	1286	1269	1252	1236	1219	1202	1185	1168	1150	1133	1116	1098	1081	1063	1046	1028	1010	992	974	957	939
675	1348	1331	1314	1296	1279	1261	1244	1226	1208	1190	1172	1154	1136	1118	1100	1081	1063	1045	1026	1007	989	970
700	1394	1376	1358	1340	1322	1304	1285	1267	1248	1230	1211	1192	1174	1155	1136	1117	1098	1078	1059	1040	1021	1001
725	1439	1420	1401	1383	1364	1345	1326	1307	1288	1269	1249	1230	1210	1191	1171	1151	1132	1112	1092	1072	1052	1032
750	1483	1464	1444	1425	1405	1386	1366	1346	1327	1307	1287	1267	1246	1226	1206	1185	1165	1144	1124	1103	1082	1061
775	1526	1506	1487	1466	1446	1426	1406	1385	1365	1344	1323	1303	1282	1261	1240	1219	1198	1176	1155	1134	1112	1090
800	1569	1549	1528	1507	1486	1466	1445	1423	1402	1381	1360	1338	1317	1295	1273	1252	1230	1208	1186	1164	1141	1119
825	1611	1590	1569	1547	1526	1504	1483	1461	1439	1417	1395	1373	1351	1328	1306	1284	1261	1238	1216	1193	1170	1147
850	1653	1631	1609	1587	1565	1542	1520	1498	1475	1452	1430	1407	1384	1361	1338	1315	1292	1268	1245	1221	1198	1174
875	1693	1671	1648	1626	1603	1580	1557	1534	1510	1487	1464	1440	1417	1393	1369	1345	1322	1298	1273	1249	1225	1200
900	1733	1710	1687	1663	1640	1616	1593	1569	1545	1521	1497	1473	1449	1424	1400	1375	1351	1326	1301	1276	1251	1226
925	1772	1748	1725	1701	1676	1652	1628	1603	1579	1554	1529	1505	1480	1455	1430	1404	1379	1354	1328	1302	1277	1251
950	1811	1786	1762	1737	1712	1687	1662	1637	1612	1586	1561	1536	1510	1484	1459	1433	1407	1381	1354	1328	1302	1275
975	1980	1823	1798	1772	1747	1721	1696	1670	1644	1618	1592	1566	1540	1513	1487	1460	1434	1407	1380	1353	1326	1299
1000	1980	1980	1980	1807	1781	1755	1729	1702	1676	1649	1622	1595	1569	1542	1514	1487	1460	1432	1405	1377	1349	1322
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1075	1980	1980	1980	1980	1980	1980	1823	1795	1767	1738	1709	1680	1652	1623	1593	1564	1535	1506	1476	1446	1417	1387
1100	1980	1980	1980	1980	1980	1980	1980	1825	1796	1766	1737	1708	1678	1648	1619	1589	1559	1529	1499	1468	1438	1407
1125	1980	1980	1980	1980	1980	1980	1980	1980	1824	1794	1764	1734	1704	1674	1643	1613	1582	1551	1520	1490	1458	1427
1150	1980	1980	1980	1980	1980	1980	1980	1980	1980	1822	1791	1760	1729	1698	1667	1636	1605	1573	1542	1510	1479	1447
1175	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1817	1786	1754	1722	1691	1659	1627	1595	1563	1530	1498	1466
1200	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1980	1810	1778	1746	1714	1681	1649	1616	1583	1550	1517	1484

Reports

The New Solar Homes Partnership (NSHP) compliance option related to PV production requires three reports. The Certificate of Compliance form, CF-1R-PV, reports the inputs describing the system and the annual TDV production from the system. Refer to the Reference Residential Appendix RA~~9~~3.6 for the field verification protocol which is used by HERS raters and system installers.

Forms CF-4R-PV and CF-6R-PV must also be completed to qualify for NSHP compliance option.

The Residential Compliance Manual provides additional information on the forms required to claim credit for residential PV production.

Residential ACM Appendix C – 2008

RACM Appendix C – Special Features

C1 Purpose and Scope

RC-2008 lists required descriptors and references to documentation for CF-1R Special Features

C2 Required Descriptors and References

Table RC-1 – Required descriptors and References

Required descriptor	*Reference*
Air-retarding wrap	This building incorporates an air retarding wrap which shall be installed to meet the requirements of Section 150 (f) of the Standards.
Multiple conditioned zones	This building uses multiple conditioned zones. The non-closable area between zones cannot exceed 40 ft^2 and each zone must be controlled with a separate thermostat. In addition the air flow requirements and fan watt draw requirements in Residential Appendix RA-6 must be met.
Sunspace attached to building	This building has an attached sunspace with interzone surfaces, custom solar heat gain distribution and sunspace thermal mass elements.
Non-standard free ventilation area	Standard free ventilation area is 10% of rough-out opening of all fenestration.
All orientations	When all orientations are specified, see section 151 (c) 2 of the Standards and section RA1-3.3 in Appendix RA-1 of the Residential Compliance Manual.
High mass building features	High-mass building features are described in the THERMAL MASS FOR HIGH MASS DESIGN table of compliance form CF-1R.
Gas Absorption equipment	Minimum efficiency for Gas Absorption equipment is specified in Table 112-D in Subchapter 2 of the 2008 Building Energy Efficiency Standards.
Cool Roofing products installed	Cool roof products installed on this building qualifying for compliance with Sections 141, 143(a)1 or 149(b) 1 B,151(b), 151(f)11, or 152(b)1G shall be rated and labeled by the Cool Roof Rating Council in accordance with Section 10-113 of the standards.
Radiant Barriers installed	The radiant barriers installed in this building shall meet eligibility and installation criteria as specified in Residential Appendix RA10.
Distribution system sealed and tested	Air distribution systems in this building must be sealed and leakage tested by a CEC-certified HERS provider using the procedures in

	section RA4-4.3 of Residential Appendix RA4-2008.
Non-standard Ventilation Height Difference	Non-standard ventilation height difference must be verified according to the rules in Residential ACM Chapter 2 under Building Zone Information.
Refrigerant Charge Indicator Light installed	Presence of a refrigerant Charge Indicator Light in the building's space conditioning system must be verified by visual inspection.
Reduced duct surface area	Reduced duct surface area is specified for this building. Distribution system specifications including distribution of duct surface areas by location are shown in the SUPPLY DUCT SYSTEM DETAILS table of compliance form CF-1R. Field inspection is required to verify that the duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts. The system must also meet the Adequate Airflow requirement as described in section RA6-4.1 of Residential Appendix RA6-2008.
Non-default duct location	The distribution system specifications for this building including duct locations are shown in the SUPPLY DUCT SYSTEM DETAILS table of compliance form CF-1R. Field inspection is required to verify that the duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts. The system must also meet the Adequate Airflow requirement as described in section RA6-4.1 of Residential Appendix RA6-2008.
Ducts in conditioned space	The distribution system specifications for this building including duct locations are shown in the SUPPLY DUCT SYSTEM DETAILS table of compliance form CF-1R. Field inspection is required to verify that the duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts. The system must also meet the Adequate Airflow requirement as described in section RA6-4.1 of Residential Appendix RA6-2008.
Ducts buried in attic insulation	The distribution system specifications for this building are shown in the SUPPLY DUCT SYSTEM DETAILS table of compliance form CF-1R. Field inspection is required to verify that the duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts. The system must also meet the Adequate Airflow requirement as described in section RA6-4.1 of Residential Appendix RA6-2008. R-values allowed for ducts buried in attic insulation are specified in section 4.8.5
Hydronic heating system	Table R3-11 specifies default assumptions for hydronic systems for existing buildings. System details are in the SPECIAL SYSTEMS - HYDRONIC DISTRIBUTION SYSTEMS AND TERMINALS table of compliance form CF-1R.
High Quality Insulation Installation	High Quality Insulation Installation in this building must be installed as specified in Residential Appendix RA8-2008 and verified by a CEC-approved HERS provider.

Reduced fan Watts	Reduced Fan Watts shall be verified according to the procedures in section RA6-3.2 of Residential Appendix RA6-2008.
Reduced infiltration and/or Mechanical ventilation	This building is modeled with reduced infiltration and/or mechanical ventilation. Consequently the homeowner's manual provided by the builder to the homeowner shall include operating instructions for the homeowner on how to use operable windows and/or mechanical ventilation to achieve adequate ventilation. Testing for reduced infiltration shall be performed as specified in ASTM E 779-03. This listings shall also report the target $CFM50_H$ required for the blower door test to achieve the modeled SLA and the minimum $CFM50_H$ (corresponding to an SLA of 1.5) allowed to avoid backdraft problems.
Metal-framed walls <construction type>	This building uses metal-framed walls that shall meet mandatory insulation requirements. In many cases sheathing insulation is used in addition to cavity insulation. Metal-framed walls shall be built according to the details in Joint Appendix 4 for this construction type.
Non-NAECA large storage gas water heater	A non-NAECA large storage gas water heater is specified for this building. System specifications are shown in the SPECIAL WATER HEATER/BOILER DETAILS table of compliance form CF-1R.
Water heating system does not have a single separate water heater serving each dwelling unit	Water heating system specifications are in the SPECIAL WATER HEATER/BOILER DETAILS table of compliance form CF-1R.
Photovoltaic system specified	Photovoltaic system output table to be verified as specified in Residential Appendix RB section RB10.
Controlled-ventilation Crawlspace	Controlled-ventilation Crawlspace is to be constructed in accordance with the alternative to section 150(d) of the Standards and section 6.2.4 of the Residential ACM Manual.
Solar thermal water heating	Solar Savings Fraction (SF) for solar thermal water heating is calculated from the equations in Residential ACM Appendix RG section RG 3.4. See also section 6.3 of the Residential ACM.
Ice Storage Air Conditioning Systems	Residential ACM section 6.3.5 specifies modelling assumptions and algorithms for ice storage air conditioning systems.
for additions or alterations:	
Lower energy factors are specified than the vintage defaults.	Field verification of lower energy factors is required.
Lower efficiencies are specified than the vintage defaults.	Field verification of specified efficiencies is required.
Higher SHGCs are specified than the vintage defaults.	Field verification of higher SHGCs as specified is required.

Higher F-factors are specified than the vintage defaults.	Field verification of higher F-factors as specified is required.
Higher U-factors are specified than the vintage defaults.	Field verification of U-factors as specified is required.

Residential ACM Appendix D – 2008

RACM Appendix D – Residential Compliance Software Electronic Data Transfer Protocol

D1 Scope

To allow for the creation of databases which will be used to verify compliance margins, building components, special compliance features, compliance document certifications, or any other compliance software data output required by the Commission, the following format must be followed by all compliance software vendors in organizing an electronic data export function.

D2 Protocol

The information contained in the data export shall have three data components:

1. Input file for the compliance software run that created the energy compliance document for the dwelling unit.
2. Representation, image, or "echo" of the formatted energy compliance document printout from the compliance software run for the dwelling unit. The input file from item 1 above should cause the same energy compliance document to be generated if processed by the compliance software.
3. A data file shall be made available based on the content and configuration of the CF-1R report. The data file shall be in a text format readable by database software applications maintained by HERS providers, Utility Rebate Program Administrators, Energy Commission Program Administrators, or other approved data users.

All three data components shall either be contained in a single electronic file, or if each data component is provided as a separate electronic file, the files shall be organized into an electronic "package" or "zip" file for use in the electronic transmittal of the data.

Additional electronic data transfer formats shall be defined and approved by the Energy Commission to accomodate standardized electronic transmittal of information for other documents such as Installation Certificates, Certificates of Field Verification and Diagnostic Testing, and Certificates of Acceptance.

D3 Sample Format

Examples of data structures for data normalization are shown below.

D3.1 Features from CF-1R that are inspectable by HERS raters – proposed XML schema for data normalization.

This is an xml schema containing the elements that can be derived from the currently existing transfer file output of both Micropas and EnergyPro. Software developers can implement this directly. This is the definition of the data normalization.


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elementFormDefault="qualified">
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```

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The following is an xml document containing example data processed by the CHEERS parser on a Micropas File. It alsoworks on EnergyPro .dat files.

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- <PlanFileInfo FileType="Micropas" Version="v7.30" Filename="MPXML2.TRF">
  <RunDate>10-24-2007 12:58:52</RunDate>
- <AuthorInfo Type="Author">
  <Name>Sample Author</Name>
  <CompanyName>Robert Scott</CompanyName>
  <Address1>P.O. Box 650</Address1>
  <Address2>Mountain Ranch, CA 95246</Address2>
  <Phone>209-754-4463</Phone>
  </AuthorInfo>
```

</PlanFileInfo>

- <Building>

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<Volume>**12800**</Volume>

<Type>**SingleFamily**</Type>

<Construction>**New**</Construction>

<FrontOrientation>**0**</FrontOrientation>

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Residential ACM Appendix E - 2008

RACM Appendix E – Water Heating Calculation Method

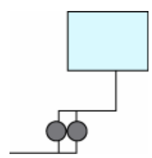
E1 Purpose and Scope

ACM Appendix ~~RG~~E 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.

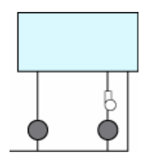
When buildings have multiple water heaters, the hourly total water heating energy use is the hourly water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

The following diagrams illustrate some of the cases that must be~~are~~ recognized by ~~ACM~~compliance programs.

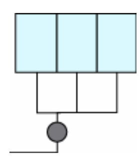
1 One distribution system with two water heaters serving a single dwelling unit.



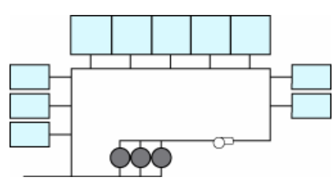
2 Two distribution systems, each with a single water heater serving a single dwelling unit.



3 One distribution system with one water heater serving multiple dwelling units.



4 Single distribution system with multiple water heaters serving multiple units.



The following rules apply to the calculation of water heating system energy use:

- One water heater type per system, e.g. no mix of gas and electric water heaters in the same system
- One solar ~~or woodstove~~ credit ~~(but not both)~~ per system. Any gas fired system using a temperature buffering storage tank that is electric heating must use the distribution factor for temperature buffering storage tanks provided in Table RG 2.

E2 Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. 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.

E3 Hourly Adjusted Recovery Load

The hourly adjusted recovery load (HARL) can be calculated by Equation RE-1Equation RE-1Equation RE-1Equation -1 through Equation RGRE-76.

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

Where:

$HARL_k$ =	Hourly adjusted recovery load (Btu).	
$HSEU_k$ =	Hourly standard end use (Btu).	See equation RE-2
DLM_k =	Distribution loss multiplier (unitless).	See equation RE-4
SSM_k =	Solar Savings Multiplier (unitless)	See equation RE-7
$HRDL_k$ =	Hourly recirculation distribution loss (Btu)	See equation RE-13.
HJL_l =	The tank surface losses of the l^{th} unfired tank of the k^{th} system (Btu)	See equation RG-29

This eEquation RGRE-1 calculates the hourly adjusted recovery load (HARL) on the water heater. The hourly adjusted recovery load (HARL) which is the heat content of the water delivered at the fixture. (HSEU) times the distribution loss multiplier (DLM) times the solar saving multiplier (SSM) plus the hourly recirculation losses between dwelling units (HRDL), which only occurs for multi-family central water heating systems and is zero for single family dwellings. The DLM will generally be greater than one, which means that heat is wasted as water flows from the water heater to the fixture. The DLM_k is constant for all hours with water heating end use. SSM_k is the solar savings multiplier for all solar systems. The methods for determining SSM_k for systems using SRCC OG 300 rating methods are in Section RG 3.4.1 and for systems using SRCC OG 100 rating methods are in Section RG 3.4.2.

Equation RGRE-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 RE-3

This eEquation RE-2 calculates the hourly standard end use (HSEU) for each hour at all fixtures. 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). GPH are calculated in a manner consistent with the Standard Recovery Load values in the current water heating methodology (see RG.3.2.1 Pipe Insulation Eligibility Requirements).

Equation RGRE-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 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in Table E3.3 Cold Water Inlet TemperatureE3.3 Cold Water Inlet Temperature.

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

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

Where:

DLM_k = Distribution loss multiplier (unitless)

$SDLM_k$ = Standard distribution loss multiplier (unitless). See equation RGRE-4 or RGRE-5

DSM_k = Distribution system multiplier (unitless)

This is the eEquation RGRE-4 for calculates the distribution loss multiplier (DLM) which. It combines two terms: the standard distribution loss multiplier (SDLM), which depends on the size of the dwelling unit and the number of stories, and the distribution system multiplier (DSM) listed in Table RE-2Table RE-2Table RE-2Table -2. For point-of-use (POU) distribution systems located in close proximity to all hot water fixtures (see RGRE.3.2.1 Pipe Insulation Eligibility Requirements), DLM is equal to one, e.g. there are no distribution losses.

Equation RGRE-5 $$SDLM_k = 1.064 + 0.000084 \times CFA_k$$

Where:

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

0.0000084 = loss per square foot (1/sq.ft.)

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

This eEquation RGRE-5 gives calculates the standard distribution loss multiplier (SDLM) for one story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). Multi-family SDLM's will be calculated based on the one story equation and the average CFA for all units. CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RGRE-6 $$SDLM_k = 1.023 + 0.000056 \times CFA_k$$

Where

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

0.000056 = loss per square foot (1/sq.ft.)

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

This eEquation RGRE-6 gives calculates the standard distribution loss multiplier (SDLM) for two and three story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RGRE-7

$$SSM_k = 1 - SSF_k$$

Where

SSM_k = the solar savings multiplier (unitless) for the k^{th} water heating system

Equation RG-7 determines the amount of the total water heating budget that is not provided by solar hot water heating. The value for SSF is provided from the results generated by the solar water heating calculations approved approaches for the OG-100 and OG-300 test proceedure.

This eEquation gives the solar savings multiplier (unitless) for the k^{th} water heating system. Equation RG-11 and Equation RG-12 provide more detail. SSF_k is the same as SF in Equation 12 (for OG 100) and as the solar collector's component of the SEF in Equation 11 (for OG 300).

where

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

$HSEU_k$ = Hourly standard end use (Btu). This is the amount of heat delivered at the hot water fixtures relative to the cold water inlet temperature.

$HRDL_k$ = Hourly recirculation distribution loss (Btu) is the hot water energy loss in multi-family central water heating recirculation systems (See E4 Hourly Recirculation Distribution Loss for Central Water Heating Systems).HRDL is zero for all single family water heating systems and for multi-family systems with individual water heaters.

DLM_k = Distribution loss multiplier (unitless).

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system provided in E3.1 Hourly Hot Water Consumption (GPH)E3.1 Hourly Hot Water Consumption (GPH).

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in E3.3 Cold Water Inlet TemperatureE3.3 Cold Water Inlet Temperature.

$SDLM_k$ = Standard distribution loss multiplier (unitless). This is calculated using Equation RE-5Equation RE-5Equation RE-5Equation -5 for single story dwelling units and from Equation RE-6Equation RE-6Equation RE-6Equation -6 for dwelling units with two or more stories. All multi-family projects utilize Equation RE-5Equation RE-5Equation RE-5Equation -5 and the average dwelling unit CFA.

DSM_k = Distribution system multiplier (unitless) provided in E3.2 Distribution System Multiplier (DSM) within the Dwelling UnitE3.2 Distribution System Multiplier (DSM) within the Dwelling Unit.

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

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 then shown in the following equation.

Equation ~~RG~~RE-8

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

where

$HARL_f$ = 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.

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 then shown in the following equation.

E3.1 Hourly Hot Water Consumption (GPH)

The average daily hot water consumption GPD for a dwelling unit is equal to 21.5 gallons/day plus an additional 14 gallons per day for each 1000 ft² of conditioned floor area. Consumption is about 31.3 gallons/day for a 700 ft² apartment and 56.5 gallons/day for a 2500 ft² dwelling unit. The equation for daily hot water consumption can be expressed as follows:

Equation ~~RG~~RE-9

$$GPD_I = 21.5 + 0.014 \times CFA_I$$

where

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

CFA_i = Conditioned floor area (ft²) of the i^{th} dwelling unit. When actual conditioned floor area is greater than 2500 ft², 2500 should be used in the above equation.

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 ~~RG~~RE-10

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

where

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

SCH_m = Fractional daily load for hour "m" from Table RE-1~~Table RE-1Table RE-1Table -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 RE-1~~Table RE-1Table RE-1Table -1~~ shall be used for calculating the hourly hot water consumption. These data are used for dwelling units of all types.

Table ~~RG~~RE-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

E3.2 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 one is used for standard distribution systems defined as a “main and branch” piping system with the portion of all lines leading from the water heater to the kitchen fixtures ~~that are equal to or greater than ¾ inch diameter~~ are insulated to a nominal R-4. Values for alternative distribution systems are given in Table RE-2~~Table RE-2Table RE-2Table -2~~.

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

Distribution System Measure	Code	DSM
Pipe Insulation (all lines)	PIA	0.90
Uninsulated Pipe below Grade	UPBG	3.8
Insulated and Protected pipe below grade	IPBG	1.0
Point of Use	POU	0.00
Standard -Kitchen Pipe Insulation (kitchen lines ≥ 3/4 inches) – Standard Case	STD	1.00
Standard pipes with no insulation	SNI	1.19
Parallel Piping	PP	1.00 1.04
Recirculation (no control)	RNC	4.50 4.52
Recirculation + timer control	RTm	3.00 3.03
Recirculation + temperature control	RTmp	3.70 3.73
Recirculation + timer/temperature	RTmTmp	2.50 2.49
Recirculation + demand control	RDmd	0.95 1.31
Temperature Buffering Tank	TBT	1.2

For eligibility criteria for distribution systems see Residential Appendix RA10.

RGRE.3.2.1 Pipe Insulation Eligibility Requirements

Pipe insulation on the first five feet of hot and cold water piping from storage gas water heaters is a mandatory measure as specified in Section 150 (j) of Title 24, Part 6. Note that exceptions 3, 4 and 5 to Section 150 (j) apply to all pipe insulation that is required to meet the mandatory measure requirement or that is eligible for compliance credit.

Pipe insulation credit available if all remaining hot water lines are insulated. Insulation shall meet mandatory minimums in Section 150 (j).

Overhead Plumbing for Non-Recirculation Systems. All plumbing located in attics with a continuous minimum of 4 in. of blown insulation coverage on top of the piping will be allowed to claim the “all lines” pipe insulation credit, provided that:

Piping from the water heater to the attic, and

Piping in floor cavities or other building cavities are insulated to the minimum required for pipe insulation credit.

RG.3.2.2 Point of Use Water (POU) Water Heaters Eligibility Requirements

Current requirements apply. All hot water fixtures in the dwelling unit, with the exception of the clothes washer, must be located within 8’ (plan view) of a point of use water heater. To meet this requirement, mostsome houses will require multiple POU units.

RG.3.2.3 Recirculation Systems Eligibility Requirements

All recirculation systems must have minimum nominal R-4 pipe insulation on all supply and return recirculation piping. Recirculation systems may not take an additional credit for pipe insulation.

~~The recirculation loop must be laid out to be within 8 feet (plan view) of all hot water fixtures in the house (with the exception of the clothes washer).~~

~~Approved recirculation controls include "no control", timer control, time/temperature control, and demand control. Time/temperature control must have an operational timer initially set to operate the pump no more than 16 hours per day. Temperature control must have a temperature sensor with a minimum 20°F deadband installed on the return line.~~

~~Demand recirculation systems shall have a pump (maximum 1/8 hp), control system, and a timer or temperature sensor to turn off the pump in a period of less than 2 minutes from pump activation. Acceptable control systems include push buttons occupancy sensors, or a flow switch at the water heater for pump initiation. At a minimum, push buttons and occupancy sensors must be located in the kitchen and in the master bathroom.~~

~~RG.3.2.4 Parallel Piping Eligibility Requirements~~

~~Each hot water fixture is individually served by a line, no larger than ½ in., originating from a central manifold located no more than 8~~10 ~~feet from the water heater. Fixtures, such as adjacent bathroom sinks, may be "doubled up" if fixture unit calculations in Table 6-5 of the California Plumbing Code allow.~~

~~Acceptable piping materials include copper and cross-linked polyethylene (PEX), depending upon local jurisdictions.~~

~~3/8 in. lines are encouraged~~acceptable~~, pending local code approval, provided minimum required pressures~~ flow rates ~~listed in the California Plumbing Code (Section 608.1) can be maintained.~~

~~Piping to the kitchen fixtures (dishwasher and sink(s)) that is equal to or greater than ¾ inch in diameter must be insulated to comply with Section 151(f)8D.~~

E3.3 Cold Water Inlet Temperature

The water inlet temperature varies monthly by climate zone and is equal to the assumed ground temperature as shown in Table RE-3~~Table RE-3Table RE-3Table -3~~.

Table RGRE-3 Monthly Ground Temperature (ºF)

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

RGRE.3.4 Solar Savings Multiplier

Solar water heating systems and collectors are rated using information from the Solar Rating and Certification Corporation (SRCC). Two types of ratings are possible: those using SRCC OG-300 are for systems, and those using SRRC OG-100 are for collectors that will be used in built-up systems.

RGRE.3.4.1 Determining Solar Savings Multiplier for SRCC OG-300 Rated Systems

For solar water heating systems rated using SRCC OG-300, the solar savings multiplier SSM_k is calculated as follows:

Equation RGRE-11

$$SSM_k = \left(1 - \left(\frac{\left(\frac{EF_{test,k} \times Q_{deltest}}{SEF_{rated,k}}\right) x \left(\frac{GPD_k}{64.3}\right) \times \left(\frac{T_s - T_{inlet}}{77}\right) + 3500 \times SYS_{type,k} \times \left(1 - EF_{test,k}\right)}{Q_{deltest}}\right) \times \left(\frac{1500}{\sum_{hr=1}^{hr=24} I_{hor,hr}}\right)\right)$$

where

$EF_{test,k}$ = Energy Factor used in SRCC OG-300 rating method for auxiliary water heater type used for rating. Two values are possible, 0.90 for a rating with an electric auxiliary water heater and 0.60 for a rating with a gas auxiliary water heater.

$Q_{deltest}$ = The standard OG-300 energy in the hot water delivered, 41,045 Btu/day.

$SEF_{rated,k}$ = The SEF rating as described in SRCC OG-300 and the Summary OG-300 directory for the k^{th} system.

3500 = Average parasitic loss for a Forced Circulation system (Btu/day).

$SYS_{type,k}$ = The OG-300 system type. There are four system types rated in OG-300. Force Circulation, Integral Collector Storage, Thermosyphon, and Self-Pumping. For Forced Circulation type systems this value is set to one. For all others, it is set to zero.

$GPDH_k$ = Hourly hot water consumption (gallons) of the k^{th} system.from Equation RE-9

64.3 = The standard OG-300 water draw of 64.3 gallons per day.

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in Table RE-3.

77 = Difference between Ts and T_{inlet} used in OG-300 test (ºF).

1500 = OG-300 test daily solar insolation (Btu/hr-ft^2).

$I_{hor,hr}$ = Hourly Horizontal solar insolation from weather data for each climate zone (Btu/hr-ft^2).

Hr = Hour of the day from 1 through 24.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

Eligibility Criteria

- In order to use this method, the system must satisfy the applicable eligibility criteria, including:
- The collectors must face within 35 degrees of south and be tilted at a slope of at least 3:12.
- The system must be installed in the exact configuration for which it was rated, e.g. the system must have the same collectors, pumps, controls, storage tank and auxiliary system fuel type as the rated condition.
- The system must be installed according to manufacturer's instructions.
- The collectors shall be located in a position that is not shaded by adjacent buildings or trees between 9:00 AM and 3:00 PM (solar time) on December 21.

RGRE.3.4.2 Determining Solar Savings Multiplier for SRCC OG-100 Rated Equipment

Calculating solar hot water system energy contributions requires that the system be modeled using Cal F-chart or any solar thermal modeling tool approved by the Commission. Version 4.0 and all later versions can be used to calculate the percent of water heating energy delivered by the solar system. The data listed in Table RE-4 should be followed as inputs for correctly modeling solar hot water systems. If the collector type is not flat plate then the user should refer to the F-chart user manual.

Table RGRE-4 Prototype Solar System

F-Chart Parameter	***Value***
Collector - Number of	Enter the number of collectors in the system
Collector Area	Enter square feet of the collector listed in the SRCC directory
Collector (test slope) or FR*UL from SRCC data	Enter the value listed in the SRCC directory (I.E. -.272)
Collector (test intercept) or FR*TAU*ALPHA from SRCC data	Enter the value listed in the SRCC directory (I.E. .500 'kepstein@archenergy.com' 7)
Collector Slope	Enter degrees from horizontal
Collector Orientation	Enter orientation as an azimuth, with 0 representing north.
Collector Incident angle modifier calculation	Set to glazing.
Number of glass covers	Enter the number of the layer of transparent covers for the collector.
Collector Flow Rate/Area	Calculate or set to a default of 11 lb/hr-ft2. If calculated, determine the value by dividing the flow rate of the system by the collector area.
Collector Fluid Specific Heat	Set to 1.00 for water, 0.8 for glycol and 0.23 for air. Units in Btu/lb-F.
Collector Modify Test Values	Set to "no."
System location	Select the climate zone the permitted building is located in.
System water volume/collector ratio	Calculate by dividing the volume of the storage tanks and collectors by the collector area. Does not include piping volume.
System Efficiency of (auxiliary) fuel usage	Set to 1 – this input does not change results.
System Daily hot water usage	Value must be calculated using Equation RGRE-9.
System water set temperature	Value must be set to 135.
System environmental temperature	Value must be the January value from table RGRE-3.
System UA of auxiliary storage tank	Calculate using the value determined with Equation RGRE-343 times 1/R value of the insulation.
System pipe heat loss	Assume value to be 0.
System collector-store heat exchanger	Enter Yes or No.
Tank-side flow-rate/area	Entered in lbs/hr-ft2 is the mass flow rate of water from the storage tank through the collector-storage heat exchanger divided by the total collector area. (Set this to a value larger than the collector flow rate/area in the collector parameters for an internal heat exchanger).
Heat exchanger effectiveness	Enter this ratio of the actual to maximum possible heat transfer rates for the heat exchanger located between the collector and storage unit.

F-chart will generate a Solar Fraction (SF). This value is an annual fraction of the total hot water demand met by the solar system. To adjust the SF to daily loads use Equation RE-12.

Equation RGRE-12 $$SSM_k = 1 - SF_k \times A$$

where

SF_k = Solar Factor (SF) derived from an approved solar thermal modeling toolF-chart.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

E4 Hourly Recirculation Distribution Loss for Central Water Heating Systems

The distribution losses accounted for in the distribution system multiplier (DSM) see table RE-2 are within each individual dwelling unit. Additional distribution losses occur in most multi-family dwelling units related to recirculation systems between dwelling units. These losses include losses from piping that is or could be part of a recirculation loop and branch piping to individual residential units. These losses are divided into losses to the outside air, the ground and the conditioned or semi-conditioned air within the building envelope.

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 (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 unitapartment.

These losses are added to the load accounted for in the hourly adjusted recovery load HARL, according to Equation RE-1Equation RE-1Equation RE-1Equation -1 and calculated in the following equation.

Equation RGRE-1113 $$HRDL_k = NL_{OA} \times UA_{OA} \times (T_s - T_{OA}) + NL_{UG} \times UA_{UG} \times (T_s - T_G) + NL_P \times UA_P$$

where

$HRDL_k$ = Hourly recirculation distribution loss (Million Btu).

T_s = Hot water supply temperature of 135°F.

T_{OA} = Hourly dry-bulb temperature of outside air (°F).

T_G = Hourly ground temperature (°F) assumed constant for each month See Table RE-3.

NL_{OA} = Normalized load coefficient for outside air term. See equation RE-14

NL_{UG} = Normalized load coefficient for underground term. See equation RE-15

NL_P = Normalized load coefficient for conditioned or semi-conditioned term. See equation RE-16

UA_{OA} = Heat loss rate of circulation pipe exposed to outside air (Btu/hr-°F). See equation RE-21 or 22

UA_{UG} = Heat loss rate of circulation pipe buried under ground (Btu/hr-°F)). See equation RE-21 or 22

.

UA_P = Heat loss rate of circulation pipe in conditioned or semi-conditioned space (Btu/hr-°F).). See

equation RGRE-19 or 20

The terms UA_{OA}, UA_{UG}, and UA_P represent the conductive area and heat loss rate for the three pipe locations. In each case the UA is a function of the pipe length, pipe diameter and pipe insulation. The program user will need to specify pipe length in each of the three locations, and specify the insulation as being either minimum (as specified in Section 150 (j), Part 6, of Title 24), or extra. Length and corresponding insulation R-value takeoffs are required for piping in each of the three locations (outdoors, underground, and conditioned or semi-conditioned space). Pipe heat loss rates (UA_{OA}, UA_{UG}, and UA_p) are then calculated for use in Equation RE-11Equation RE-11Equation RE-11Equation -11.

The normalized load coefficients, NL_{OA}, NL_{UG}, and $NL_{P,}$ are climate zone specific multipliers for the pipe losses to the outside air, ground and conditioned or semi-conditioned space, respectively. They are calculated according to the following equations:

Equation RGRE-1412

$$NL_{OA} = \frac{C_{OA1} \times \exp\left(\frac{C_{OA2} \times UA_{OA}}{GPD_k}\right)}{WHDH_{OA}}$$

Equation RGRE-1513

$$NL_{UG} = \frac{C_{UG1} \times \exp\left(\frac{C_{UG2} \times UA_{UG}}{GPD_k}\right)}{WHDH_{UG}}$$

Equation RGRE-1614

$$NL_{P} = \frac{C_{P1} \times \exp\left(\frac{C_{P2} \times UA_{P}}{GPD_k}\right)}{8760}$$

where

GPD_k = The hot water consumption per day for the k^{th} system. It is the sum of hot water consumption per day for all dwelling units served by the k^{th} system.

$WHDH_{OA}$ = Water heating degree hours based on outside air temperature (hr-°F).

$WHDH_{UG}$ = Water heating degree hours based on ground temperature (hr-°F).

C_{OA1} , C_{OA2} = Coefficients for outside air pipe loss term.

C_{UG1} , C_{UG2} = Coefficients for underground pipe loss term.

C_{P1} , C_{P2} = coefficients for conditioned or semi-conditioned space pipe loss term.

Coefficients of C_{OA}, C_{UG}, and C_P vary by climate zones and control schemes of the circulation system. Table RE-4Table RE-4Table RE-4Table -4 lists values of these coefficients.

Table ~~RG~~RE-4 Coefficients of $C_{OA,}$ C_{UG} and C_P

Climate Zone	No Controls						Timer Controls					
	COA1	COA2	CUG1	CUG2	CP1	CP2	COA1	COA2	CUG1	CUG2	CP1	CP2
1	0.8933	-0.694	0.8922	-1.346	0.6259	-1.673	0.8658	-2.336	0.793	-2.062	0.6344	-4.475
2	0.854	-0.71	0.8524	-1.348	0.6433	-1.383	0.8269	-2.456	0.7572	-2.056	0.6529	-4.138
3	0.8524	-0.709	0.851	-1.355	0.6826	-1.464	0.8252	-2.37	0.7553	-2.049	0.6927	-4.438
4	0.8349	-0.688	0.8345	-1.343	0.6502	-0.706	0.8096	-2.433	0.7427	-2.071	0.667	-3.759
5	0.8494	-0.706	0.8476	-1.341	0.6873	-1.076	0.8218	-2.409	0.7536	-2.061	0.6922	-3.979
6	0.8095	-0.704	0.808	-1.341	0.7356	-1.697	0.7836	-2.367	0.718	-2.059	0.7341	-4.512
7	0.796	-0.673	0.7964	-1.349	0.735	-1.581	0.7734	-2.395	0.7082	-2.064	0.7416	-4.579
8	0.7941	-0.704	0.7925	-1.341	0.7321	-1.471	0.7683	-2.414	0.7049	-2.064	0.7333	-4.318
9	0.7853	-0.707	0.7843	-1.352	0.7208	-1.212	0.7599	-2.447	0.6971	-2.064	0.7248	-4.141
10	0.7854	-0.714	0.7843	-1.352	0.7193	-1.273	0.7595	-2.5	0.6971	-2.067	0.7188	-4.041
11	0.8137	-0.69	0.8139	-1.35	0.6149	-1.22	0.788	-2.443	0.7228	-2.051	0.6315	-4.306
12	0.8283	-0.685	0.8286	-1.349	0.6001	-0.323	0.8029	-2.451	0.7367	-2.061	0.621	-3.493
13	0.7818	-0.705	0.7813	-1.352	0.6699	-1.541	0.7564	-2.465	0.6937	-2.052	0.6752	-4.305
14	0.8094	-0.706	0.809	-1.351	0.6424	-0.866	0.784	-2.49	0.7187	-2.059	0.6515	-3.588
15	0.6759	-0.692	0.6764	-1.348	0.7514	-1.383	0.6535	-2.552	0.601	-2.061	0.7493	-4.182
16	0.9297	-0.701	0.929	-1.352	0.5231	-1.519	0.9007	-2.401	0.825	-2.053	0.5437	-4.423

Table RE-4~~Table RE-4Table RE-4Table -4~~ provides coefficients for recirculation systems where the pumps are always on and coefficients for recirculation systems that are shut off during hours 1 through 5, and hours 23 and 24 (from 10p.m. to 5a.m.). Except for systems serving only a very small number of dwelling units, there is no set of coefficients provided for the case where the circulation system does not rely on a recirculation pump. Such a system would be unlikely to supply hot water within parameters acceptable to tenants. It can be assumed that any distribution systems for supplying hot water from a central boiler or water heater require a recirculation pump and one would be supplied retroactively if not initially. For central hot water systems serving six or fewer dwelling units which have (1) less than 25' of distribution piping outdoors; (2) zero distribution piping underground; (3) no recirculation pump; and (4) insulation on distribution piping that meets the requirements of Section 150 (j) of Title 24, Part 6, the distribution system in the Standard Design and Proposed design will both assume a pump with timer controls.

$WHDH_{OA}$ is the sum of the differences between the temperature of the supply hot water (135˚F) and the hourly outdoor temperature for all 8760 hours of the year. This term varies by climate zone. The values for this term are listed in Table RE-5~~Table RE-5Table RE-5Table -5~~ below. The equation uses the hourly outdoor temperatures from the weather files incorporated in the CEC approved programs.

$WHDH_{UG}$ is the sum of the differences between the supply hot water temperature (135˚F) and the hourly ground temperature for all 8760 hours of the year. This term varies by climate zone. The appropriate values for this term are listed in Table RE-5~~Table RE-5Table RE-5Table -5~~ below. The equation uses the ground temperatures from the weather files incorporated in the CEC approved programs, which are assumed to be stable on a monthly basis.

Table ~~RG~~RE-5 Water Heating Degree Hours for Outside Air and Underground

Climate Zone	$WHDH_{OA}$ (hr-°F)	$WHDH_{UG}$ (hr-°F)
1	712810	710306
2	680634	678425
3	679350	677026
4	666823	664459
5	677373	674935
6	645603	643236
7	636342	633811
8	633244	630782
9	626251	623822
10	625938	623741
11	649661	647770
12	661719	659676
13	623482	621526
14	645367	643517
15	539736	537782
16	741372	739378

UA terms are calculated using inputs provided by the user and base assumptions about the pipe diameter: The user inputs are:

1. Pipe length in each of the three locations.
2. Insulation R value of the pipe in each location.
3. Number of stories above grade.
4. Number of apartment units.

The total length of the circulation pipe is calculated, along with the fraction in each location (PF_{OA}, PF_{UG} and PF_P). The square feet of surface area is calculated according to the following equation:

Equation ~~RG~~RE-~~17~~15

$$SF_{total} = LF_{total} \times Dia \times \pi$$

where

SF_{Total} = The total surface area of the circulation piping, square feet.

LF_{Total} = The total lineal feet of all circulation piping, feet.Dia = Average calculated (Equation RE-~~Equation RE-Equation RE-Equation~~) diameter of pipe in circulation piping, feet.

π = Pythagorean constant (ratio of perimeter to diameter), 3.1416

The average diameter of hot water piping, Dia, is calculated by the following equation:

Equation ~~RG~~RE-~~18~~16

$$Dia = 0.045 \times \left(\frac{LF_{Total}}{\Delta P}\right)^{0.21} \times (AptGPM)^{0.37} \times \frac{(NumApts)^{0.37}}{1.37}$$

The terms of the above equation are described below. The total system pressure drop, ΔP, given in psf is calculated in Equation RE-~~Equation RE-Equation RE-Equation~~ .

Equation ~~RG~~RE-~~19~~17

$$\Delta P = [P_{meter} - 4.3 \times (NumStories - 1) - 15] \times 144$$

where

P_{meter} = Water system supply pressure, (60 psig by assumption).

NumStories = Number of stories above grade, (but enter "4" if more than 4 stories).

Equation ~~RG~~RE-~~20~~18

$$AptGPM = \frac{1.765 \times \left(12 \times NumApts\right)^{0.687}}{NumApts}$$

NumApts = Number of apartments in the building served by the hot water system, apts

The UA for each of the three locations is derived as a function of the fraction of the total pipe in that location times a factor that represents the conductivity of the standard (minimum) insulation or the "extra" insulation condition. The following two equations provide the alternate equations for the two insulation cases. The factors do not vary by location so the equations for the other two locations are of exactly the same form, varying only by the fraction of pipe in that location.

The benefits of additional insulation shall be calculated as required in Section 150 (j) of Title 24. The insulation value of the ground and of protective coverings may not be used for achieving the minimum insulation values required by Section 150 (j). To qualify as extra insulation, the insulation must be at least 1/2" thicker than the insulation required by Section 150 (j).

Equation ~~RG~~RE-~~21~~ 19 For extra insulation for the standard design:

$$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick + 0.5}{Radius}\right)} \right)$$

Equation ~~RG~~RE-~~22~~ 20 For minimum insulation:

$$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick}{Radius}\right)} \right)$$

where

i = Subscript indicating pipe location OA = outside, UG = underground, P = conditioned or semi-conditioned space

PF_i = Pipe fraction in i^{th} location, no units

k = Insulation conductivity, (assumed 0.25 Btu inch/h·sf·°F)

Radius = Average pipe radius in inches, (Radius = Dia x 12 / 2), inches

Thick = Base case insulation thickness, Thick = 1 if average pipe radius is less than or equal to 2";Thick = 1.5 if radius is greater than 2", inches

E5 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.

E5.1 Small[1] Gas, Oil, or Electric Storage 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 ~~RG~~RE-~~23~~21

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

where

$WHEU_j$ = Hourly energy use of the water heater (Btu for fuel or kWh for electric), adjusted for tank insulation ~~and wood stove boilers~~.

$HARL_j$ = 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.

~~The energy consumption of one or more independent hot water storage tanks that are not rated as water heaters is calculated by substituting $xHARL_j$ for $HARL_j$ where $xHARL_j$ is defined in Section __.~~

Table ~~RG~~RE-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 standard EF for different load conditions.

Equation ~~RG~~RE-~~24~~22

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

where

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

[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, a gas instantaneous water heater with an input of 200,000 Btu per hour or less, an oil instantaneous water heater with an input of 210,000 Btu 1602 per hour or less, an electric instantaneous water heater with an input of 12 kW or less, or a heat pump water heater rated at 24 amps or less.

Table RGRE-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: 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.

~~WSAFj = Wood stove boiler adjustment factor for the j^th water heating system. This is given in Section RG.4.6 Wood Stove Adjustment Factors. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.~~

E5.2 Small Gas Large Gas or Oil Instantaneous[2]

The hourly energy use for instantaneous gas or oil water heaters is given by the following equations.

Equation RGRE-253

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

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

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu)~~, adjusted for wood stove boilers~~.

$HARL_j$ = 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.

~~$PILOT_j$ = Energy consumption of the pilot light (Btu/h). Default if no information provided in manufacturer's literature or CEC Appliance Database is 500 Btu/hr.~~

0.92 = Efficiency adjustment factor

~~$WSAF_j$ = Wood stove boiler adjustment factor for the j^th water heating system. This is an optional capability and is set to 1.00 for ACM without wood stove boiler modeling capability.~~

Note: Small gas or oil instantaneous water heaters can be used in conjunction with demand recirculation. No other recirculation systems may be used.

E5.3 Small Electric Instantaneous

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

2 "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.

Equation RGRE-11
$$WHEU_{j,electric} = \frac{HARL_j}{EF_j * 0.92} \quad WHEU_j = \frac{HARL_j}{1000 * EF_j}$$

where

WHEU$_{j, elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

HARL$_j$ = Hourly adjusted recovery load.

EF$_j$ = Energy factor from DOE test procedure (unitless). EF is adjusted for electricity by multiplying 1000* TDV mulitiplier.

0.92 = Adjustment factor to adjust for overall performance.

WSAF$_j$ = Wood stove boiler adjustment factor for the jth water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

E5.4 Large[3] 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 RGRE-12
$$WHEU_j = \left[\frac{HARL_j}{EFF_j} + SBL\right]$$

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 xHARL$_j$ from Section RGREE 4.9 for HARL$_j$.

SBL = Total Standby Loss. Obtain from CEC Appliance Database or from manufacturer literature. This value includes tank losses and pilot energy.

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.

E5.5 Large[4] Gas or Oil Storage. Large Instantaneous, Indirect Gas and Hot Water Supply Boilers[5].

Energy use for large storage gas and indirect gas water heaters is given 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.

[3] "Large water heater" means a water heater that is not a small water heater.

[4] "Large water heater" means a water heater that is not a small water heater.

[5] "Hot water supply boiler" means an appliance for supplying hot water for purposes other than space heating or pool heating.

Equation RGRE-13 $$WHEU_j = \left[\frac{HARL_j}{EFF_j \times 0.92} + PILOT_j \right] \quad WHEU_j = \left[\frac{HARL_j}{EFF_j \times EAF_j} + PILOT_j \right]$$

where

WHEU$_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation and wood stove boilers.

HARL$_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute xHARL$_j$ from Section for HARL$_j$.

HJL$_j$ = Hourly jacket loss (Btu/h) for tank rated with the water heater. For nonstorage water heaters and boilers set this term to zero. To account for independent hot water storage tanks substitute xHARL$_j$ (from Section) 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). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.

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. For storage type water heaters the default is zero.

WSAF$_j$ = Wood stove boiler adjustment factor for the jth water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

E5.6 Large Electric Storage

Energy use for large storage electric water heaters is given by the following equation.

Equation RGRE-14 $$WHEU_{j,elec} = \left[\frac{HARL_j}{EFF\bar{j}} \right] + SBL \quad WHEU_{j,elec} = \left[\frac{HARL_j}{EFF\bar{j} \times 3.413} \right] + SBL$$

where

WHEU$_{j, elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

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.

HARL$_j$ = Hourly adjusted recovery load.

SBL = Total Standby Loss. Obtain from CEC Appliance Database or from manufacturer literature. If standby is reported as a percent then the standby shall be determined by taking a percent of the equipment input rating times 3413. If no standby value is reported the standby shall be assumed to be 1 percent of the equipment input rating * 3413..

HJL$_j$ = Hourly jacket loss (Btu/h) for the tank rated with the heater.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.6 Wood Stove Adjustment Factors

This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether the wood stove boiler has a recirculation pump. The inclusion of this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.

Table RGRE-9 Wood Stove Adjustment Factors

Climate Zone	Wood Stoves with Pumps	Wood Stoves without Pumps
1	0.775	0.750
2	0.775	0.750
3	0.775	0.750
4	0.865	0.850
5	0.865	0.850
6	0.910	0.900
7	0.910	0.900
8	0.955	0.950
9	0.910	0.900
10	0.955	0.950
11	0.910	0.900
12	0.865	0.850
13	0.910	0.900
14	0.910	0.900
15	1.000	1.000
16	0.730	0.700

E5.7 Jacket Loss

The hourly jacket loss for the l^{th} unfired tank or indirectly fired storage tanks in the k^{th} system for large storage gas and indirect gas water heaters is calculated as

Equation RGRE-15

$$HJL_l = \frac{TSA_l \times \Delta TS}{RTI_l + REI_l} + FTL_l$$

Where

HJL_l = The tank surface losses of the l[th] unfired tank of the k[th] system

TSA_{jl} = 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 135ºF. 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_{jl} = Fitting losses. This is a constant 61.4 Btu/h.

REI_{jl} = R-value of exterior insulating wrap. No less than R-12 is required.

RTI_{lj} = Calculated R-value of insulation internal to water heater. Assume 0 without documentation.

For water heaters with standby loss rated in percent heat content of the stored water:

Equation RGRE-30
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[\left(8.345 \times VOL_j \times SBL_j \times \Delta TS\right) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

For water heaters with standby loss rated in Btu/hr:

Equation RGRE-31
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[\left(SBE_j \times \left(\frac{\Delta TS}{60}\right)\right) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

SBE_j = Standby loss expressed in Btu/hr from the CEC Appliance Database or from manufacturer's literature.

SBL_j = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the CEC Appliance Database or from manufacturer's literature.

$PILOT_j$ = Pilot light energy (Btu/h). If no information is provided in manufacturer's literature or CEC Appliance Database default to zero.

ΔTS = Temperature difference between ambient surrounding water heater and hot water supply temperature (ºF). Hot water supply temperature shall be 135ºF. 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.

The hourly jacket loss for large storage electric heaters is calculated as:

Equation RGRE-32
$$HJLi = \frac{TSA \times \Delta T}{(RTIj + REIj)}$$

(same definitions as above)

RTIj = Calculated R-value of insulation internal to water heater.

REIj = R-value of exterior insulating wrap.

Where the calculated insulation R-value RTI_j is calculated by:

Equation RGRE33
$$RTIj = \frac{(TSAj \times \Delta TS)}{[(8.345 \times VOLj \times SBLj \times \Delta TS) \times EFFj]}$$

where

SBLj = Standby loss expressed in percent heat content loss of the stored water, from manufacturer's data.

EFFj = Efficiency, from manufacturer's data.

E5.8 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 RGRE-16

$$TSA_j = e \times \left(f \times VOL_j^{0.33} + g\right)^2$$

where

VOL_j = Tank capacity (gallons).

e, f, g = Coefficients given in the following table.

Table RGRE-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

RG.4.9 Independent Hot Water Storage Tanks

The additional loads due to independent hot water storage tanks which are not rated as water heaters is calculated by adding the sum of the jacket losses for one or more of these tanks to the Hourly Adjusted Recovery Load for the jth water heater and substituting $xHARL_j$ for $HARL_j$ in the appropriate equation above for the jth water heater:

Equation RGRE-35

$$xHARL_j = HARL_j + \sum_k HJL_{j,k}$$

where

$xHARL_j$ = Hourly Adjusted Recovery Load for the jth water heater plus the load due to independent hot water storage tanks serving the jth hot water heater.

$HARL_j$ = Hourly Adjusted Recovery Load for the jth water heater as defined by Equation RG-1.

~~$HJL_{j,k}$ = Hourly Jacket Loss of the kth independent hot water storage tank serving the jth water heater.~~

~~The hourly jacket loss, HJL is calculated per RG.4.7 Jacket Loss using Equation RG-29. When the Standby Loss for the tank is not available or not listed, RTIj may be set at zero and the total tank insulation may be entered for REI. The minimum value of REI allowed by the ACMshall be a 0.68 still air film.~~

E5.9 Electricity Use for Circulation Pumping

For single-family recirculation systems, hourly pumping energy is fixed as shown in following table.

Table ~~RG~~RE-9 Single Family Recirculation Energy Use (kWh) by Hour of Day

Hour	Uncontrolled Recirculation	Timer Control	Temperature Control	Timer/Temp Control	Demand Recirculation
1	0.040	0	0.0061	0	0.0010
2	0.040	0	0.0061	0	0.0005
3	0.040	0	0.0061	0	0.0006
4	0.040	0	0.0061	0	0.0006
5	0.040	0	0.0061	0	0.0012
6	0.040	0	0.0061	0	0.0024
7	0.040	0.040	0.0061	0.0061	0.0045
8	0.040	0.040	0.0061	0.0061	0.0057
9	0.040	0.040	0.0061	0.0061	0.0054
10	0.040	0.040	0.0061	0.0061	0.0045
11	0.040	0.040	0.0061	0.0061	0.0037
12	0.040	0.040	0.0061	0.0061	0.0028
13	0.040	0.040	0.0061	0.0061	0.0025
14	0.040	0.040	0.0061	0.0061	0.0023
15	0.040	0.040	0.0061	0.0061	0.0021
16	0.040	0.040	0.0061	0.0061	0.0019
17	0.040	0.040	0.0061	0.0061	0.0028
18	0.040	0.040	0.0061	0.0061	0.0032
19	0.040	0.040	0.0061	0.0061	0.0033
20	0.040	0.040	0.0061	0.0061	0.0031
21	0.040	0.040	0.0061	0.0061	0.0027
22	0.040	0.040	0.0061	0.0061	0.0025
23	0.040	0	0.0061	0	0.0023
24	0.040	0	0.0061	0	0.0015
Annual Total	350	234	53	35	23

Multi-family recirculation systems may have vastly different pump sizes and is therefore calculated based on the installed pump size. The hourly electricity use for pumping (HEUP) water in the circulation loop can be calculated by the hourly pumping schedule and the power of the pump motor as in the following equation.

Equation ~~RG~~RE-17

$$HEUP_k = \frac{0.746 \times PUMP_k \times SCH_{k,m,}}{\eta_k}$$

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. For 24-hour operation (no controls), the value is always 1. For timer controls, the value is 1 when pump is on and 0 otherwise. The pump is assumed off from 10 p.m. to 5 a.m. and on for the remaining hours.

E5.10 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 RE-18.

Equation RE-18

$$Fraction_I = \frac{GPD_I}{\left(\sum_{I}^{NmbrDU} GPD_i\right)}$$

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 RE-9.