Residential Appendix RA3

Appendix RA3 – Residential Field Verification and Diagnostic Test Protocols

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RA3.1 Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

RA3.1.1 Purpose and Scope

RA3.1 contains procedures for measuring the air leakage in forced air distribution systems as well as procedures for verifying supply duct location, supply duct surface area, supply duct ~~and~~ R-value, return duct design, return grille design, and air filter installation.

RA3.1 applies to air distribution systems in both new and existing low-rise residential buildings.

RA3.1 provides required procedures for installers, HERS raters and others who need to perform field verification of ~~the efficiency of~~ air distribution systems.

~~Algorithms for determining distribution system efficiency are contained in Chapter 3 of the residential ACM Manual.~~ Table RA3.1-1 is a summary of the tests and criteria included in RA3.1.

Table RA3.1-2 Provides compliance criteria for the duct leakage test protocols in Section RA3.1.4.3.

Table RA3.1-1 – Summary of Duct System Field Verification and Diagnostic Test Protocols~~Diagnostic Measurements~~

Verification/Diagnostic	Description	Procedure
Supply Duct Location, Surface Area and R-value	Verify ~~that~~ duct system was installed according to the specifications on the Certificate of Compliance or in accordance with an approved duct system design layout.~~, including location, size and length of ducts, duct insulation R-value, and installation of buried ducts.~~	RA3.1.4.1 ~~Diagnostic Supply Duct Location, Surface Area and R-value RA3.1.4.1.1.1 Verified Duct Design~~
Verified Duct System Design	Procedure for duct system design layout approval and field verification	RA3.1.4.1.1
Duct Leakage	Verify that duct leakage is less than or equal to the compliance criteria given in Table RA3.1-2.~~or in the case of existing ducts that all accessible leaks have been sealed.~~	~~Diagnostic Duct Leakage~~ RA3.1.4.3
Return Duct Design	Verify compliance with the return duct and return grill sizing requirements of Table 150.0-E or Table 150.0-F).	RA3.1.4.4
Air Filter Device Design	Verify compliance with the requirements in 150(m)12.	RA3.1.4.5
Bypass Duct Prohibition	Verify compliance with the bypass prohibition in 150.0(m) 14	RA3.1.4.6

RA3.1.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RA3.1.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of plus or minus 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes, Dwyer A303 or equivalent.

RA3.1.2.2 Duct Leakage Measurements

Duct leakage airflows during duct leakage testing shall be measured with digital gauges that have an accuracy of plus or minus 3 percent or better.

RA3.1.2.3 Calibration

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified in Section RA3.1.2. ~~All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.~~

RA3.1.3 Diagnostic Apparatus

RA3.1.3.1 Apparatus for Duct Pressurization and Leakage Flow Measurement

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section RA3.1.2.

RA3.1.3.2 Apparatus for Duct Leakage to Outside Measurement ~~(Existing Duct Systems)~~

The apparatus for measuring duct leakage to outside shall include a fan that is capable of maintaining the pressure within the conditioned spaces in the house at 25 Pa relative to the outdoors. The fan most commonly used for this purpose is known as a "blower door" and is typically installed within a temporary seal of an open exterior doorway.

RA3.1.3.3 Apparatus for Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining leakage in and verifying sealing of all accessible leaks in existing duct~~s systems shall also include~~ provide means for introducing controllable amounts of non-toxic visual/theatrical smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. The means for generating smoke shall ~~Adequate smoke shall be used to assure~~ have sufficient capacity to ensure that any accessible leaks will emit visibly identifiable smoke.

RA3.1.4 Verification and Diagnostic Procedures

This section describes the procedures used to verify compliance with the mandatory and performance compliance requirements for air distribution systems.~~diagnostic inputs for the calculation of improved duct efficiency.~~

RA3.1.4.1 Diagnostic Supply Duct Location, Surface Area and R-value

The performance compliance calculations ~~in the Residential ACM Manual, Section 3.12.3,~~ allow credit for duct systems that are designed to be in advantageous locations, that have reduced supply duct surface areas, and/or that provide higher R-values for portions of the system. ~~Compliance credit may be taken for one or more of these duct system improvements in any combination. The procedure in this~~ This section ~~is used to verify that~~ specifies procedures for verification of~~the~~ duct systems for conformance with the requirements for the performance compliance credits. When indicated on the Certificate of Compliance, the Installer shall certify compliance with the applicable procedures in RA3.1.4.1 on an Installation Certificate, and a HERS rater shall verify compliance on a Certificate of Field Verification and Diagnostic Testing.~~duct system is installed according to the design and meets the requirements for compliance credit.~~

RA3.1.4.1.1 Verified Duct System Design ~~Requirements~~

An installed duct system meets the Verified Duct System Design compliance criteria if it is field verified by a HERS rater to be in conformance with a duct design layout that meets all applicable duct design and documentation requirements given in Section RA3.1.4.1.1. The duct design layout shall be approved by the enforcement agency.

RA3.1.4.1.1.1 Verified Duct System Design - Duct Design Layout

The duct system design shall be documented on the Duct Design Layout, a scaled layout drawing that identifies ~~show~~ the location of the space conditioning equipment, ~~and~~ all supply and return registers/grilles, the ~~. The~~ size, R-value, and location of each duct ~~segment shall be shown in the design drawing, which shall be cross referenced to~~ segment. The Duct Design Layout shall incorporate all other ~~the~~ supply duct details report~~ed in~~ on the registered Certificate of Compliance. ~~For ducts buried in attic insulation, the portion in contact with the ceiling or deeply buried shall be shown and the design shall include provisions for ducts crossing each other, interacting with the structure, and changing vertical location to connect with elevated equipment or registers as required. Credit shall be allowed for buried ducts 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.~~

~~*RA3.1.4.1.1.1 Verified Duct Design*~~

RA3.1.4.1.1.2 Verified Duct System Design - Compliance Criteria

~~The system meets the Verified Duct Design criteria if it is verified to be consistent with a documented duct design that meets the requirements of this section.~~ The duct system design shall be based on an industry standard design methodology such as ACCA Manual D or an equivalent, and shall take into account: the available external static pressure from the air handler, the equivalent length or pressure drop of external devices, and the pressure drop of the duct runs accounting for size, type and configuration of the ducts and fittings. The duct system shall be designed to meet the required system airflow rate with the manufacturer-specified available external static pressure for the specified system air handler at that airflow. The duct system design shall ~~have~~ include calculations ~~showing~~ that indicate the duct system will operate at equal to or greater than 0.0292 cfm/Btu (350 cfm/12000 Btu) in cooling speed (350 cfm per nominal ton of cooling capacity specified by the manufacturer) or, if heating only, equal to or greater than 16.8 cfm per 1000 Btu/hr furnace nominal output specified by the manufacturer. ~~The duct design shall be based on an industry standard design methodology such as ACCA Manual D or equivalent, and shall take into account: the available external static pressure from the air handler, the pressure drop of external devices, the equivalent length of the duct runs, as well as the size, type and configuration of the ducts and fittings.~~

RA3.1.4.1.1.3 Verified Duct System Design - Duct Design Layout Approval

The ~~duct design~~ Duct Design Layout ~~specifications and layout~~ shall be included with the building design plans and the registered Certificate of Compliance submitted to the enforcement agency in conjunction with the application for the building permit~~, and a~~. ~~duct design layout~~ A copy of the Duct Design Layout approved by the enforcement agency shall be posted or made available with the building permit(s) issued for the building, and shall be made available to the enforcement agency, installing contractor, and HERS rater for use during the installation work and for all applicable inspections.

~~*RA3.1.4.1.1.2*~~*RA3.1.4.1.1.4 Verified Duct System Design - Field Verification of ~~Duct System~~ Installation*

The location of all supply and return registers shall be verified ~~from an~~by inspection of the interior of the dwelling unit. The location of the space conditioning equipment and the size, R-value, and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the approved Duct Design Layout~~design~~ shall not be allowed~~.~~ without a revised a Duct Design Layout approved by the enforcement agency.

~~**RA3.1.4.1.2 Verifying the Duct System Installation**~~

~~The location of all supply and return registers shall be verified from an inspection of the interior of the dwelling unit. The location of the equipment and the size, R-value, and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the design shall not be allowed.~~

~~**RA3.1.4.1.3 Verification for Ducts to be buried in Attic Insulation**~~

~~This procedure and the procedure of RA3.1.4.2 shall be carried out prior to covering the ducts with insulation. Ducts to be buried shall be insulated to R4.2 or greater. In addition ducts designed to be in contact with the ceiling shall be in continuous contact with the ceiling drywall or ceiling structure not more than 3.5 inches from the ceiling drywall. A sign must be hung near the attic access reading "Caution: Buried Ducts. Markers indicate location of buried ducts." All ducts which will be completely buried shall have vertical markers which will be visible after insulation installation at not more than every 8 feet of duct length and at the beginning and end of each duct run.~~

RA3.1.4.1.2 Verification of 12 Linear Feet or Less of Duct Located Outside Of Conditioned Space

A visual inspection shall confirm space conditioning systems with air handlers located outside the conditioned space have 12 linear feet or less of duct located outside the conditioned space including air handler and plenum. If the space conditioning system has more than 12 feet of duct outside of conditioned space, the system does not pass.

RA3.1.4.1.3 Verification of Ducts Located In Conditioned Space

A visual inspection shall confirm space conditioning systems are located entirely in conditioned space. If any part of the space conditioning duct system is outside of conditioned space, the system does not pass.

RA3.1.4.1.4 Verification of Supply Duct Surface Area Reduction

Compliance with Verified Duct System Design procedures specified in RA3.1.4.1.1 are prerequisite for compliance with the Supply Duct Surface Area Reduction compliance credit. A visual inspection shall confirm the installed duct system layout conforms to the Duct Design Layout.

RA3.1.4.1.5 Verification of Buried Ducts on The Ceiling R-Value

Compliance with Verified Duct System Design procedures specified in RA3.1.4.1.1 is prerequisite for compliance with the Buried Ducts on the Ceiling compliance credit. A visual inspection shall confirm the installed duct system layout conforms to the Duct Design Layout. This procedure shall be carried out prior to covering the ducts with insulation.

Ducts designed to be buried shall be insulated to R4.2 or greater. In addition, ducts designed to be in contact with the ceiling shall be not more than 3.5 inches from the ceiling drywall. A sign shall be hung near the attic access that displays a warning: "Caution: Buried Ducts. Markers indicate location of buried ducts." All ducts that will be completely buried shall have vertical markers that are visible after insulation installation, placed at least every 8 feet of duct length and at the beginning and end of each duct run.

RA3.1.4.1.6 Verification of Deeply Buried Ducts R-Value

Compliance with Verified Duct System Design procedures specified in RA3.1.4.1.1 is prerequisite for compliance with the Deeply Buried Ducts compliance credit. A visual inspection shall confirm the installed duct system layout conforms to the Duct Design Layout. This procedure shall be carried out prior to covering the ducts with insulation.

Ducts designed to be buried shall be insulated to R4.2 or greater. In addition, ducts designed to be in contact with the ceiling shall be not more than 3.5 inches from the ceiling drywall. A sign shall be hung near the attic access that displays a warning: "Caution: Buried Ducts. Markers indicate location of buried ducts." All ducts that will be completely buried shall have vertical markers that are visible after insulation installation, placed at least every 8 feet of duct length and at the beginning and end of each duct run.

RA3.1.4.2 ~~System Fan Flow~~Air Handler Airflow

For use in ~~the purpose of~~ establishing the target duct leakage rate criteria for an air conditioner or heat pump, the system ~~fan flow~~air handler airflow shall be calculated using RA3.1.4.2.1, RA3.1.4.2.2, or RA3.1.4.2.3.

RA3.1.4.2.1 Default ~~System Fan Flow~~Air Handler Airflow

Default ~~system fan flow~~air handler airflow may be used only for homes where the duct system is being tested before the air conditioning and heating system is installed and the equipment specification is not known. For heating only systems the default ~~fan flow~~air handler airflow shall be 0.5 CFM per ft² of Conditioned Floor Area.

RA3.1.4.2.2 Nominal ~~System Fan Flow~~Air Handler Airflow

For heating only systems the nominal ~~fan flow~~air handler airflow shall be 21.7 CFM per ~~x Heating Capacity in thousands of k~~Btu/hr of rated heating output capacity. For systems with cooling, the nominal ~~fan flow~~air handler airflow shall be 400 CFM per nominal ton of cooling capacity as specified by the manufacturer or the heating only value, whichever is greater.

RA3.1.4.2.3 Measured System ~~Fan Flow~~Airflow

The ~~fan flow~~system airflow shall be as measured according to a procedure in Section RA3.3.3. The system airflow can be used as the air handler airflow for the purpose of establishing duct leakage percentage.

RA3.1.4.3 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Diagnostic Duct Leakage from Fan Pressurization of Ducts (Section RA3.1.4.3.1) is the only procedure that may be used by a HERS rater to verify duct sealing in a new home. Table RA3.1-2 shows the leakage compliance criteria and test procedures that may be used to demonstrate compliance.

Table RA3.1-2 – Duct Leakage Verification and Diagnostic Tests Protocols and Compliance Criteria

Case	User Application	Leakage Compliance Criteria (% of Air Handler Airflow)	Procedure(s)
Sealed and tested new duct systems in single family homes and townhomes	Installer Testing at Final HERS Rater Testing	6%	RA3.1.4.3.1
Sealed and tested new duct systems in single family homes and townhomes	Installer Testing at Rough-in, Air Handling Unit Installed	6% Installer Inspection at Final	RA3.1.4.3.2 RA3.1.4.3.2.1 RA3.1.4.3.3
Sealed and tested new duct systems in single family homes and townhomes	Installer Testing at Rough-in, Air Handling Unit Not Installed	4% Installer Inspection at Final	RA3.1.4.3.2 RA3.1.4.3.2.2 RA3.1.4.3.3
Sealed and tested new duct systems in multi-family homes regardless of duct system location.	Installer Testing at Final HERS Rater Testing	12%Total Duct Leakage	RA3.1.4.3.1
Sealed and tested new duct systems in multi-family homes regardless of duct system location.	Installer Testing at Final HERS Rater Testing	6% Leakage to Outside	RA3.1.4.3.4
Verified Low Leakage Air Handler with Sealed and Tested Duct System Compliance Credit	Installer Testing at Final HERS Rater Testing	compliance target values 6% or less as specified on the Certificate of Compliance	RA3.1.4.3.1 and RA3.1.4.3.9
Low leakage Ducts in conditioned space compliance credit	Installed Testing HERS Rater Testing	25 CFM Leakage to Outside	RA3.1.4.3.8
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	15% Total Duct Leakage	RA3.1.4.3.1
Sealed and tested altered existing duct systems	Installer Testing HERS Rater Testing	10% Leakage to Outside	RA3.1.4.3.4
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Inspection and Smoke Test	RA3.1.4.3.5 RA3.1.4.3.6, RA3.1.4.3.7
Sealed and tested altered existing duct systems	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Tests but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	RA3.1.4.3.5 RA3.1.4.3.6 RA3.1.4.3.6 RA3.1.4.3.7, RA3.1.4.3.7 RA3.1.4.3.8

RA3.1.4.3.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing the entire duct system to plus a positive pressure of 25 Pa (0.1 inches water) with respect to outside. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots and registers are installed. The entire duct system shall be included in the total leakage test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used and if a platform or other building cavity used to house the air distribution system has been newly installed or altered, it contains a duct or is ducted with duct board or sheet metal.
3. Seal all the supply registers and return registers grilles except for one large centrally located return register grille or the system fanair handler cabinet access panel.
4. Attach the fan flowmeter device to the duct system at the unsealed register return grille or the air handler cabinet access doorpanel.
5. Install a static pressure probe at a supply register located close to the air handler, or at the supply plenum.

6. Adjust the fan flowmeter to produce a ~~plus~~ positive 25 Pa (0.1 inches water) pressure at the supply register or the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the flow through the flowmeter; this is the leakage flow at 25 Pa (0.1 inches water).
8. Divide the leakage flow by the total ~~fan~~ air handler airflow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow~~s~~ percentage is equal to or less than the compliance ~~criteria~~ criterion from Table RA3.1-2 the system passes.

RA3.1.4.3.2 Diagnostic Duct Leakage at Rough-in Construction Stage

Installers may determine duct leakage in new construction by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing. When using this measurement technique, the installer shall complete additional inspection (as described in section RA3.1.4.3.~~2.~~3) of duct integrity after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa (0.1 inches water). The following procedure (either RA3.1.4.3.2.1 or RA3.1.4.3.2.2) shall be used:

RA3.1.4.3.2.1 Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the collars, connectors, transition pieces, ~~and~~ duct boots, and return boxes have been installed. If a platform or other building cavity is used to house portions of the air distribution system, it shall contain a duct, be lined with duct board or sheet metal, and all ~~return~~ duct connectors and transition parts shall be installed and sealed. The platform, ducts, and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed return duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots located close to the supply plenum or at the supply plenum.
5. Adjust the fan flowmeter to maintain a ~~plus~~ positive 25 Pa (0.1 inches water) pressure in the duct system with respect to the outside, or with respect to the building space with the entry door open to the outside.
6. Record the flow through the flowmeter; this is the leakage flow at 25 Pa (0.1 inches water).
7. Divide the leakage flow by the total ~~fan flow~~air handler airflow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow percentage is less than or equal to the compliance ~~criteria~~ criterion from Table RA3.1-2 the system passes.

RA3.1.4.3.2.2 Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that supply and return plenums and all the collars, connectors, transition pieces, ~~and~~ duct boots, and return boxes have been installed. If a platform or other building cavity is used to house portions of the air distribution system, it ~~must~~ shall contain a duct, be lined with duct board or sheet metal, and all ~~return~~ duct connectors and transition parts shall be installed and sealed. The platform, ducts and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. ~~Use a duct connector to connect the supply and/or return duct box to the fan flowmeter.~~ Supply and return leaks may be tested separately, or the supply and return plenums may be connected together using

suitable temporary air-tight means to facilitate testing the total system. If the supply and return systems are to be tested separately, the opening to the supply or return plenums shall be sealed to prevent leakage unless used as the point of attachment for the fan flowmeter.

3. Seal all the supply duct boots and/or return duct boxes except for a location where the fan flowmeter device will be attached.~~one supply or return duct box~~.
4. Attach the fan flowmeter device at the unsealed location.~~ duct box~~.
5. Insert a static pressure probe at one of the sealed supply duct boots, or return duct boxes, located at a point in the system close to the fan flowmeter.
6. Adjust the fan flowmeter to produce a ~~plus~~ positive 25 Pa (0.1 inches water) pressure at the supply plenum with respect to the outside or with respect to the building space with the entry door open to the outside.
7. Record the ~~flow~~ airflow through the flowmeter; this is the leakage flow at 25 Pa.
8. If the supply and return ducts are tested separately, repeat items 4 through 6 with the flow meter attached to the unsealed return box and the static pressure probe in the return duct boxes, located at a point in the system close to the fan flowmeter~~plenum~~, then add the two leakage rates together to get a total leakage flow.
9. Divide the leakage flow by the total ~~fan flow~~air handler airflow determined by the procedure in Section RA3.1.4.2 and convert to a percentage. If the leakage flow percentage is less than or equal to the compliance ~~criteria~~ criterion from Table RA3.1-2 the system passes.

RA3.1.4.3.3 Installer Visual Inspection at Final Construction Stage

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, the following procedure shall be used:

1. Remove at least one supply and one return register, and verify that the spaces between the register boot and the interior finishing wall are properly sealed.
2. If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.
3. Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.

RA3.1.4.3.4 Duct Leakage to Outside from Fan Pressurization of Ducts

The objective of this test is to determine the amount of duct leakage ~~to~~ to outside the air barrier for the conditioned space. This measurement is ~~used~~ utilized to verify that duct systems are ~~entirely~~ located entirely within conditioned space. The procedure is also ~~used~~ utilized to provide an alternate leakage measurement ~~where~~ for situations when it is likely that ~~some~~ a portion of the total duct leakage is ~~to within~~inside the air barrier for the conditioned space. The duct leakage to outside shall be determined by pressurizing the ducts and the conditioned space of the house to 25 Pa with respect to outside. The following procedure shall be used for the fan pressurization test of leakage to outside:

1. Seal all the supply registers and return ~~registers~~ grilles except for one large centrally located return ~~register~~ grille or the ~~fan~~ air handler cabinet access ~~door~~panel.
2. Attach the fan flowmeter device to the duct system at the unsealed ~~register~~ return grille or the air handler cabinet access ~~door~~panel.
3. Install a static pressure probe at the supply plenum.
4. Attach a blower door to an external doorway.
5. If any ducts are located in an unconditioned basement, all doors or accesses between the conditioned space and the basement shall be closed, and at least one operable door or window (if it exists) between the basement and outside shall be open during the test.

6. If the ducts are located in a conditioned basement, any door between the basement and the remaining conditioned space shall be open, and any basement doors or windows to outside must be closed during the test.
7. Adjust the blower door fan to provide ~~plus~~ positive 25 Pa (0.1 inches of water) pressure in the conditioned space with respect to outside.
8. Adjust the fan/flowmeter to maintain a zero pressure difference (plus or minus 0.5Pa) between the ducts and the conditioned space, and adjust the blower door fan to maintain a ~~plus~~ positive 25 Pa (0.1 inches of water) pressure in the conditioned space with respect to outside. This step may require several iterations.
9. Record the flow through the flowmeter; ~~(Q25;~~ this is the duct leakage flow to outside at 25 Pa (0.1 inches water). ~~To verify ducts in conditioned space compare this~~If the leakage flow ~~to the criterion~~is less than or equal to the applicable compliance criteria in Table RA3.1-2, the system passes.
10. ~~Where the criterion is a percentage of total flow,~~ If required for compliance, divide the leakage flow by the ~~total fan flow~~system air handler airflow determined by the procedure in Section RA3.1.4.2, and convert to a percentage. If the leakage flow percentage is less than or equal to the ~~criteria~~ criterion from Table RA3.1-2 the system passes

~~**RA3.1.4.3.5 Leakage Reduction from Fan Pressurization of Ducts**~~

~~For altered existing duct systems that do not pass the Total Leakage (RA3.1.4.3.1) or Leakage to Outside (RA3.1.4.3.4) tests, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table RA3.1-2. The following procedure shall be used:~~

~~1.Use the procedure in RA3.1.4.3.1 to measure the leakage before commencing duct sealing.~~

~~2.After sealing is complete use the same procedure to measure the leakage after duct sealing.~~

~~3.Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60 percent or greater of the original leakage, the system passes.~~

~~4.Complete the Smoke Test specified in RA3.1.4.3.7.~~

~~5.Complete the Visual Inspection specified in RA3.1.4.3.8.~~

~~RA3.1.4.3.6~~RA3.1.4.3.5 Sealing of All Accessible Leaks

For altered existing duct systems that ~~do not~~are unable to pass ~~any~~ either ~~of~~ the ~~Total Leakage~~ Fan Pressurization of Ducts test (RA3.1.4.3.1), or the Duct Leakage to Outside test (~~RA3.1.4.3.3~~RA3.1.4.3.4) ~~or Leakage Improvement (RA3.1.4.3.4) tests~~, the objective of this test is to ~~show~~ verify that all accessible leaks are sealed. The following procedure shall be used:

1. ~~At a minimum, complete~~~~Follow the procedure~~Complete the leakage test specified in Section RA3.1.4.3.1 to measure the leakage before commencing duct sealing.
2. Seal all accessible ducts.
3. After sealing is complete, again use the ~~same~~ procedure in RA3.1.4.3.1 to measure the leakage after duct sealing.
4. Complete the Smoke Test as specified in RA3.1.4.3.~~7~~6.
5. Complete the Visual Inspection as specified in RA3.1.4.3.~~8~~7.

~~6.Install the required label on the system stating that the system fails the leakage tests.~~

~~RA3.1.4.3.7~~RA3.1.4.3.6 Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa (0.1 inches water) relative to the duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if one of the following conditions is met:

   i.a. No visible smoke exits the accessible portions of the duct system.

   ii.b. Smoke only emanates from the furnace cabinet which is gasketed and sealed by the manufacturer and no visible smoke exits from the accessible portions of the duct system.

RA3.1.4.3.8RA3.1.4.3.7 Visual Inspection of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of this inspection in conjunction with the smoke test (RA3.1.4.3.76) is to confirm that all accessible leaks have been sealed. Visually inspect to verify that the following locations have been sealed:

1. Connections to plenums and other connections to the forced air unit
2. Refrigerant line and other penetrations into the forced air unit
3. Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
4. Register boots sealed to surrounding material
5. Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.

RA3.1.4.3.9RA3.1.4.3.8 Verified Verification of Low Leakage Ducts in Conditioned Space

When ducts are located in conditioned space, additional credit is available for Low Leakage Ducts., if If duct leakage to outside is equal to or less than 25 cfm when measured in accordance with Section RA3.1.4.3.4, the system passes. The home dwelling must also be qualified to receive the credit for verified ducts in conditioned space as reported on the Certificate of Compliance for the dwelling, and as verified according to Section RA3.1.4.1.3. The ACM credit for Low Leakage Ducts in Conditioned Space is shown on Table R3-34 of the Residential ACM.

RA3.1.4.3.10RA3.1.4.3.9Verified Verification of Low Leakage Air-Handling Unit Handler with Sealed and Tested Duct System

An additional performance compliance credit is available for verified low leakage ducts if a qualified Low Leakage Air Handlerlow leakage air-handling unit is installed. The low leakage air-handling unit handler cabinet (furnace, or heat pump fan and inside coil) must shall conform to the qualification requirements given in Reference Joint Appendix JA9, and shall be included in the list of low leakage air handling units published by the Energy Commission. be certified to the Commission to leak 2 percent or less of its nominal air conditioning cfm delivered when pressurized to 1-inch water gauge with all present air inlets, air outlets, and condensate drain port(s) sealed. The qualified air handler must be connected to a sealed and tested new duct systemSealed and Tested New Duct System to receive the credit.

The ACM performance compliance calculation allows shall allow the duct efficiency calculation to use of the actual measured duct leakage if it is equal to or less than 6 percent of the of the air handler's nominal airflow.

In order to comply with this credit, the duct system shall be verified to leak less than or equal to the leakage rate specified on the Certificate of Compliance using the methods in Section RA3.1.4.3.1, and the air handler manufacturer make and model number shall be verified to be a model certified to the Energy Commission as qualified for credit as a low leakage air handler.

RA3.1.4.4 Verification of Return Duct Design

Verification shall consist of a visual inspection to confirm that the duct design conforms to the criteria given in Table 150.0-E or Table 150.0-F.

RA3.1.4.5 Verification of Air Filter Device Design

Verification shall consist of a visual inspection to confirm that the air filter devices conform to the requirements given in Section 150.0(m)12.

RA3.1.4.6 Verification of Bypass Duct Prohibition

Verification shall consist of a visual inspection to confirm if the system is zonally controlled, and confirm that the duct design conforms to the criteria given in Standards Section 150.0(m)14.

RA3.2 Procedures for Determining Refrigerant Charge for Split System Space Cooling Systems Without a Charge Indicator Display

RA3.2.1 Purpose and Scope

The purpose of this procedure is to determine and verify that residential split system space cooling systems and heat pumps have the required refrigerant charge and that the metering device is working as designed. The procedures only apply to ducted split system central air conditioners and ducted split system central heat pumps. The procedures do not apply to packaged systems. For dwelling units with multiple split systems or heat pumps, the procedure shall be applied to each system separately. The procedures detailed in Section RA3.2 are to be used after the HVAC installer has installed and charged the air conditioner or heat pump system in accordance with the manufacturer's instructions and specifications. Failure to follow the manufacturer's instructions may result in significant refrigeration system faults that may invalidate refrigerant charge and metering device results. The installer shall certify to the builder, building official and HERS rater that he/she has followed the manufacturer's instructions and specifications prior to proceeding with the procedures in this appendix.

Appendix RA3.2 defines two procedures, the Standard Charge Measurement Procedure in Section RA3.2.2 and the Weigh-In Charging Method~~Alternate Charge Measurement Procedure~~ in Section RA3.2.3. The standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the alternate procedure.

Refrigerant charging procedures other than that described in RA3.2 are possible, and when vapor compression air conditioner and heat pump system refrigerant charge and metering device operating performance can be reliably determined by methods and instrumentation other than those specifically defined in section RA3.2, such alternative charging procedures shall be allowed if the air conditioner equipment manufacturer requests approval from the Executive Director. The Executive Director will grant such approval after reviewing submittals from the applicant. Charging procedures that are approved by the Executive Director will be published as an addendum to Reference Residential Appendix RA1.

The applicant shall provide information that specifies the required instrumentation, the instrumentation accuracy, the parameters measured, the required calculations, the allowable deviations from target values for system operating parameters, and the requirements for system fault indication. Manufacturers shall certify to the Energy Commission that the charging procedure produces a sensible EER at 95/80/67 that is within 5% of the sensible EER produced in a laboratory test at 95/80/67 of the air conditioner with the designated refrigerant weight. Manufacturers using alternative charging procedures shall, upon request, provide comprehensive engineering specification documentation, installation and technical field service documentation, and user instructions documentation to installers and service personnel that utilize the procedure.

The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure.

The reference method algorithms adjust (improve) the efficiency of split system air conditioners and heat pumps when they are diagnostically tested to have the correct refrigerant charge and the metering device is operating properly. Table RA3.2-1 summarizes the algorithms that are affected by refrigerant charge testing.

Table RA3.2-1 – Refrigerant Charge ~~Summary of Diagnostic Measurements~~Verification Protocols and Compliance Criteria

Case	User Application	Compliance Criteria	Procedure(s)
Standard Charge Measurement Procedure - Fixed Metering Device	Installer Testing at Final	Superheat tolerance ±5°F of the specified target	RA3.2.2.6.1
Standard Charge Measurement Procedure - Fixed Metering Device	HERS Rater Testing	Superheat tolerance ±8°F of the specified target	RA3.2.2.6.1
Standard Charge Measurement Procedure - Variable Metering Device	Installer Testing at Final	Subcooling tolerance ±3°F of the specified target Metering Device tolerance: Superheat meets the Manufacturer's specifications or 4°F ≤ Superheat ≤ 25°F	RA3.2.2.6.2
Standard Charge Measurement Procedure - Variable Metering Device	HERS Rater Testing	Subcooling tolerance ±6°F of the specified target and Subcooling ≥2°F Metering Device tolerance: Superheat meets the Manufacturer's specifications or 3°F ≤ Superheat ≤ 26°F	RA3.2.2.6.2

~~Input to the Algorithm~~	~~Description~~	~~Standard Design Value~~	~~Proposed Design~~	
			~~Default Value~~	~~Procedure~~
~~Cooling System Refrigerant Charge and Metering~~	~~FCID takes on a value of 0.96 when the system has been diagnostically tested for the correct refrigerant charge, or a charge Indicator Display is field verified. Otherwise, FCID has a value of 0.90.~~	~~Split systems are assumed to have refrigerant charge testing or a Charge Indicator Display when required by Package D.~~	~~No refrigerant charge testing or Charge Indicator Display.~~	~~RA3.2.2 or RA3.2.3~~

Note that diagnostically testing the refrigerant charge requires a minimum level of airflow across the evaporator coil, as defined in RA3.2.2.7.

RA3.2.2 Standard Charge Measurement Procedure

This section specifies the Standard charge measurement procedure. Under this procedure, required refrigerant charge is calculated using the Superheat Charging Method for Fixed Metering Devices and the Subcooling Charging Method for Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV).

~~The method also checks airflow across the evaporator coil to determine whether the charge test is valid using the Temperature Split Method. The measurement methods in RA3.3 may be substituted for the Temperature Split Method; however the Temperature Split Method may not be substituted for the measurement methods in RA3.3.~~

The standard procedure detailed in this section shall be completed when the outdoor temperature is within the manufacturer's specified temperature range, or the outdoor temperature is greater than 55°F, ~~or higher~~ after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. ~~If the outdoor temperature is between 55°F and 65°F t~~The return dry bulb temperature shall be maintained above 70°F during the test. ~~All HERS rater verifications are required to use this standard procedure.~~

This procedure does not relieve the installing contractor from any obligations to follow manufacturers' specifications. This procedure is used to assure conformance to Title 24.

RA3.2.2.1 Minimum Qualifications for this Procedure

Persons carrying out this procedure shall be qualified to perform the following:

1. Obtain accurate pressure/temperature readings from refrigeration gauges.
2. Obtain accurate temperature readings from electronic thermometer and temperature sensors.
3. Check calibration of refrigerant gauges using a known reference pressure
4. Check calibration of electronic thermometer and temperature sensors using a known reference temperature.
5. Check calibration of electronic temperature thermometer and pipe temperature sensors using a pipe at a known reference temperature in a surrounding atmosphere at least 40°F different from the pipe temperature.
6. Determine best location for temperature measurements in duct system and on refrigerant lines.
7. Calculate the measured superheat and temperature split.
8. Determine the required superheat and temperature split, based on the conditions present at the time of the test.
9. Determine if measured values are reasonable.

RA3.2.2.2 Instrumentation Specifications

Instrumentation for the procedures described in this section shall conform to the following specifications:

RA3.2.2.2.1 Digital Thermometer

Digital thermometer shall have dual channel capability in Celsius or Fahrenheit readout with:

1. Accuracy: ± (0.1% of reading + ~~1.3~~1.8°F).
2. Resolution: 0.2°F.

RA3.2.2.2.2 Temperature Sensors and Temperature Measurement Access Holes (TMAH)

Measurements require three (3) temperature sensors that pass the following test:

~~An air filled box without forced circulation~~ test location is at dry bulb temperature T1
The temperature sensor is outside the box and stabilized at T2
The absolute value of (T1 minus T2) is greater than 40ºF
The sensor has a response time that produces the accuracy specified in Section RA3.2.2.2.1 within 90 seconds of insertion at the test location.

Measurements require one (1) cotton wick or electronic sensor for measuring wet-bulb temperatures.

Measurements require two (2) pipe temperature sensors that pass the following test:

Six pipes (1/4” dia., 3/16” dia., 3/8” dia., 3/4” dia., 7/8” dia., 1 1/8” dia.) at temperature T1 in an environment at T2 where the absolute value of (T1 minus T2) is greater than 40ºF
The temperature sensor is stabilized at T2
The sensor has a response time that produces the accuracy specified in Section RA3.2.2.2.1 within 90 seconds of application to the pipe of the size for which it is approved.

A sensor may be used for more than one pipe size if it passes the above test for each pipe size for which it is used.

~~Measurements require four (4) temperature sensors with a response time that produces the accuracy specified in Section RA3.2.2.2.1 within 15 seconds of immersion in a bath at least 40°F different from the surrounding conditions.~~

~~Measurements require one (1) cotton wick for measuring wet-bulb temperatures.~~

~~Measurements require at two (2) pipe temperature sensors that produce the accuracy specified in Section RA3.2.2.2.1 within 15 seconds of being applied to a pipe at least 40°F different from the surrounding conditions.~~

There shall be two labeled temperature measurement access holes, one in the supply plenum and one in the return plenum as specified in Figure 3.2-1. ~~The temperature~~Return plenum temperature measurements shall be taken at the ~~following locations:~~location specified in Figure 3.2-1 when required by the procedures in RA3.2.

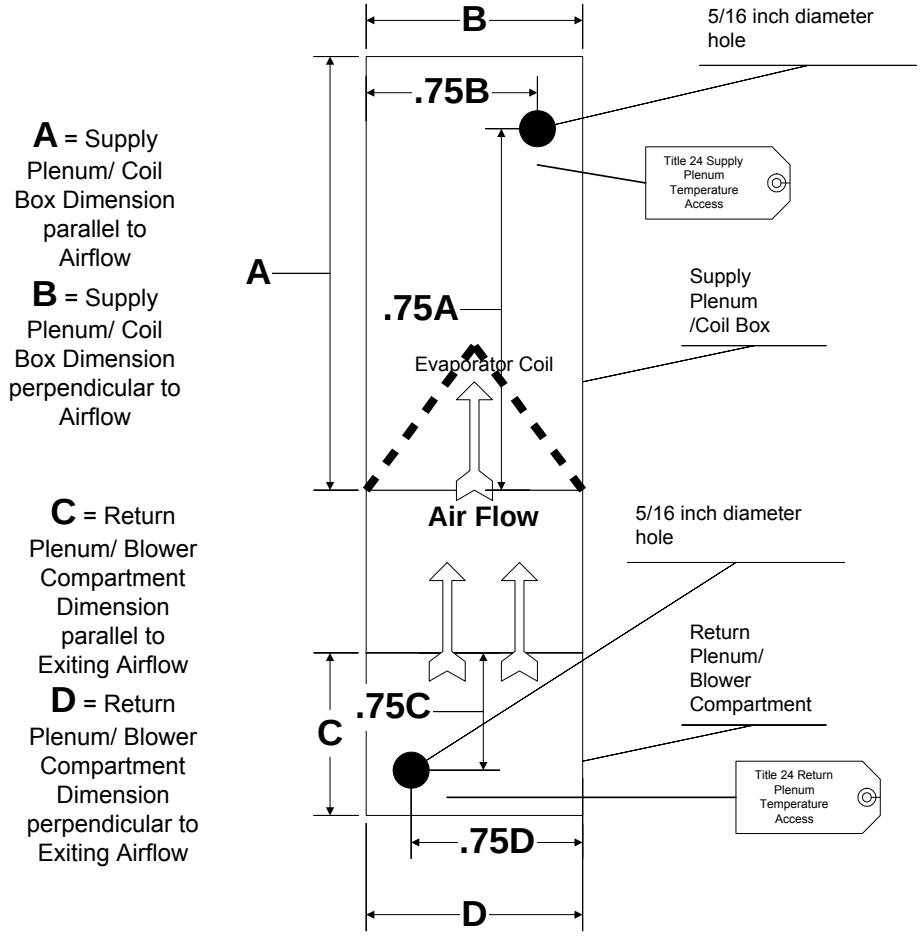

Figure RA3.2-1 Temperature Measurement Access Hole

Each location shall have a 5/16" (8 mm) diameter hole. The supply location shall be labeled "Title 24 – Supply ~~Temperature~~ Measurement Access" in at least 12-point type. The return location shall be labeled "Title 24 – Return ~~Temperature~~ Measurement Access" in at least 12-point type. These locations can be in any one of the four sides of the plenums.

RA3.2.2.3 Digital Refrigerant Gauges~~Refrigerant Gauges and Saturation Temperature Measurement Sensors (STMS)~~

A digital refrigerant gauge with an accuracy of plus or minus 3.0 psig discharge pressure and plus or minus 1.0 psig suction pressure shall be used. Other saturation temperature measurement sensor instrumentation methodologies shall be allowed if the specifications for the methodologies are approved by the Executive Director.

~~A refrigerant gauge with an accuracy of plus or minus 3 percent shall be used.~~ As an alternative, two saturation ~~temperature~~ pressure measurement sensors (SPMS) ~~(sensors)~~ ~~shall~~ may be permanently ~~placed~~ installed by the equipment manufacturer, or in a manner and location ~~determined~~ approved by the equipment manufacturer

~~as~~for use for measuring the saturation ~~temperature~~ pressure of the refrigerant in the evaporator coil and in the condenser coil with an accuracy of plus or minus 3.0 psig discharge pressure and plus or minus1.0 psig suction pressure~~within 1.3°F. These sensors shall be permanently mounted and have standard temperature sensor mini plugs accessible to the installing technician and the HERS rater without changing the airflow through the condenser coil. Other saturation temperature measurement sensor instrumentation methodologies shall be allowed if the specifications for the methodologies are approved by the Executive Director~~. Refer to Reference Joint Appendix JA6.2 for additional specification for SPMS.

RA3.2.2.4 Calibration

The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.

RA3.2.2.4.1 Thermometer/ and Temperature Sensor Field Calibration Procedure

Thermometers/temperature sensors shall be calibrated monthly to ensure that they are reading accurate temperatures.

The following procedure shall be used to check thermometer/temperature sensor calibration:

1. Fill an insulated cup (foam) with crushed ice from distilled water. The ice shall completely fill the cup. Add distilled water to fill the cup.
2. Insert two sensors into the center of the ice bath and attach them to the digital thermometer.
3. Let the temperatures stabilize. The temperatures shall be 32°F (plus or minus 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any sensors that are off by more than 2°F shall be replaced.
4. Switch the sensors and ensure that the temperatures read on both channels are still within plus or minus 1°F of 32°F.
5. Affix sticker with calibration check date onto sensor.
6. Repeat the process for all sensors.

RA3.2.2.4.2 Refrigerant Gauge Field Check Procedure

Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration:

1. Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.
2. Attach a calibrated sensor to the refrigerant cylinder using tape so that there is good contact between the cylinder and the sensor.
3. Insulate over the sensor connection to the cylinder.
4. Zero the low side and high side refrigerant gauges with all ports open to atmospheric pressure (no hoses attached).
5. Re-install the hose, attach the high side gauge to the refrigerant cylinder, and open the valves to measure the pressure in the refrigerant cylinder.
6. Read the temperature of the sensor on the refrigerant cylinder.
7. Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.
8. If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be recalibrated.~~replaced or returned to the manufacturer for calibration.~~

9. Close the valve to the refrigerant cylinder, and bleed off a small amount of refrigerant to lower the high side pressure to give a corresponding temperature to between 45°F and 55°F.
10. Open the valves between the high side gauge and low side gauge.
11. If the two gauges corresponding refrigerant temperatures do not read within 1°F of each other, the low side gauge is out of calibration and needs to be ~~replaced or returned to the manufacturer for calibration~~recalibrated~~.~~.
12. Affix sticker with calibration check date onto refrigerant gauge.

RA3.2.2.5 Charge Measurement

The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge as described in the following sections:

1. Ensure that the inside and outside temperatures remains within the manufacturer's specifications, and ~~If the condenser air entering temperature is less than 65°F, establish a~~the return air dry bulb temperature ~~sufficiently high that the return air dry bulb temperature will be not less than~~remains greater than 70°F prior to and while performing the measurements at the end of the 15-minute period in step 2.
2. Connect the refrigerant gauges to the service ports, taking normal precautions to not introduce air into the system.
3. Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature sensors.
4. Attach one pipe temperature sensor to the suction line near the suction line service valve with the sensor between 10 oclock and 2 oclock and attach one pipe temperature sensor to the liquid line near the liquid line service valve.
5. Attach a temperature sensor to measure the condenser entering air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.
6. Be sure that all cabinet panels that affect airflow are in place before making measurements. The temperature sensors shall remain attached to the system until the final charge is determined.
7. If used, place the cotton wick~~Place~~ wet-bulb temperature sensor ~~(cotton wick)~~ in water to ensure it is saturated when needed. Do not get the dry-bulb temperature sensors wet.
8. If a fixed metering device, at 12 minutes, insert a ~~Insert the~~ dry-bulb temperature sensor and a wet-bulb temperature sensor into ~~in~~ the return ~~supply~~ plenum at the "Title 24 – Supply Temperature Access" detailed in Section RA3.2.2.2.2.

~~8.~~A

~~9.At 12 minutes, insert a dry-bulb temperature sensor and a wet-bulb temperature sensor into the return plenum at the "Title 24 – Return Temperature Access" detailed in Section RA3.2.2.2.2.~~

~~10.~~9. ~~A~~t 15 minutes when the return plenum wet-bulb temperature has stabilized, using the temperature sensors already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return,\ db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return,\ wb}$).

~~11.~~10. Using the dry-bulb temperature sensor already in place, measure and record the supply (evaporator leaving) air drybulb temperature ($T_{supply,\ db}$).

~~12.~~11. ~~Using the refrigerant gauge or saturation temperature measurement sensor already attached, measure and record the evaporator saturation temperature ($T_{evaporator,\ sat}$) from the low side gauge.~~Using the refrigerant gauge already attached, measure and record the evaporator saturation temperature ($T_{evaporator,\ sat}$) from the low side gauge.

~~13.~~12. Using the refrigerant gauge or saturation temperature measurement sensor already attached, measure and record the condenser saturation temperature ($T_{condenser,\ sat}$) from the high side gauge.

~~14.~~13. Using the pipe temperature sensor already in place, measure and record the suction line temperature ($T_{suction,}$).

~~15.~~14. Using the pipe temperature sensor already in place, measure and record the liquid line temperature (T_{liquid}).

~~16.~~15. Using the dry-bulb temperature sensor already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser, db}$).

The above measurements shall be used to adjust refrigerant charge ~~and airflow~~ as described in following sections.

RA3.2.2.6 Refrigerant Charge and Metering Device Calculations

The following steps describe the calculations to determine if the system meets the required refrigerant charge and metering device function using the measurements described in Section RA3.2.2.5. If a system fails, then remedial actions must be taken. ~~If the refrigerant charge is changed and the airflow is being tested with the Temperature Split Method, then the airflow shall be re-tested.~~ Be sure to run the air conditioner for 15 minutes after the final adjustments before taking any measurements. ~~Both the airflow and charge must be re-tested until they simultaneously pass~~.

RA3.2.2.6.1 Fixed Metering Device Calculations

The Superheat Charging Method is used only for systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices.

1. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.

   Actual Superheat = $T_{suction,} - T_{evaporator, sat}$.

2. Determine the Target Superheat using Table RA3.2-2 or the manufacturer's superheat chart using the return air wet-bulb temperature ($T_{return, wb}$) and condenser air dry-bulb temperature ($T_{condenser, db}$).

3. If a dash mark is read from Table RA3.2-2, the target superheat is less than 5°F. Note that **a valid refrigerant charge verification test cannot be performed under these conditions**. A severely undercharged unit will show over 9°F of superheat. However overcharged units cannot be detected from the superheat method. The usual reason for a target superheat determination of less than 5°F is that outdoor conditions are too hot and the indoor conditions are too cool~~dry~~. One of the following is needed so a target superheat value can be obtained from Table RA3.2-2 either 1) turn on the space heating system and/or open the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. Repeat the measurement procedure as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before the final measurements are taken.

4. Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat).

5. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.

   For the Installer, if the difference is within the criteria in Table RA3.2-1~~between minus 5~~8°F ~~and plus 5~~8°F, then the system **passes** the required refrigerant charge criterion.

   For the HERS Rater inspecting the system, if the difference is within the criteria in Table RA3.2-1~~between minus 6°F and plus 6°F~~, then the system **passes** the required refrigerant charge criterion.

~~6.~~For the Installer, if the system fails to meet the criteria, refrigerant needs to be added if the superheat is too high and refrigerant needs to be removed if it is too low. The installer needs to remain aware of other potential system faults. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.~~For the Installer, if the difference is greater than plus 5°F, then the system **does not pass** the required refrigerant charge criterion and the Installer shall add refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass~~

~~the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.~~

~~7.~~6. ~~For the Installer, if the difference is between minus 5°F and minus 100°F, then the system **does not pass** the required refrigerant charge criterion, the Installer shall remove refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.~~

RA3.2.2.6.2 Variable Metering Device Calculations

The Subcooling Charging Method is used for systems equipped with variable metering devices. These include Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV). The amount of refrigerant is set based on the subcooling and the superheat determines whether the device is working properly.

~~The Subcooling Charging Method is used only for systems equipped with variable metering devices. These include Thermostatic Expansion Valves (TXV) and Electronic Expansion Valves (EXV). Since variable metering devices are constant superheat valves, measuring the superheat determines whether they are working properly.~~

1. Calculate Actual Subcooling as the condenser saturation temperature minus the liquid line temperature. Actual Subcooling = $T_{condenser,\ sat} - T_{liquid}$.
2. Determine the Target Subcooling specified by the manufacturer.
3. Calculate the difference between actual subcooling and target subcooling (Actual Subcooling - Target Subcooling

~~4.~~In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer ~~and~~ than for the HERS Rater.

4. ~~For the Installer,~~ If the difference is within the ~~criteria in~~ tolerance allowed by Table RA3.2-1, then the system **complies** with the subcooling criterion. ~~**passes** the required refrigerant charge criterion.~~

   ~~For the HERS Rater inspecting the system, if the difference is within the criteria in Table RA3.2-1, then the system **passes** the required refrigerant charge criterion~~

~~5.For the Installer, if the difference is greater than plus 3°F, then the system **does not pass** the required refrigerant charge criterion and the Installer shall remove refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.~~

~~6.~~5. For the Installer, if the difference exceeds the tolerance allowed by Table RA3.2-1 then the system **does not comply** with the subcooling criterion. If the subcooling is greater than the target tolerance, the Installer shall remove refrigerant. If the subcooling is less than the target tolerance, the Installer shall add refrigerant. The Installer shall remain aware of other potential system faults that may affect the validity of the refrigerant charge verification procedure, and make any needed system repairs or adjustments to clear such other system faults prior to completion of the refrigerant charge verification procedure. The Installer shall adjust the refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, the Installer shall allow the system to run 15 minutes before completing the final measurement procedure.~~For the Installer, if the difference is between minus 3°F and minus 100°F, then the system **does not pass** the required refrigerant charge criterion, the Installer shall add refrigerant. Adjust refrigerant charge and check the measurements as many times as necessary to pass the test. After the final adjustment has been made, allow the system to run 15 minutes before completing the final measurement procedure.~~

~~7.~~6. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature. Actual Superheat = $T_{suction,} - T_{evaporator,\ sat}$.

~~8.~~7. If possible, determine the Superheat Range specified by the manufacturer.

~~9.~~8. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer than for~~and~~ the HERS Rater.

~~For the Installer, if~~If the superheat is within the tolerance allowed by Table RA3.2-1,~~manufacturer's superheat range, then the system **passes** the metering device criterion. If the manufacturer's specification is not available and the superheat is between 4°F and 25°F, then the system **passes** the metering device criterion.~~

~~For the HERS Rater inspecting the system, if the superheat is between 3°F and 26°F,~~ then the system ~~**passes**~~ **complies** with the metering device criterion.

RA3.2.2.7 Minimum System Airflow

For new or replacement space-conditioning systems, ~~I~~in order to have a valid ~~refrigerant~~ charge test, the minimum airflow shall be verified by demonstrating compliance with either the mandatory return duct sizing requirements in Section 150.0(m)13A, or the alternate mandatory Fan Watt draw and airflow verification requirements in Section 150.0(m)13B.

For altered space conditioning systems, the minimum airflow requirement ~~can~~shall be verified by ~~passing the temperature split test. Alternatively,~~ one of the ~~three~~ air handler airflow measurements in RA3.3 ~~may be used~~ with a measured airflow ~~in excess of~~equal to or greater than 300 cfm/ton. ~~The temperature split test method is designed to provide an efficient check to see if airflow is above the required minimum for a valid refrigerant charge test. The following steps describe the calculations using the measurement procedure described in Section RA3.2.2.5.~~ If a system fails, then remedial actions ~~must~~ shall be taken to ensure the system conforms to the minimum 300 cfm/ton airflow requirement. If the airflow is changed~~ and the refrigerant charge has previously been tested~~, then the refrigerant charge shall be re-tested. Be sure to run the air conditioner for 15 minutes after the final adjustments before taking any measurements.~~ Both the airflow and charge must be re-tested until they simultaneously pass.~~

~~1. Calculate the Actual Temperature Split as the return air dry bulb temperature minus the supply air dry bulb temperature. Actual Temperature Split = $T_{return, db} - T_{supply, db}$~~

~~2. Determine the Target Temperature Split from Table RA3.2-3 using the return air wet-bulb temperature ($T_{return, wb}$) and return air dry-bulb temperature ($T_{return, db}$).~~

~~3. If a dash mark is read from Table RA3.2-3 then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section RA3.3.~~

~~4. Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split).~~

~~5. In order to allow for inevitable differences in measurements, the Pass/Fail criteria are different for the Installer and the HERS Rater.~~

~~For the Installer,~~

~~a. If the difference is between plus 3°F and minus 3°F, then the system **passes** the adequate airflow criterion.~~

~~b. If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat the measurement procedure as often as necessary to establish adequate airflow. After the final adjustment, allow the system to stabilize for 15 minutes before taking the final measurements.~~

~~c. If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured in a manner that obtains the average temperature in the airflow.~~

~~d. If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).~~

~~For the HERS Rater inspecting the system,~~

~~a. If the difference is between plus 4°F and minus 4°F, then the system **passes** the adequate airflow criterion.~~

~~b. If the difference is between minus 4°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured in a manner that obtains the average temperature in the airflow.~~

~~c. If the re-measured difference is between plus 4°F and minus 4°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 4°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).~~

RA3.2.3 ~~Alternate Charge Measurement Procedure~~Weigh-In Charging Method

This section specifies ~~the~~ a ~~alternate~~ charge measurement procedure~~. Under this procedure,~~ in which the required refrigerant charge is calculated using the *Weigh-In Charging Method*.

The Weigh-In Charging Method may be used by the Installing Contractor to demonstrate compliance with the refrigerant charge verification requirement for the space conditioning system as reported on an Installation Certificate. When ~~HVAC installers who must complete system installation verification when~~ the outdoor temperature is below 55°F, or when the Standard Charge Measurement Procedure given in Section RA3.2.2 cannot be used to demonstrate compliance, and if an applicable Special Case Diagnostic Protocol in Reference Residential Appendix RA1 is not available for use, HVAC installers shall use ~~this alternate~~the Weigh-In charging procedure ~~in conjunction with installing and charging the system~~ in accordance with the space conditioning system manufacturer's specifications. All systems for which the Standards require compliance with Installer field verification and diagnostic testing may be charged using the Weigh-In Charging Method. All units for which the Standards require HERS Rater field verification and diagnostic testing shall be verified by a HERS Rater using one of the RA3.2 Standard Charge Measurement Procedures, or an approved Special Case diagnostic procedure from Reference Residential Appendix RA1, unless compliance is demonstrated by installation of a qualifying Charge Indicator Display (CID) device installed on that system. HERS Raters shall not use the Weigh-in Charging Method~~this procedure~~ to verify compliance with the refrigerant charge verification requirement.

Refer to Residential Appendix RA2.4.4 for additional direction for complying with HERS Rater field verification and diagnostic testing requirements for refrigerant charge verification when the when the outside temperature is below 55°F and the Standard Charge Measurement Procedure cannot be used.

Split system air conditioners ~~come~~ are shipped from the factory ~~already~~ charged with ~~the~~ a standard amount of refrigerant ~~charge~~as indicated on the nameplate. The manufacturer-supplied refrigerant ~~supplies the~~ charge is expected to be the correct amount ~~proper~~ for the ~~application~~ system based on ~~their~~ a standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line lengths ~~different~~ that deviate from the manufacturer's standard line length specification.

[additional weigh-in details tbd]

Table RA3.2-2 Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F) (T condenser, db)	Return Air Wet-Bulb Temperature (°F) (T return, wb)																													
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5

Shaded area requires return plenum temperature of 70°F or higher.

Table RA3.2-2 Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F) (T condenser, db)	Return Air Wet-Bulb Temperature (°F) (T return, wb)																											
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Table RA3.2-3 Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry-Bulb (°F) (T return, db)	Return Air Wet-Bulb (°F) (T return, wb)																												
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8									
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5								
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1							
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7						
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2					
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7				
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1			
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5		
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

RA3.3 Field Verification and Diagnostic Testing of Forced Air System Airflow and ~~Fan Flow and~~ Air Handler Fan Watt Draw

RA3.3 contains procedures for verifying airflow in split system and packaged ~~air~~ space conditioning systems serving low-rise residential buildings. The procedure is also used to verify reduced fan watts achieved through improved air distribution design, including more efficient motors and air distribution systems with less resistance to airflow.

~~The refrigerant charge test described in Section RA3.2 requires verification of airflow sufficient for the refrigerant charge test. Table RA3.3-1 Summarizes the diagnostic measurement procedures in RA3.3 and shows their relationship to the equipment efficiency algorithms in RACM chapter 3.~~

~~*Table RA3.3-1 – Summary of Diagnostic Measurements*~~

~~Features that require verification~~	~~Variables and Equation Reference~~	~~Description~~	~~Standard Design Value~~	~~Proposed Design~~	
				~~Default Value~~	~~Procedure~~
~~Fan Watts~~	~~FanW/cfm RACM Eq. R3-20~~	~~The term FanW/cfm is the ratio of fan power in Watts to the cooling coil airflow.~~	~~FanW/cfm = 0.58~~	~~FanW/cfm = 0.80~~	~~RA3.3.3.3 Diagnostic Air Handler Watt Draw~~
~~Cooling Coil Airflow~~	~~FanCfm/ton RACM Eqs. R3-20~~	~~The term FanCfm/ton is the ratio of the Cooling coil airflow to the nominal cooling capacity in tons.~~	~~FanCfm/ton = 350~~	~~FanCfm/ton = 300~~	~~RA3.3.3.1 Diagnostic Fan Flow~~
~~Refrigerant Charge Prerequisite~~	~~n. a.~~	~~The unit must pass~~test ~~System Fan Flows using RA3.3.2.1methods the temperature split test or an to confirm airflow of at least 300 cfm/ton must be obtained for a valid refrigerant charge test~~	~~n. a.~~	~~n. a.~~	~~RA3.2.2.7 Temperature Split Method or RA3.3.3.1 Diagnostic Fan Flow~~

RA3.3.1 Instrumentation Specifications

The instrumentation for the diagnostic measurements shall conform to the following specifications:

RA3.3.1.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of plus or minus ~~-~~ 1% of pressure reading or 0.2 Pa (whichever is greater). All pressure measurements within the duct system shall be made with static pressure probes Dwyer A303 or equivalent.

When supply plenum pressure measurements are used for plenum pressure matching or flow grid measurements, the supply plenum pressure shall be taken at the Supply Measurement Access ~~following~~ location shown in Figure RA3.3-1.

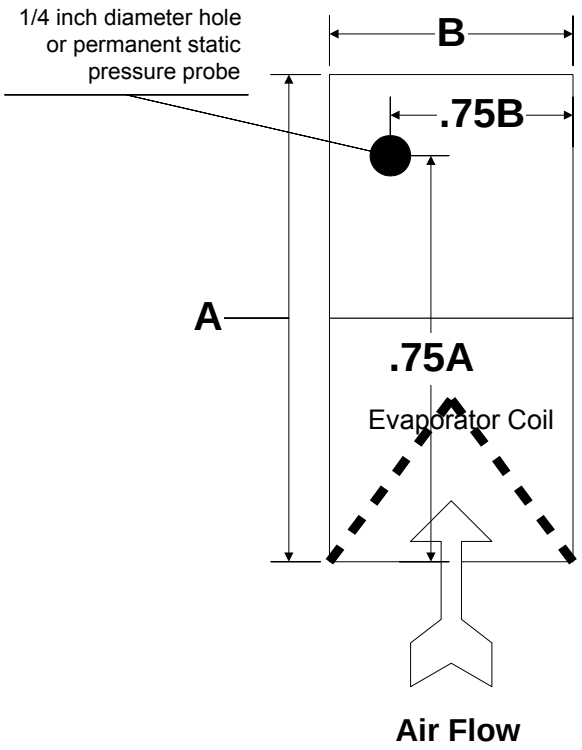

Figure RA3.3-1 Hole for the Placement of a Static Pressure Probe (HSPP) or a Permanently Installed Static Pressure Probe (PSPP)

~~This~~ The hole location shown in Figure RA3.3-1 can be ~~in~~ applied to any one of the four sides of the coil box/supply plenum.

This location shall have a ~~1/4~~5/16" inch (~~6~~ 8 mm) diameter hole (HSPP) or a permanently affixed static pressure probe (PSPP). The location shall be labeled "Title 24 – Supply Pressure Measurement Location" in at least 12-point type.

RA3.3.1.2 ~~Fan Flow~~Airflow Measurements

All measurements of ~~distribution~~ system ~~fan~~ airflows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 7% reading or ± 5 cfm whichever is greater.

RA3.3.1.3 Watt Measurements

All measurements of air handler watt draws shall be made with true power measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 2% reading or ± 10 watts whichever is greater.

RA3.3.2 Apparatus

RA3.3.2.1 System ~~Fan Flows~~Airflow

HVAC system fan flow shall be measured using one of the following methods.

RA3.3.2.1.1 Plenum Pressure Matching Measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter) meeting the specifications in RA3.3.1, a static pressure transducer meeting the specifications in Section RA3.3.1, The measuring device shall be attached at the ~~air handler blower compartment door, or alternatively at the~~ inlet to a return from the conditioned space. Unless the system is a multi-zoned automatic dampered system, the device may be alternatively placed at the air handler blower compartment door. The measuring device shall be attached at a point where all the ~~fan~~ airflow through the system shall flow through it. When the air handler blower compartment door is used an air barrier must be placed between the return duct system and the air handler inlet(s). All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum at the location specified in Section RA3.3.1.1 so that it is not moved during this test.

RA3.3.2.1.2 Powered Flow Capture Hood Measurement

A powered and pressure balanced flow capture hood approved for use by the Energy Commission that has the capability to balance the flow capture static pressure to 0.0 plus or minus 0.2 Pa and meets ~~meeting~~ the specifications in Section RA3.3.1 may be used to verify the fan flow at the return ~~register(s)~~grille(s) if the device has a flow capture area at least as large as the ~~returns~~ grill in all dimensions. All supply registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RA3.3.2.1.3 Flow Grid Measurement

The apparatus for measuring the system fan flow shall consist of a flow measurement device (subsequently referred to as a fan flow grid) meeting the specifications in RA3.3.1 and a ~~static~~ digital pressure measurement device that meets~~t~~ ~~ransducer meeting~~ the specifications in Section RA3.3.1. The flow measuring device shall be attached at a point where all the fan airflow shall flow through the flow grid. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum at the location specified in Section RA3.3.1.1 so that it is not moved during this test.

RA3.3.2.2 Air Handler Watts

The air handler watt draw shall be measured using one of the following methods.

RA3.3.2.2.1 Portable Watt Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of a wattmeter meeting the specifications in RA3.3.1. The measuring device shall be attached to measure the air handler fan watt draw. All registers and blower access panel(s) shall be in their normal operating condition.

RA3.3.2.2.2 Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the utility revenue meter meeting the specifications in RA3.3.1 and a stopwatch measuring in seconds. All registers and blower access panel(s) shall be in their normal operating condition.

RA3.3.2.2.3 Digital Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the digital utility revenue meter meeting the specifications in RA3.3.1, that provides direct digital display of the Watt draw. All registers and blower access panel(s) shall be in their normal operating condition.

RA3.3.3 Procedure for Verification of System Airflow and Fan Watt Draw

This procedure determines the ~~cooling coil~~ system airflow and~~,~~ fan Watt~~s~~ draw~~, and duct design~~ compliance.

To determine and verify airflow and fan watt draw credit, in addition to verifying airflow, the air handler fan watt draw measurement shall show fan watts less than that claimed in compliance software calculations and shown on the CF-1R.

RA3.3.3.1 Diagnostic ~~Fan Flow~~ System Airflow

~~For compliance calculations using verified prescriptive cooling coil airflow, or for compliance calculations using target values for verified cooling coil airflow that exceed prescriptive airflow, the~~ The installed system airflow shall be diagnostically tested using one of the methods specified in this section.

For systems utilizing an intentional ducted ventilation flow from outside the conditioned space into the return system, the outside airflow may be included in the system flow if that flow occurs in all operating modes of the HVAC system.

For multi-zone systems the airflow must be measured for each and every operating mode of the system. This must be accomplished without bypasses from the supply ductwork to the return ductwork. Note: All airflows are for the fan set at the speed used for air conditioning.

~~The system passes the Diagnostic Fan Flow test if the measured cooling coil airflow is equal to or greater than the value claimed in compliance calculations and reported by the ACM on the CF-1R.~~

Diagnostic ~~fan flows~~system airflows shall be converted to Fan Cfm/ton by dividing the measured fan flow (Qah) by the nominal tons of the air conditioner. The measured airflow shall be expressed in cubic feet per minute of standard air (standard air has a density of 0.075 lb/ft³). When the airflow measurement is made at altitudes significantly different from sea level or at temperatures significantly different from 70°F, the airflow indicated on the device gauge may differ from the standard CFM by as much as 15 percent. Corrections from indicated to standard CFM shall be made using the procedure specified by the flow measurement device manufacturer.

RA3.3.3.1.1 Diagnostic ~~Fan Flow~~System Airflow Using Plenum Pressure Matching

This ~~fan flow~~system airflow measurement shall be performed using the following procedures:

1. If the fan flowmeter is to be connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.
2. With the system fan on at the maximum speed used in the installation (the cooling speed when air conditioning is present), measure the pressure difference (in Pa) between the supply plenum and the conditioned space (Psp). Psp is the target pressure to be maintained during the ~~fan flow~~system airflow tests. Place the pressure probe in the Supply Pressure Measurement Location described in Section RA3.3.1.1. Adjust the probe to achieve the highest pressure and then firmly attach the probe to ensure that it does not move during the ~~fan flow~~system airflow test.
3. If the fan flowmeter is to be connected to the air handler at the access, block the return duct system from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.
4. Attach the fan flowmeter to the duct system at the ~~air handler or alternatively at the~~ inlet to ~~the~~ one return from the conditioned space with the grille and filter removed (if there are more than one return grilles, block off return grilles other than the one used for this measurement. Alternatively the flowmeter may be placed at the air handler.
5. Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches Psp.
6. Record the flow through the flowmeter (Qah, cfm) - this is the diagnostic ~~fan flow~~system airflow. In some systems, system fan and fan flowmeter combinations may not be able to produce enough flow to reach Psp. In this case record the maximum flow (Qmax, cfm) and pressure (Pmax) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Qmax and Pmax) to operating condition at operating pressure (Psp).

Equation RA3.3-1 Air Handler Flow Qah = Qmax x (Psp/Pmax) ^0.5

RA3.3.3.1.2 Diagnostic ~~Fan Flow~~System Airflow Using Flow Grid Measurement

The ~~fan flow~~system airflow measurement shall be performed using the following procedures:

1. With the system fan on at the maximum speed used in the installation (the cooling speed when air conditioning is present), measure the pressure difference (in Pascal) between the supply plenum and the conditioned space (Psp). Place the pressure probe in the Supply Pressure Measurement Location described in Section RA3.3.1.1. Adjust the probe to achieve the highest pressure and then firmly attach the probe to ensure that it does not move during the ~~fan flow~~system airflow test.
2. The flow grid shall be attached at a point where all the ~~fan air flows~~system air flows through the flow grid. Multiple flow grids may be used for systems with multiple returns.
3. Re-measure the system operating pressure with the flow grid in place.
4. Measure the airflow through the flow grid (Qgrid) and the test pressure (Ptest). If multiple flow grids are used Qgrid is the sum of the flows through the flow grids.
5. The following equation for air handler flow shall be used to correct flow through the flow grid and pressure (Qgrid and Ptest) to operating condition at operating pressure (Psp).

Equation RA3.3-2 Qah = Qgrid~~max~~ x (Psp/Ptest) ^0.5

~~**RA3.3.3.1.3 Diagnostic Fan Flow Using Flow Capture Hood**~~

~~**The fan flow measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the cooling speed and measure the fan flow at the return grille(s) with a calibrated flow capture hood to determine the total system return fan flow. The system fan flow (Qah, cfm) shall be the sum of the measured return flows.**~~

RA3.3.3.1.3 Diagnostic System Airflow Using Powered Flow Capture Hood

Turn on the system fan at the cooling speed and measure the fan airflow at the return grille(s) with a calibrated powered flow capture hood to determine the total system return fan flow. The system return airflow (Qah, cfm) shall be the sum of the system's measured return airflows.

~~***RA3.3.3.2 RESERVED***~~

~~***RA3.3.3.3***~~***RA3.3.3.2 Diagnostic Air Handler Fan Watt Draw***

~~The system passes the Watt Draw test if the air handler watt draw is less than or equal to the value claimed in compliance calculations and reported by the ACM on the CF-1R.For multi-zone systems the measured air handler watt draw must be less than or equal to the value claimed in compliance calculations and reported by the compliance software on the CF-1R. This must be accomplished with all zones operating and without bypasses from the supply ductwork to the return ductwork.~~

The diagnostic air handler watt draw shall be measured using one of the following methods:

~~**RA3.3.3.3.1**~~**RA3.3.3.2.1 Diagnostic Air Handler Watt Draw Using Portable Watt Meter**

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present, usually the cooling speed with outdoor air introduction if ventilation is provided through the return duct system~~present~~) and measure the fan watt draw (Wfan).

~~RA3.3.3.3.2~~RA3.3.3.2.2 Diagnostic Air Handler Watt Draw Using Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and turn off every circuit breaker except the one exclusively serving the air handler. Record the Kh factor on the revenue meter, count the number of full revolutions of the meter wheel over a period exceeding 90 seconds. Record the number of revolutions (Nrev) and time period (trev, seconds). Compute the air handler watt draw (Wfan) using the following formula:

Equation RA3.3-3

Air Handler Fan Watt Draw Wfan = (Kh x Nrev x 3600) / trev

Return all circuit breakers to their original positions.

RA3.3.3.2.3 Diagnostic Air Handler Watt Draw Using Digital Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present, usually the cooling speed with outdoor air introduction if ventilation is provided through the return duct system) and turn off every circuit breaker except the one exclusively serving the air handler. Read the Watt draw from the digital utility meter digital display. Return all circuit breakers to their original positions.

RA3.4 Procedures for Verifying the Presence of a Charge Indicator Display or High Energy Efficiency Ratio Equipment

RA3.4.1 Purpose and Scope

The purpose of these procedures is to verify that residential space cooling systems and heat pumps have the required components to achieve the energy efficiency claimed in the compliance documents. The procedures ~~only~~ apply when a Charge Indicator Display (CID) is specified for split system equipment, or when an EER higher than the default is claimed, or when installations use condenser and evaporator coil combinations that are not listed in the database of certified appliances published by the Energy Commission. For dwelling units with multiple systems, the procedures shall be applied to each system separately.

The installer shall certify to the builder, building official and HERS rater that he/she has installed all the correct components.

~~The reference method algorithms adjust (improve) the efficiency of air conditioners and heat pumps when field verification indicates the specified components are installed. Table RA3.4-1 summarizes the algorithms that are affected.~~

~~*Table RA3.4-1 – Summary of Field Verification*~~

			~~Proposed Design~~	
~~Field Verification Check~~	~~Description~~	~~Standard Design Value~~	~~Default Value~~	~~Procedure~~
~~Presence of a CID~~	~~F_{CID} takes on a value of 0.96 when the system has a verified CID or has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{CID} has a value of 0.90.~~	~~Split systems are assumed to have refrigerant charge testing or a CID, when required by Package D.~~	~~No CID or refrigerant charge testing.~~	~~Section RA3.4.2~~
~~Presence of a matched High Efficiency Compressor Unit, Evaporator Coil, Refrigerant Metering Device, and (where specified) Air Handling Unit and/or Time Delay Relay.~~	~~The EER is the Energy Efficiency Ratio at 95 F outdoors specified according to ARI procedures for the matched combination~~	~~Systems are assumed to have the default EER based on SEER.~~	~~Default EER~~	~~Sections RA3.4.3 and RA3.4.4~~

The CID provides an alternative to Refrigerant Charge Verification when field verification is required. CID devices with

RA3.4.2 CID Verification Procedure

The CID verification procedure shall consist of visual ~~verification~~ inspection to confirm that the CID is installed on the system~~.~~, and that the manufacturer has certified to the Energy Commission that the CID model meets the applicable requirements of Reference Joint Appendix JA6. In addition, the space conditioning system shall comply with the procedures specified in Sections RA3.4.2.1, or RA3.4.2.2, or RA3.4.2.3.

RA3.4.2.1 Verification of installation of a CID with "self diagnostic reporting" functionality when outdoor air temperature is less than 55F

The space conditioning system installer shall use the weigh-in procedure to comply with refrigerant charge requirements, and HERS verification compliance for the refrigerant charge requirement shall be satisfied by verifying the system has a CID installed on it, and confirming the installed CID "self diagnostic reporting function" indicates CID sensors and internal processes are operating within acceptable parameters.

RA3.4.2.2 Verification of Installation of a CID that does not have "self diagnostic reporting" functionality when outdoor air temperature less than 55F

The space conditioning system installer shall use the weigh-in procedure to comply with the refrigerant charge requirements, and HERS verification compliance for the refrigerant charge requirement shall be delayed until a time when the outdoor air temperature is greater than 55F, at which time the procedure in RA3.4.2.3 shall be performed.

RA3.4.2.3 Verification of Installation of a CID when the outdoor air temperature is greater than 55F

When the outdoor air temperature is warmer than 55F, the space conditioning system installer shall use either the Standard Charge Measurement Procedure or the weigh-in procedure to comply with the refrigerant charge requirement, and HERS verification compliance for the refrigerant charge requirement shall be validation of the CID installation when the outdoor air temperature is warm enough for the installed CID to perform a valid refrigerant charge test according to the CID manufacturer specification. The HERS verification shall consist of operating the air conditioner for at least 15 minutes and a visual inspection to verify the CID reports the system is operating within acceptable parameters, or reports a system fault. If the CID reports that there is a system fault, the system does not comply with the refrigerant charge verification requirement.

RA3.4.3 Time Delay Relay Verification Procedure

When a high EER system specification includes a time delay relay, the installation of the time delay relay shall be verified.

The procedure shall be:

1. Turn the thermostat down until the compressor and indoor fan are both running.
2. Turn the thermostat up so the compressor stops running.
3. Verify that the indoor fan continues to run for at least 30 seconds.

RA3.4.4 Matched Equipment Procedure

When installation of specific matched equipment is necessary to achieve a high EER, installation of the specific equipment shall be verified. The verification shall utilize certified rating data from the AHRI Directory of Certified Product Performance at http://www.ahridirectory.org or another directory of certified performance approved by the Energy Commission for use for determining compliance.

The procedure shall consist of visual verification of installation of the following equipment and confirmation that the installed equipment matches the equipment required to achieve the ~~high~~ required SEER or EER rating:

1. The specified labeled make and model number of the outdoor unit.
2. The specified labeled make and model number of the inside coil.
3. The specified labeled make and model of the furnace or air handler when a specific furnace or air handler is necessary to achieve the ~~high~~ SEER or EER rating,
4. The specified metering device when a specific refrigerant metering device (such as a TXV or an EXV) is necessary to achieve the high efficiency rating.

RA3.5 ~~High~~ Quality Insulation Installation Procedures

~~RA3.5.1~~ RA3.5.0 Purpose and Scope

RA3.5 is a procedure for verifying the quality of insulation installation and air leakage control used in low-rise residential buildings. ~~A compliance credit is offered when~~ This procedure is to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c)13, and 110.7(a) and (b) of the Standards.

The procedure ~~and credit~~ applies to wood and metal ~~framed~~ construction of framed and non-framed envelope assemblies. Framed assemblies include ~~with~~ wall stud cavities, roof/ceiling~~s, and roof~~ assemblies, and floors typically insulated with: (1) batts of mineral fiber and mineral wool; (2) ~~fiber or~~ loose-fill ~~cellulose insulation~~ materials of mineral fiber, mineral wool, and cellulose; (3) spray polyurethane foam; and, (4) rigid board sheathing materials. Non-framed assemblies include wall, roof/ceiling, and floors constructed of structural insulated panels and insulated concrete forms.~~in low-rise residential buildings~~

Note 1: This procedure applies to the entire thermal envelope of the building. In many instances, residential homes will use several types of insulation material, even in the same framed assembly. Each insulation material and the integrity of air leakage control for the building's entire thermal envelope must be verified by the HERS rater for the home to comply with the Standards.

~~.~~Note 2: Structural bracing, tie-downs, and framing of steel or specialized framing used to meet structural requirements of the CBC are allowed. These areas shall be called out on the building plans with diagrams and/or specific design drawings indicating the R-value amount and fastening method to be used. All structural framing areas shall be insulated in a manner that resists thermal bridging from the outside to the inside of the assembly separating unconditioned from conditioned space. The insulation and air barrier integrity shall be verified by the HERS rater.

~~The procedure for verifying the quality of closed-cell spray polyurethane foam (SPF) insulation installation is outlined Joint Appendix JA7.~~

RA3.5.1~~(a)~~ TERMINOLOGY

Continuous Air Barrier	A combination of interconnected materials and assemblies joined and sealed together to provide a continuous air-tight boundary of the building envelope separating conditioned from unconditioned space, or adjoining conditioned spaces of different occupancies or uses. Insulation must be in substantial contact with the assembly air barrier on one side for it to perform at its rated R-value. An air barrier is required in all thermal envelope assemblies to prevent air movement between unconditioned/outside spaces and conditioned/inside spaces and must meet one of the following: 1. Using individual materials that have an air permeance not exceeding 0.004cfm/ft^2 under a pressure differential of 0.3in. w.g. (1.57psf) (0.02 L/s.m^2 at 75 pa) when tested in accordance with ASTM E2178; or 2. Using assemblies of materials and components that have an average air leakage not to exceed 0.04 cfm/ft2 under a pressure differential of 0.3 in. w.g (1.57psf) (0.2 L/s.m^2 at 75 pa) when tested in accordance with ASTM E1677; or 3. Testing the completed building and demonstrating that the air leakage rate of the building envelope does not exceed 0.40 cfm/ft^2 at a pressure differential of 0.3 in w.g. (1.57 psf) (2.0 L/s.m^2 at 75 pa) in accordance with ASTM E779 or an equivalent approved method. Individual materials and assemblies of materials that can demonstrate compliance with the air barrier testing requirements must be installed according to the manufacturer's instructions and a

	HERS rater shall verify the integrity of the installation. Below are example materials meeting the air permeance testing performance levels of 1 above. Manufacturers of these and other product types must provide a specification or product data sheet showing compliance to the ASTM testing requirements to be considered as an air barrier. -- Plywood – minimum 3/8 inch -- Oriented strand board – minimum. 3/8 inches -- Extruded polystyrene insulation board – minimum. ½ inch -- Foil-back polyisocyanurate insulation board – minimum. ½ inch -- Extruded polystyrene insulation board – minimum ½ inch -- Foil backed urethane foam insulation (1 inch) -- Closed cell spray polyurethane foam with a minimum density of 2.0 pcf and a minimum thickness of 1½ inches -- Open cell spray polyurethane foam with a minimum density of 0.4 to1.5 pcf and a minimum thickness of 5½ inches -- Exterior or interior gypsum board - minimum 1/2 inch -- Cement board - minimum 1/2 inch -- Built up roofing membrane -- Modified bituminous roof membrane -- Particleboard-minimum1/2 inch -- Fully adhered single-ply roof membrane -- Portland cement/sand parge ,or gypsum plaster minimum 5/8 inch -- Cast-in-place and precast concrete. -- Fully grouted uninsulated and insulated concrete block masonry -- Sheet steel or aluminum
Air-tight	Not permitting the passage of air either in or out of the building envelope. Note: Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement brings unconditioned air and moisture through or into the assembly. For these procedures, air-tight shall be defined as an assembly or air barrier with all openings caulked, or sealed with minimally expansive foam, or taping/sealing of adjoining surfaces of air barrier materials and assemblies.
Compression	Compacting of insulation in an assembly that results in elimination of the air pockets trapped in the material that gives the insulation its R-value per inch. Batt insulation should be “lofted” and loose-fill and spray foam material properly field applied to the manufacturer specified density to achieve its full R-value. Limited compression is allowed at plumbing, vents, and other obstructions and in cavities of non-standard framing. Compression of insulation in these situations by more than 50% is excessive and shall not be allowed.
Delaminated	Separation of the insulation's full thickness to facilitate it's installation around or between obstructions. Batt and blanket insulation are often split or delaminated to fit around electrical wires and plumbing runs through a wall cavity. The delamination must ensure that the full thickness of the insulation is installed between the obstruction and the finish material covering the framing. For example, an electrical wire located one-third of the distance from the front of the

	cavity should have batt insulation delaminated so that two-thirds of the batt is installed behind the wire and one-third is installed in front of the wire.
Draft Stops	A material, device or construction installed to prevent the movement of air within open spaces of concealed areas of building components, such as crawl spaces, floor/ceiling assemblies, wall assemblies, roof/ceiling assemblies and attics. Note: Draft stops are important components of the air barrier and shall be air-tight. Fire blocks constructed of porous insulation materials cannot serve as draft stops since they are not air tight.
Friction Fit	A means of attaching insulation within the framed cavity without the use of mechanical fasteners such that the material's full thickness in all directions is sufficient to maintain its installation integrity. In standard framing dimensions of 2x4' and 2x6" @ 16" oc and 24" oc batt and blanket insulation materials have enough side-to-side frictional force to hold the insulation in place without any other means of attachment. Note: Friction fitting of faced batt and blanket insulation, with or without an attachment flange, is allowed provided the insulation's installation integrity can be maintained.
Gaps	Uninsulated areas at the edge of insulation where insulation is not in contact with framing members or other materials at the edge of the insulation. Gaps occur when insulation length and width is too short for the cavity. Gaps in insulation are avoidable and are not permitted.
Hard Covers	Building materials, such as plywood or gypboard, which become part of the ceiling air barrier. Note: Hard covers shall be installed above areas where there is a drop ceiling. For example, a home with 10ft ceilings may have an entry closet with a ceiling lowered to 8ft. In this case, a hard cover is installed at the 10ft level above the entry closet. Hard covers become part of the ceiling air barrier and shall be air-tight.
Inset Stapling	A method of attaching faced batt or blanket insulation to wood framing. The flange of the insulation facing is pushed inside the face of the framing member and stapled as opposed to In windy areas installers often staple the flanges of faced batts to the sides of the stud in order to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.
Insulation Types--framed assemblies	There are four basic types of insulation used and their use varies based on the design and type of construction: 1. **Batt and Blanket**: Batt and blanket insulation is made of mineral fiber and mineral wool -- either processed fiberglass, rock or slag wool -- and is used to insulate below floors, above ceilings, below roofs, and within walls. 2. **Loose-fill**: Loose-fill insulation includes loose fibers or fiber pellets that are blown into building cavities or attics using special equipment. Loose-fill insulations typically are produced using mineral fiber, mineral wool, or cellulose. They are installed in walls, floors, attics and below roofs using a dry-pack process or a moist-spray technique, and may include a netting material. 3. **Rigid Board**: Rigid board insulation sheathing is made from fiberglass, expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate, or polyurethane. This type of insulation is used for above roof decks, exterior walls, cathedral ceilings, basement walls, as perimeter insulation at concrete slab edges, and to insulate special framing situations such as window and door headers, and around metal seismic bracing.

	4. **Spray Polyurethane Foam (SPF)**: A two-part liquid foamed plastic (such as polyurethane or modified urethane) material formed by the reaction of an isocyanurate and a polyol that uses a blowing agent to develop a cellular structure when spray applied onto a substrate. SPF insulation is a two-component reactive system mixed at a spray gun or a single-component system that cures by exposure to humidity. The liquid is sprayed through a nozzle into wall, roof/ceiling, and floor cavities. SPF insulation can be formulated to have specific physical properties (i.e., density, compressive strength, fire resistance and R-value). There are two types of SPF insulation: a. *Low Density Open-Cell SPF (ocSPF) Insulation*: A spray applied polyurethane foam insulation having an open cellular structure resulting in an installed nominal density of 0.4 to 1.5 pounds per cubic foot (pcf). b. *Medium Density Closed-Cell SPF (ccSPF) Insulation*: A spray applied polyurethane foam insulation having a closed cellular structure resulting in an installed nominal density of greater than 1.5 to less than 2.5 pounds per cubic foot (pcf).
Insulation Types--non-framed assemblies	There are two basic types of insulation used and their use varies based on the design and type of construction: 1. **Structural Insulated Panel (SIP):** A composite building material consisting of an insulating layer of rigid polymer foam sandwiched between two layers of structural board. The board can be sheet metal, plywood, cement or oriented strand board (OSB) and the foam is either expanded polystyrene foam (EPS), extruded polystyrene foam (XPS) or polyurethane foam. SIPs combine several components of conventional building, such as studs and joists, insulation, vapor barrier and air barrier. They can be used for many different applications, such as exterior walls, roofs, floors, and foundation systems. 2. **Insulated Concrete Form (ICF):** A system of formwork for concrete that stays in place as permanent building insulation and is used for cast-in-place, reinforced above and below-grade concrete walls, floors, and roofs. ICFs are interlocking modular units that can be dry-stacked (without mortar) and filled with concrete as a single concrete masonry unit (CMU). ICFs lock together externally and have internal metal or plastic ties to hold the outer layer(s) of insulation to create a concrete form for the structural walls, roof/ceilings, or floors of a building. ICFs are manufactured from several materials including: expanded and extruded polystyrene foam, polyurethane foam, cement-bonded wood fiber, and cement-bonded polystyrene beads.
Minimally Expansive Foam Sealing Material	A single-component polyurethane foam system typically formulated in a handheld can or portable container to seal and fill construction gaps and crevasses, holes, and cracks without distorting adjacent framing. These materials are not used for insulation purposes, rather as agents for air sealing of gaps and crevasses that are too small to be insulated.
Net Free-Area	The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by a screen or louver used for ventilation. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.
Voids & Air Spaces	An uninsulated space within an enclosed building assembly created where the assembly has been insulated by partial filling of the framed cavity. The partial fill results in an air space (void) between the insulation surface and the assembly's exterior or interior layers which form the assembly's air barrier. Voids occur when insulation depth is too shallow to provide the expected R-value and for the insulation to maintain contact with the assembly's air barrier.

RA3.5.22.0 BATT AND BLANKET INSULATION ~~Batt and Blanket Insulation~~

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of batt and blanket insulation. These procedures must be field verified before the building construction permit is finalized in order to claim QII energy compliance.

Theses procedures are to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance to meet the requirements of Sections 150.1(c)13, and 110.7(a) and (b) of the Standards.

RA3.5.22.0.1 Thermal Specification

This insulation type is manufactured in different widths, lengths, and thicknesses and is available with or without a facing. Faced batts and blanket insulation material are also available with or without an attachment flange. Specific product R-values are readily available from the manufacturer for the specific materials being installed and the R-value of the product is marked on the face of the product (faced or unfaced material). The installed insulation must meet the R-value stated on the compliance documentation.

RA3.5.22.0.2 Requirements for Walls, Roof/Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.
- ~~20.~~Batt and blanket insulation shall be correctly sized to fit snugly at the sides and ends.
- Batt and blanket insulation shall be installed so that they will be in contact with the air barrier.
- Where necessary, batt and blanket insulation shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batt and blanket insulation are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without excessive compression.
- Batt and blanket insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts and blanket insulation that is taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.

- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.2.0.3~~4~~ R-value Measurement Equipment

- The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings, and floors, and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CFR~~R~~-6R.

RA3.5.2.0.4~~5~~ Certificates

- An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation company and manufacturer's name and material identification, and the installed R-value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.

RA3.5.2.0.5~~6~~ Certificates and Availability

- The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.5.2.1~~2.4~~ Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. All plumbing and wiring penetrations through the top and bottom plates, and electrical boxes that penetrate the sheathing shall be sealed. All gaps in the air barrier shall be caulked, taped, or sealed with minimally expansive foam.
- Bottom plates of framed and non-framed assemblies shall be sealed to the ground subfloor or slab, and above ground subfloor.
- Insulation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- The batt shall be friction fitted into the cavity unless another support method is used.
- Batt and blanket insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.
- Non-standard-width cavities shall be filled with insulation fitted into the space without excessive compression.
- Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

RA3.5.2.1.1~~.2.5~~ Narrow-Framed Cavities

- Non-standard width cavities shall be filled with insulation to snuggly fit into the space, or with minimally expansive foam sealing material.
- Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with insulation snuggly fitted into the space, or with minimally expansive foam sealing.
- Narrow spaces less than 2 inches in width, such as between studs at building corners, and at the intersection of interior partition walls to exterior walls, shall be filled with insulation snuggly fitted in the space, or minimally with expansive foam sealing.

RA3.5.2.1.2~~2.6~~ Special Situations--Installation Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities, such as corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. In most cases this can only be completed prior to the installation of the tub/shower enclosure, the exterior sheathing, or the exterior stucco lath.
- An air barrier shall be installed on the inside of the exterior wall(s) directly adjacent to the tub/shower enclosure.

RA3.5.2.1.3~~2.7~~ Special Situations--Obstructions

- Insulation shall be cut to fit around wiring and plumbing without compression.
- Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least 2/3 of the insulation between the water pipe and the outside surface of the exterior wall. If the pipe is near the exterior finish assembly layers, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the interior assembly material.

RA3.5.2.1.4~~2.8~~ Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.
- The insulation shall be installed without gaps, voids, or compression.

RA3.5.2.1.5~~2.9~~ Special Situations--Kneewalls, Skylight Shafts, and Gable Ends

- Framing for kneewalls, skylight shafts and gable ends that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls, skylight shafts, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either friction fitting to the framing, inset or face stapling of flanges, or using other support such as netting.
- Insulation for all kneewall and skylight shafts shall be completely enclosed by vertical and horizontal framing, including horizontal plates at top and bottom of the insulation.
- In unvented attics, where insulation is applied directly to the underside of the roof deck, kneewalls, skylight shafts, and gable ends shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.

RA3.5.2.1~~..6~~2.10 Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in compliance documentation.

RA3.5.2.1.7 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.2.1.8 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.2.1.9 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.2.2 ~~2.11~~ Roof/Ceilings

- Batt and blanket insulation shall be correctly sized to fit snugly at the sides and ends.
- Batt and blanket insulation shall be installed to be in contact with the air barrier.
- Where necessary, batt and blanket insulation shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batt and blanket insulation are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without compression.
- Batt and blanket insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- Batt and blanket insulation that are thicker than truss depth, shall be installed so that the insulation expands to touch adjoining cavity over each truss member.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under the insulation. The required net free-ventilation shall be maintained.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall cover all recessed lighting fixtures. Fixtures that are not rated for insulation cover (IC), and air-tight, shall be replaced.

RA3.5.2.2.1~~2.12~~ Special Situations--Enclosed Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing per California Building Code, Sections 1203.2 and R805.2, or as specified by the local building department.
- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RA3.5.2.2.2 Special Situations--Attics and Cathedral Ceilings

- In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.

- In unvented attics where insulation is applied directly to the underside of the roof deck, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.2.2.3~~22.13~~ *Special Situations*--HVAC Platform

- Batt and blanket insulation shall be placed below any platform or cat-walk for HVAC equipment installation and access.
- Batt and blanket insulation shall be installed so that they will be in contact with the air barrier.

RA3.5.2.2.4~~32.14~~ Special Situations--Attic Access

- Permanently attach rigid board insulation or batt or blanket insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air leakage of conditioned air to the unconditioned attic.

RA3.5.2.3~~2.15~~ Raised Floors

Batt and blanket insulation shall be correctly sized to fit snugly at the sides and ends~~, but not be so large as to buckle.~~

- .
- Batt and blanket insulation shall be cut to fit properly without gaps. Insulation shall not be doubled-over ~~-~~or compressed.
- Batt and blanket insulation shall be in contact with the air barrier - usually the subfloor.

RA3.5.2.3.1 Homes ~~With~~with~~and~~ Floors Over Garages~~s~~

- Batt and blanket insulation shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.
- Batt and blanket insulation shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.
- Batt and blanket insulation shall be in contact with the air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Batt and blanket insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- Faced batts or blankets shall be placed toward the living space and be in contact with the underside of the floor sheathing. Continuous support shall be provided to keep the facing in contact with the floor sheathing. The insulation shall be properly supported by stapling of flanges, netting or other method approved by the manufacturer for the product.
- Batt and blanket insulation shall be properly supported to avoid gaps, voids, and compression.

RA3.5.2.3.2~~2.16~~ Homes with Conditioned Space Over Garage

- The floor over the garage shall be insulated with batt or blanket insulation against the subfloor of the conditioned space. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. All rim and band joists adjoining conditioned space shall be air tight and insulated.

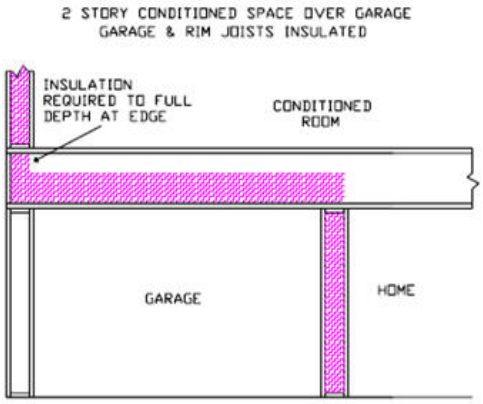

FIGURE 3

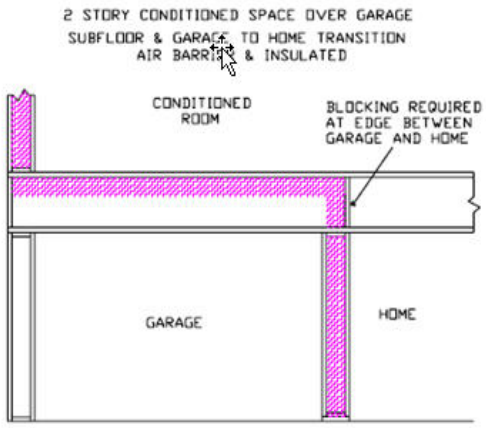

FIGURE 4

RA3.5.2.3.3~~2.17~~ Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

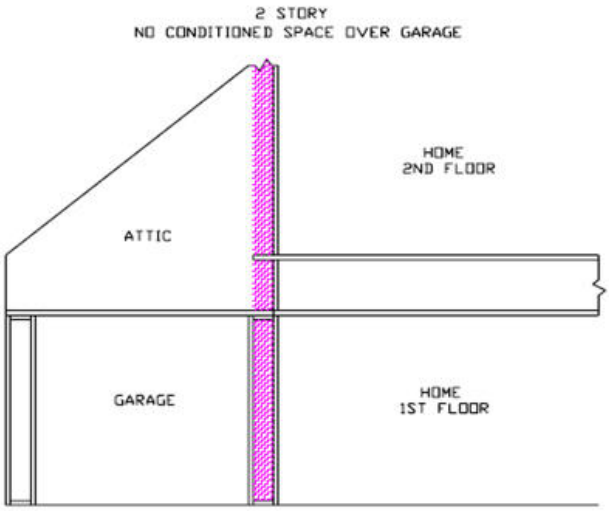

FIGURE 1

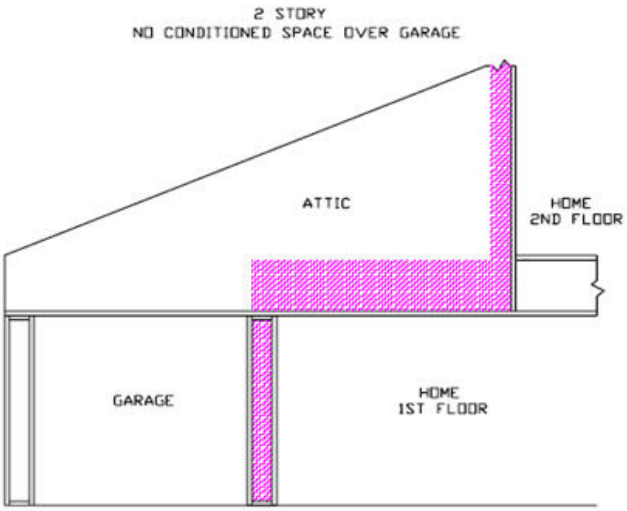

FIGURE 2

~~*RA3.4.5.2.18 R-value Measurement Equipment*~~

~~The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CR-6R.~~

~~*RA3.4.5.2.19 Certificates*~~

~~An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.~~

~~*RA3.4.5.2.20 Certificates and Availability*~~

~~The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the insulation installer, shall be available on the building site for each of the HERS~~

~~rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.~~

RA3.5.3.04.5.3 LOOSE FILL INSULATIONLoose-Fill Insulation

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of loose-fill insulation. These procedures must be field verified before the building construction permit is finalized in order to claim QII energy compliance.

These procedures are to be followed by the insulation installer and a qualified Home Energy System (HERS) rater must verify conformance to meet the requirements of Sections 150.1(c)13 and 110.7(a) and (b) of the Standards.

RA3.54.5.3.0.11 Thermal Specification

This insulation type is manufactured to be blown or sprayed into framed cavity walls, floors, and ceilings. It is installed with or without a net depending on the loose-fill type or in special installations where neeting is required, such as below a roof deck or under floors. Its overall R-value is dependent on the installed density and installed thickness. Specific product R-values are readily available from the manufacturer for the specific materials being installed. R-value and coverage chart of the product is typically marked on the bag which the insulation was drawn from and from the manufacturer's product data sheet or product specification information. The installed insulation must meet the R-value stated on the compliance documentation.

RA3.5.3.0.2 Requirements for Walls, Roof/Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- 0.Loose-fill insulation shall be must completely fill the framed cavity.
- Loose-fill insulation shall be installed so that they will be in contact with the air barrier.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.

- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.3.0.3~~4~~ R-value Measurement Equipment

- The HERS rater shall measure the installed thickness and density of insulation in at least 6 random locations on walls, roof/ceilings and floors (i.e., 6 measurements per opaque surface type: wall, roof/ceiling or floor) to ensure minimum thickness levels and the installed density meets the R-value specified on the Certificate of Compliance, CF-1R and CF-6R. For walls, measurement areas shall include low and high areas of the insulated assembly and the HERS rater shall verify density measurements are consistent with the manufacturer's coverage chart.

~~The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CR-6R.~~

RA3.5.3.0.4~~5~~ Certificates

- An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value. The insulation installer shall complete the applicable sections of the Installation Certificate form and attach a bag label or a manufacturer's coverage chart for every different type of loose-fill insulation material used.
- For ~~, and, in applications of~~ loose-fill insulation, compliance information shall include the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-v~~V~~alue, and the number of inches required to achieve the desired R-Value.

~~The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a bag label or a manufacturer's coverage chart for every insulation material used.~~

RA3.5.3.0.5~~6~~ Certificates and Availability

- The Insulation Installation Certificate (CF-6R), with insulation material bag labels or coverage charts attached, signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.5.3.14 Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate. All gaps in the air barrier shall be caulked, or sealed with expansive or minimally expansive foam.
- Bottom plates of framed and non-framed assemblies shall be sealed to the ground subfloor or slab, and above ground subfloor.
- Insulation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- Loose fill insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Loose fill wall insulation shall be installed to fit around wiring, plumbing, and other obstructions.

- Non-standard-width cavities shall be filled with insulation fitted into the space without excessive compression.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.

RA3.5.3.1.1~~5~~ Narrow-Framed Cavities

- Non-standard width cavities shall be filled with insulation to snuggly fit into the space, or with minimally expansive foam sealing material.
- Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with insulation snuggly fitted into the space, or with minimally expansive foam sealing.
- Narrow spaces less than 2 inches in width, such as between studs at building corners, and at the intersection of interior partition walls to exterior walls, shall be filled with insulation snuggly fitted in the space, or with minimally expansive foam sealing.

RA3.5.3.1.2~~6~~ Special Situations--Installation Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities, such as; corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. In most cases this can only be completed prior to the installation of the tub/shower enclosure, the exterior sheathing, or the exterior stucco lath.
- An air barrier shall be installed on the inside of the exterior wall(s) directly adjacent to the tub/shower enclosure.

RA3.5.3.1.3~~7~~ Special Situations--Obstructions

- Insulation shall completely fill around wiring and plumbing without compression.
- Insulation shall fill between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least 2/3 of the insulation between the water pipe and the outside surface of the exterior wall. If the pipe is near the exterior finish assembly layers, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the interior assembly material.

RA3.5.3.1.4~~8~~ Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-value as the adjacent walls.
- The insulation shall be installed without gaps, voids, or excessive compression.

RA3.5.3.1.5~~9~~ Special Situations--Kneewalls, Skylight Shafts, and Gable Ends

- Framing for kneewalls, skylight shafts and gable ends that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls, skylight shafts, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by using support such as netting.

- Insulation for all kneewall and skylight shafts shall be completely enclosed by vertical and horizontal framing, including horizontal plates at top and bottom of the insulation.
- In unvented attics, where insulation is applied directly to the underside of the roof deck, kneewalls, skylight shafts, and gable ends shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.

RA3.5.3.1.6~~0~~ Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in compliance documentation.

RA3.5.3.1.7 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.3.1.8 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.3.1.9 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.3.~~11~~2 Roof/Ceilings

- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed or the entire drop area shall be filled with loose-fill insulation level with the rest of the attic.
- Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under the insulation. The required net free-ventilation shall be maintained.
- Attic rulers appropriate to the material shall be installed and evenly distributed throughout the attic to verify depth: one ruler for every 250 square feet and clearly readable from the attic access. Attic rulers shall be scaled to read inches of insulation and the R-value installed.
- Insulation shall be applied underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall cover recessed lighting fixtures. Fixtures that are not rated for insulation cover (IC), and air tight, shall be replaced.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.

- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and weight-per-square-foot.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The HERS rater shall verify that the manufacturer's minimum weight-per-square-foot requirement has been met for attics insulated with loose-fill insulation. Verification shall be determined using the methods of the Insulation Contractor's Association of America (ICAA) Technical Bulletin #17 except that only one sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record the weight-per-square-foot of the sample on the Certificate of Field Verification and Diagnostic Testing (CF-6R).
- The HERS rater shall verify that the manufacturer's minimum insulation thickness has been installed. For cellulose insulation, this verification shall take into account the time that has elapsed since the insulation was installed. At the time of installation, the insulation shall be greater than or equal to the manufacturer's minimum initial insulation thickness. If the HERS rater does not verify the insulation thickness at the time of installation, and if the insulation has been in place less than seven days, the insulation thickness shall be greater than the manufacturer's minimum required thickness to achieve the given R-value at the time of installation, less 1/2 inch to account for settling. If the insulation has been in place for seven days or more, the insulation thickness shall be greater than or equal to the manufacturer's minimum required settled thickness to achieve the given R-value.

RA3.5.3.~~1~~2.1~~2~~ Special Situations--Enclosed Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing per California Building Code Sections 1203.2 and R805.2, or as specified by the local building department.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RA3.5.2.2.2 Special Situations--Attics and Cathedral Ceilings

- In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.
- In unvented attics where insulation is applied directly to the underside of the roof deck, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.3.~~1~~32.3~~1~~ Special Situations--HVAC Platform

- Loose-fill insulation shall be placed below any platform or cat-walk for HVAC equipment installation and access.
- Loose-fill insulation shall be installed so that it will be in contact with the air barrier.

RA3.5.3.~~1~~42.4~~2~~ Special Situations--Attic Access

- Permanently attach rigid board insulation or batt or blanket insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air leakage of conditioned air to the unconditioned attic.

RA3.5.3.~~1~~53 Raised Floors

- Loose-fill insulation shall be in contact with the air barrier - usually the subfloor.
- Loose-fill insulation shall completely fill around wiring and plumbing.
- Loose-fill insulation shall be properly supported where necessary to avoid sagging, gaps, voids, and compression.~~and~~

RA3.5.3.3.1 Homes ~~With~~with Floors Over Garages~~

- Loose-fill insulation shall be in contact with the air barrier - usually the subfloor.

- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Loose-fill insulation shall completely fill around wiring and plumbing.
- Loose-fill insulation shall be properly supported to avoid sagging, gaps, voids, and compression.

RA3.5.3.3.2~~16~~ Homes with Conditioned Space Over Garage

- The floor over the garage shall be insulated with fully supported loose-fill insulation against the subfloor of the conditioned space. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. All rim and band joists adjoining conditioned space shall be air tight and insulated.

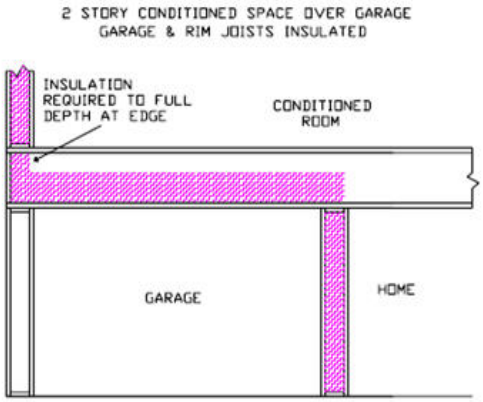

FIGURE 3

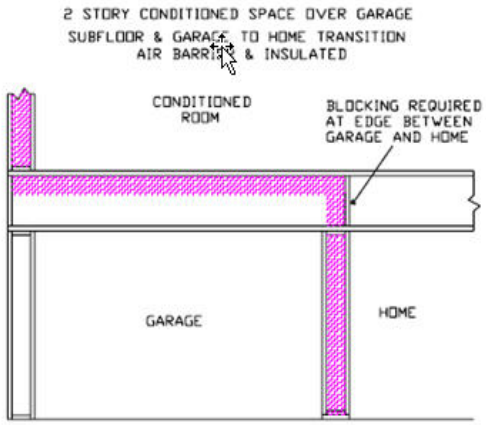

FIGURE 4

RA3.5.3.1~~73~~.3 Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

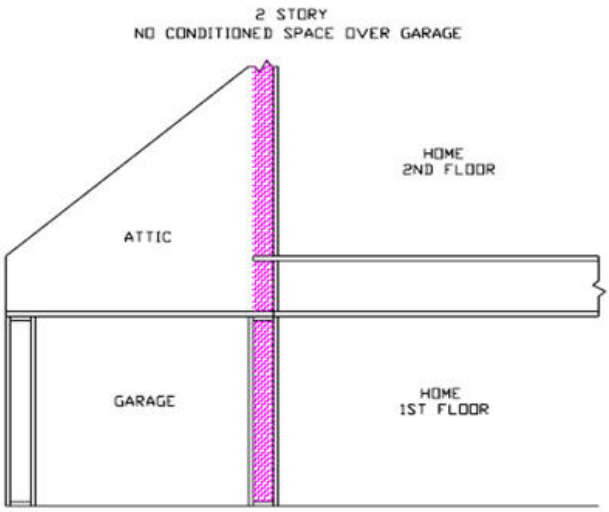

FIGURE 1

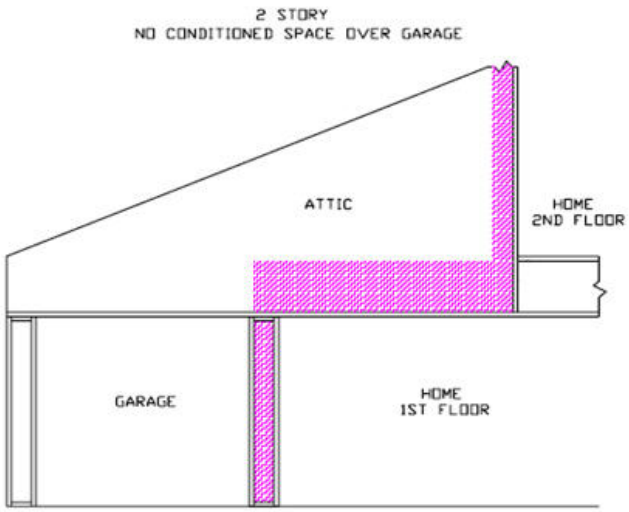

FIGURE 2

~~*RA3.5.3.18 R-value Measurement Equipment*~~

~~The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CR-6R.~~

~~*RA3.5.3.19 Certificates*~~

~~An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of loose-fill insulation, the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design density for the desired R-Value, and the number of inches required to achieve the desired R-Value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a bag label or a manufacturer's coverage chart for every insulation material used.~~

~~*RA3.5.3.20 Certificates and Availability*~~

~~The Insulation Installation Certificate (CF-6R), with insulation material bag labels or coverage charts attached, signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.~~

RA3.5.4 RIGID BOARD INSULATION~~Rigid Board Insulation~~

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of rigid board insulation sheathing material. These procedures must be field verified before the building construction permit is finalized in order to claim QII energy compliance.

These procedures are to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c)13 and 110.7(a) and (b) of the Standards.

RA3.5~~.~~.4.0.1~~1~~ Thermal Specification

This insulation type is manufactured of different materials and is in sheet or board form. Rigid board insulation materials are typically used on the exterior side of framed wall assemblies and over the top of exterior roof decks. These products also may be used for special situations in rafter spaces of cathedral ceilings, floors, at floor rim joists, and within or on the outside of window and door headers. Rigid board insulation material most often is used in conjunction with other insulation materials installed within the framed cavity. The R-value is dependent on the type of material and its thickness. Specific product R-values are readily available from the manufacturer for the specific materials being installed. R-value of the product is typically marked on the product. The installed insulation must meet the R-value stated on the compliance documentation.

RA3.5.4.0.2 Requirements for Walls, Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.
- ~~0.~~Rigid board insulation shall be attached according to the manufacturer's specifications.
- Rigid board insulation may be used as the air barrier provided it has been tested to conform to the air barrier performance conditions of the Standards.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.4.0.3~~4~~ R-value Measurement Equipment

- The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings, and floors, and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and ~~CR-6R~~CF-6R.

RA3.5.4.0.4~~5~~ Certificates

- An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, and the installed R-value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.

RA3.5.4.0.5~~6~~ Certificates and Availability

The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.5.4.1.4 Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. All plumbing and wiring penetrations through the top and bottom plates, and electrical boxes that penetrate the sheathing shall be sealed. All gaps in the air barrier shall be caulked, or sealed with minimally expansive foam.
- Bottom plates of framed and non-framed assemblies shall be sealed to the ground subfloor or slab, and above ground subfloor.
- Installation shall uniformly fit across the plane of the wall and taping and/or caulking of all joints and seams of the insulation shall be maintained to be considered as the air barrier.

RA3.5.4.1.1~~5~~ Narrow-Framed Cavities

- Non-standard with cavities shall be filled with insulation to snuggly fit into the space, or with minimally expansive foam sealing material.
- Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with insulation snuggly fitted into the space, or with minimally expansive foam sealing material.
- Narrow spaces less than 2 inches in width, such as between studs at building corners, and at the intersection of interior partition walls to exterior walls, shall be filled with insulation snuggly fitted in the space, or with minimally expansive foam sealing.

RA3.5.4.1.2~~6~~ Special Situations--Installation Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities, such as corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. In most cases this can only be completed prior to the installation of the tub/shower enclosure, the exterior sheathing, or the exterior stucco lath.
- An air barrier shall be installed on the inside of the exterior wall(s) directly adjacent to the tub/shower enclosure.

RA3.5.4.1.3~~7~~ Special Situations--Obstructions

- Penetrations and obstructions to the insulation shall be completely caulked and sealed.
- Insulation shall fill between the sheathing and the rear of electrical boxes and phone boxes.

RA3.5.4.1.4~~8~~ Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-value as the adjacent walls.
- The insulation shall be installed without gaps and voids.

RA3.5.4.1.5~~9~~ Special Situations--Kneewalls, Skylight Shafts and Gable Ends

- Framing for kneewalls, skylight shafts and gable ends that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- For steel-framed kneewalls, skylight shafts, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of air permeable insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.

RA3.5.4.1.6~~10~~ Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in compliance documentation.

RA3.5.4.1.7 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.4.1.8 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.4.1.9 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.4.2~~11~~ Roof/Ceilings

- Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under the insulation. The required net free-ventilation shall be maintained.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Rigid board insulation installed above the roof deck shall be applied to the outer edge of the plane of the wall top plate.

RA3.5.4.2.1~~12~~ Special Situations--Enclosed Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing per California Building Code Section 1203.2 and R805.2, or as specified by the local building department.

RA3.5.4.2.2 Special Situations--Attics and Cathedral Ceilings

- In unvented attics, where insulation is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.
- In unvented attics where insulation is applied directly to the underside of the roof deck, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.4.2.3~~2~~13 Special Situations--HVAC Platform

- Insulation shall be placed below any platform or cat-walk for HVAC equipment installation and access.

RA3.5.4.2.4~~3~~14 Special Situations--Attic Access

- Permanently attach rigid board insulation or batt or blanket insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air leakage of conditioned air to the unconditioned attic.

RA3.5.4.3~~3.15~~ Raised Floors ~~and~~

- Rigid board insulation shall be in contact with the air barrier - usually the subfloor.

RA3.5.4.3.1 Homes w~~W~~ith Floors Over Garages~~

- Rigid board insulation shall be in contact with the air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.

RA3.5.4.3.2~~3.16~~ Homes with Conditioned Space Over Garage

- The floor over the garage shall be fully insulated with fully supported rigid board insulation against the subfloor of the conditioned space. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. All rim and band joists adjoining conditioned space shall be air tight and insulated.

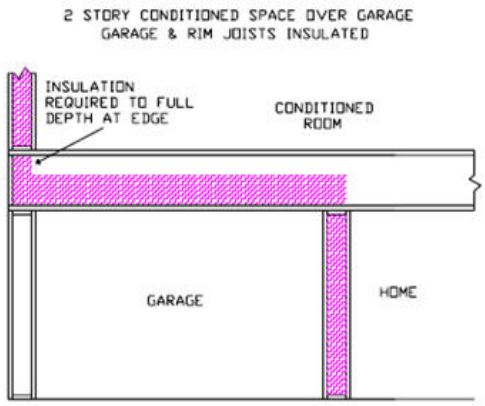

FIGURE 3

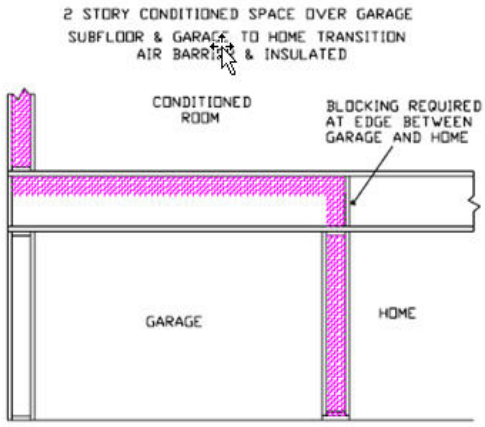

FIGURE 4

RA3.5.4.3.3~~17~~ Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

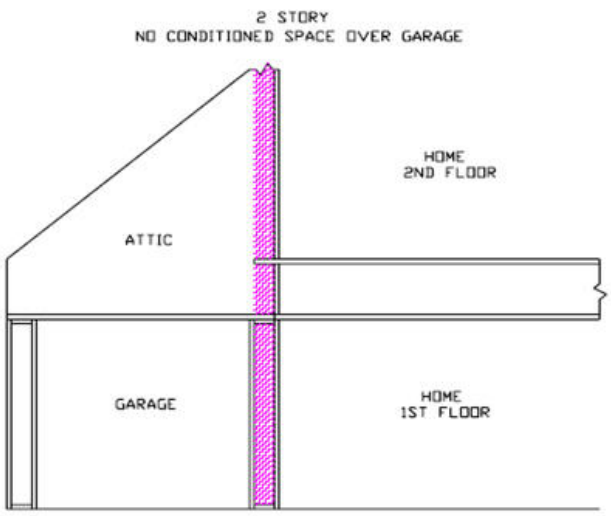

FIGURE 1

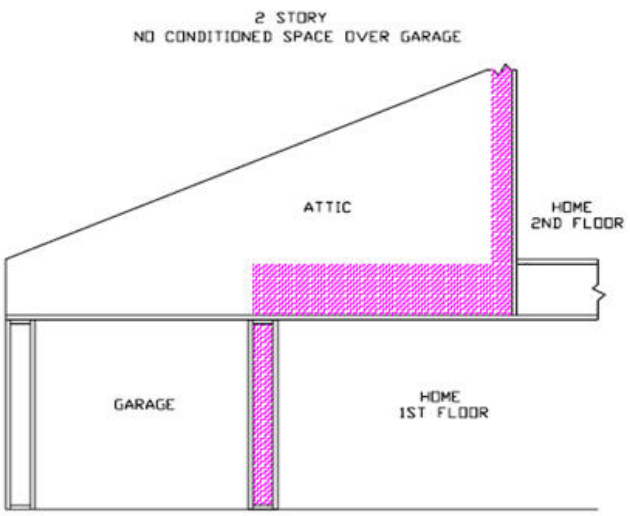

FIGURE 2

~~*RA3.5.4.18 R-value Measurement Equipment*~~

~~The HERS raters shall verify the installed thickness of insulation in all assemblies and locations on walls, roof/ceilings and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CR-6R.~~

~~*RA3.5.4.19 Certificates*~~

~~An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.~~

~~*RA3.5.4.20 Certificates and Availability*~~

~~The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.~~

RA3.5.5 SPRAY POLYURETHANE FOAM INSULATION ~~Spray Polyurethane Foam Insulation~~

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of spray polyurethane foam (SPF) insulation. These procedures must be field verified before the building construction permit is finalized in order to claim the QII energy compliance.

These procedures are to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c)13 and 110.7(a) and (b) of the Standards.

These procedures apply to two types of SPF used as building insulation: medium-density closed cell SPF (ccSPF) and low-density open cell SPF (ocSPF). Most often, the same procedures will apply to both ccSPF and ocSPF. However, in some construction situations the procedures will be different.

NOTE:

SPF insulation shall be field verified using these procedures whenever R-values other than the default R-value per inch are used for compliance (see *"R-value"* in sections RA3.5.5.0.1(a) and RA3.5.5.0.1(b) below).

RA3.5.5.0.1 Thermal Specification

RA3.5.5.0.1a ccSPF

A spray applied polyurethane foam insulation having a closed cellular structure resulting in an installed nominal density of 1.5 to less than 2.5 pounds per cubic foot (pcf).

R-value: The total R-value shall be calculated based on the nominal required thickness of the insulation multiplied by an R-value of 5.8 per inch. Alternatively, the total R-value may be calculated based on the thickness of insulation multiplied by the "tested R-value per inch" as listed in the Table of R-values or R-value Chart from the manufacturer's current ICC Evaluation Service Report (ESR) that shows compliance with *Acceptance Criteria for Spray-Applied Foam Plastic Insulation--AC377*.

Based on this calculation, the overall assembly U-factor shall be determined by selecting the assembly that matches the assembly type, framing configuration, and cavity insulation from the appropriate Reference Joint Appendix JA4 table. The R-value of ccSPF insulation shall meet or exceed the installed thickness specified in Table 1.

The R-value of the installed insulation shall be based on the verified thickness at an R-value of 5.8 per inch unless an ESR is provided with compliance documentation that verifies use of other values. Approved compliance software shall make appropriate adjustments to account for the R-value and U-factor effects of the ccSPF assembly.

Nominal Thickness: ccSPF sprayed into framed cavities or on flat surfaces will expand with variable thicknesses, visibly appearing as undulations on the surface of the insulation. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation's surface shall not be greater than 1/2-inch of the required thickness at any given point of the surface area being insulated.

Filling of Framed Assemblies: ccSPF insulation is not required to fill the cavities of framed assemblies provided the installed thickness of insulation conforms to compliance documentation and that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 2.0 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Air Barrier: ccSPF installed as an air barrier shall be a minimum of 2.0 inches in thickness; alternatively, ccSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m^2 at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.

RA3.5.5.0.1b ocSPF

A spray applied polyurethane foam insulation having an open cellular structure resulting in an installed nominal density of 0.4 to less than 1.5 pounds per cubic foot (pcf).

R-value: The total R-value shall be calculated based on the nominal required thickness of the insulation multiplied by an R-value of 3.6 per inch. Alternatively, the total R-value may be calculated based on the thickness of insulation multiplied by the "tested R-value per inch" as listed in the Table of R-values or R-value Chart from the manufacturer's current International Code Council (ICC) Evaluation Service Report (ESR) that shows compliance with *Acceptance Criteria for Spray-Applied Foam Plastic Insulation--AC377*.

Based on this calculation, the overall assembly U-factor shall be determined by selecting the assembly that matches the assembly type, framing configuration, and cavity insulation from the appropriate Reference Joint Appendix JA4 table. The R-value of ocSPF insulation shall meet or exceed the installed thickness specified in Table 1.

The R-value of the installed insulation shall be based on the verified thickness at an R-value of 3.6 per inch unless an ESR is provided with compliance documentation that verifies use of other values. Approved compliance software shall make appropriate adjustments to account for the R-value and U-factor effects of the ocSPF assembly.

Nominal Thickness: ocSPF sprayed into framed cavities or on flat surfaces will expand with variable thicknesses, visibly appearing as undulations on the surface of the insulation. The average thickness of the foam insulation must meet or exceed the required R-value. Depressions in the foam insulation surface shall not be greater than 1-inch of the required thickness provided these depressions do not exceed 10% of the surface area being insulated.

Filling of Framed Assemblies: ocSPF insulation shall completely fill cavities of 2x4 inch framing or less. Cavities greater than 2x4 inch framing dimensions may be filled to the thickness that meets the required R-value used for compliance provided that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 5.5 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Air Barrier: ocSPF installed as an air barrier shall be a minimum of 5.5 inches in thickness; alternatively, ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m^2 at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.

Table 1: Required Thickness (inches) of SPF Insulation to Achieve Specified R-values

Equivalent R-Values for SPF insulation	**11**	**13**	**15**	**19**	**21**	**22**	**25**	**30**	**38**
Required thickness of ccSPF insulation @ R5.8/inch	2.00	2.25	2.75	3.50	3.75	4.00	4.50	5.25	6.75
Required thickness of ocSPF insulation @ R3.6/inch	3.0	3.5	4.2	5.3	5.8	6.1	6.9	8.3	10.6

RA3.5.5.0.2 Requirements for Walls, Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread index and smoke developed index requirements of the CBC, Title 24, Part 2, Section 2603.5.4.
- The installer shall determine and the HERS rater shall verify that the manufacturer's nominal insulation thickness has been installed and certified and that all requirements of the Certificate of Field Verification and Diagnostic Testing (CF-4R) have been met.
- The installer shall determine and the HERS rater shall verify that insulation is in substantial contact with the assembly air barrier. When SPF insulation is being used to provide air barrier control, the SPF insulation must cove and be in contact with the entire surface of the framing, filling the cavity to a distance away from the framing specified in "Filling of Framed Assemblies" above.
- SPF insulation shall be applied by SPF applicators trained and experienced in the use and maintenance of high-pressure, plural-component equipment. SPF applicators shall be certified by the SPF insulation manufacturer for the application of SPF insulation systems.
- SPF insulation shall be spray-applied to fully adhere to assembly framing, floor and ceiling the joists, and other framing surfaces within the construction cavity. When multiple layers of SPF material are applied, each foam lift (i.e. spray application) shall have adhesion at substrate and foam interfaces. SPF insulation shall not exhibit areas that:
    - Have voids or gaps in the uniformity of the insulation
    - Are extremely soft or spongy
    - Show the presence of liquid
    - Have blistering between lifts
    - Show differences in coloration of adjacent foam layers
    - Indicate the presence of other materials between lifts
- SPF insulation shall be installed in conformance with the manufacturer's specifications, recommendations and temperature/humidity limitations.
- Substrates to which SPF insulation is applied shall be secure and free of surface moisture, frost, grease, oils, dirt, dust or other contaminants that would adversely affect SPF adhesion.
- SPF insulation shall meet all provisions of the California Building Code (CBC), Title 24, Parts 2 and 2.5. SPF shall be separated from occupied spaces by an approved thermal barrier, such as 0.5 inch gypsum wallboard or other approved material, or show equivalence through testing in accordance with CBC, Title 24, Part 2, Section 2603, and Part 2.5, Section R316.
- In unvented attics where SPF insulation is used to insulate roof and attic surfaces, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- ~~0.~~SPF insulation may be used as the air barrier provided it has been tested to conform to the air barrier performance conditions of the Standards.

- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- SPF shall not be applied directly to recessed lighting fixtures and left exposed. Recessed light fixtures insulated with SPF insulation shall be protected from ignition by a combination of one or more of the following methods: (1) be covered with a minimum of 1.5 inches of mineral fiber insulation, or (2) be enclosed in a box fabricated from 1/4 inch plywood, 18 gauge metal, 3/8inch hard board or gypboard. The exterior of the box may then be insulated with SPF provided: (1) the SPF insulation is covered with an approved ignition barrier coating tested and supported by an ICC Evaluation Services Report (ESR) or code compliance research report approved by the local agency; or (2) the exposed condition of the SPF insulation is supported by testing with an ICC ESR or research report approved by the local building department.

RA3.5.5.0.3~~4~~ R-value Measurement Equipment

- The HERS rater shall measure the installed thickness of insulation in at least 6 random locations on walls, roof/ceilings and floors (i.e., 6 measurements per opaque surface type: wall, roof/ceiling or floor) to ensure minimum thickness levels necessary to meet the R-value specified on the Certificate of Compliance, CF-1R and ~~CR-6R~~CF-6R ~~have been met~~. Measurement areas shall include low and high areas of the SPF insulated surface.
- Probes for inspection of installed thickness of SPF insulation. The insulation thickness shall be verified by using a probe, gauge or device capable of measuring the installed thickness of insulation. A pointed measurement probe or other gauge or device, capable of penetrating the full thickness of the insulation, shall be used having measurements marked by at least one-eighth inch increments. Insulation thickness measurement probes and gauges or devices shall be accurate to within ±1/8 inch and shall be designed and used in a manner to cause minimal damage to the insulation.

RA3.5.5.0.4~~5~~ Certificates

- All provisions of Residential Appendix RA2 shall be met. The~~An~~ Insulation Certificate (CF-6R) shall be signed by the SPF applicator ~~that~~ statinges that the installation is consistent with the plans and specifications for which the building permit was issued shall be provided. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, and that the labeled installed nominal thickness, and installed R-value for SPF insulation meets those specified in Section 3, Thermal Specification. The SPF applicator shall ~~also~~ also attach a R-value ~~C~~cmanufacturer's ~~coverage c~~hart or an ICC ESR showing compliance with AC377 for ~~Specification Sheet with insulation coverage information for every~~ each SPF insulation material used.

RA3.5.5.0.5~~6~~ Certificates and Availability

- All provisions of Residential Appendix RA2 shall be met. The CF-6R with complete information, signed by the SPF applicator, and a measuring probe or similar device shall be available at the building site for the HERS rater's verification inspection. Note: The HERS rater shall not verify compliance credit without these completed forms.

RA3.5.5.14 Wall Insulation

- SPF insulation shall be applied to provide an air-tight envelope to the outdoors and between adjoining cavity surfaces of conditioned and unconditioned space, such as the: attic, garage, and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates and bottom plate

framing, and electrical boxes that penetrate the sheathing and the sheathing seal to the top and bottom plate framing.

- Bottom plates of framed and non-framed assemblies shall be sealed to the ground subfloor or slab, and above ground subfloor.
- SPF insulation installation shall uniformly cover the cavity side-to-side and end-to-end and shall be installed to cover and form an air barrier on the framing at the top, bottom and sides of each cavity.

NOTE:

Filling of Framed Assemblies: ccSPF insulation is not required to fill the cavities of framed assemblies provided the installed thickness of insulation conforms to compliance documentation and that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 2.0 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Filling of Framed Assemblies: ocSPF insulation shall completely fill cavities of 2x4 inch framing or less. Cavities greater than 2x4 inch framing dimensions may be filled to the thickness that meets the required R-value used for compliance provided that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 5.5 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Air Barrier: ccSPF installed as an air barrier shall be 2.0 inches in thickness. ocSPF installed as an air barrier shall be a minimum of 5.5 inches in thickness. Alternatively, ccSPF and ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m^2 at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.

RA3.5.5.1.1~~5~~ Narrow-Framed Cavities

- Non-standard width cavities shall be filled with SPF insulation at a depth consistent with the SPF thickness required to achieve the specified R-value.
- Narrow spaces less than 1 inch in width at windows and door jambs, shall be filled with minimally expansive foam sealing material or SPF insulation.
- Narrow spaces less than 2 inches in width, such as between studs at building corners and at the intersection of interior partition walls, shall be filled with insulation snuggly fitted into the space, with minimally expansive foam, or SPF insulation.

RA3.5.5.1.2~~6~~ Special Situations--Installation Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities, such as corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. In most cases, this can only be completed prior to the installation of the tub/shower enclosure, the exterior sheathing, or the exterior stucco lath.
- An air barrier shall be installed on the inside of the exterior wall(s) directly adjacent to the tub/shower enclosure.

RA3.5.5.1.3~~7~~ Special Situations--Obstructions

- SPF insulation shall be applied to fully seal around wiring and plumbing.
- SPF insulation shall be applied to fully seal between the sheathing and the rear of electrical boxes and telephone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16), pipes shall have at least 2/3 of the insulation between the water pipe and the outside surface of the exterior wall. If the pipe is near the exterior finish assembly layers, as much insulation as possible shall be placed between the pipe and the exterior assembly material.

RA3.5.5.1.4~~8~~ Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.
- The insulation shall be installed without gaps or voids.

RA3.5.5.1.5~~9~~ Special Situations--Kneewalls, Skylight Shafts and Gable Ends

- Framing for kneewalls and skylight shafts that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- Kneewalls within conditioned space do not need to be insulated.
- For steel-framed kneewalls, skylight shafts, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of air permeable insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- Insulation for all kneewall and skylight shafts shall be completely enclosed by vertical and horizontal framing, including horizontal plates at top and bottom of the insulation.
- In unvented attics, where SPF is applied directly to the underside of the roof deck, all kneewalls, skylight shafts, and gable ends shall be insulated to the same R-value as the exterior walls and as specified in the compliance documentation.
- SPF insulation shall be installed without gaps.
- SPF insulation shall be fully adhered and self-supporting so that it will remain in place.

NOTE:

Filling of Framed Assemblies: ccSPF insulation is not required to fill the cavities of framed assemblies provided the installed thickness of insulation conforms to compliance documentation and that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 2.0 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Filling of Framed Assemblies: ocSPF insulation shall completely fill cavities of 2x4 inch framing or less. Cavities greater than 2x4 inch framing dimensions may be filled to the thickness that meets the required R-value used for compliance provided that the bottom and top plates of vertical framing and both ends of horizontal framing, including band and rim joists, are sprayed to completely fill the cavity adjacent to and in contact with the framing to a distance of 5.5 inches away from the framing for ocSPF insulation, or filled to the thickness meeting ASTM testing as an air barrier.

Air Barrier: ccSPF installed as an air barrier shall be 2.0 inches in thickness. ocSPF installed as an air barrier shall be a minimum of 5.5 inches in thickness. Alternatively, ccSPF and ocSPF insulation shall be installed at a thickness that meets an air permeance no greater than 0.02 L/s-m^2 at 75 Pa pressure differential when tested in accordance to ASTM E2178 or ASTM E283.

RA3.5.5.1.6~~10~~ Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment that require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.

RA3.5.5.1.7 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.5.1.8 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.4.1.9 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.5.~~12~~1 Roof/Ceilings

- SPF insulation shall be applied to fully adhere to the substrate of the ceiling or roof deck.
- SPF insulation shall be applied to fully adhere to the joist and other framing faces to form a complete air seal within the construction cavity.
- SPF insulation shall be spray-applied to fully adhere to and seal around wiring and plumbing.
- Hard covers shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers, they shall be in place before insulation is installed.
- In vented attics, required eave ventilation shall not be obstructed; the net free-ventilation area of the eave vent shall be maintained.
- In unvented attics where SPF is applied directly to the underside of the roof deck, all gable end areas shall be insulated to the same R-value as the walls and as specified on compliance documentation. It is not necessary to place hard covers over drop ceilings and interior wall cavities in this situation.
- All recessed light fixtures that penetrate the ceiling shall be IC rated and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- SPF insulation shall not be applied directly to recessed lighting fixtures. Recessed light fixtures must be either insulated with CBC approved materials (i.e., mineral fiber) or enclosed in a box fabricated from ½-inch plywood, 18 gauge sheet metal, 1/4-inch hard board, drywall or other approved materials. The exterior of the box may then be insulated with SPF. Fixtures that are not air tight and rated for insulation contact (IC) shall be removed and/or replaced.
- SPF insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue for clearance.

RA3.5.5.2.1~~2~~ Special Situations--Enclosed Rafter Ceilings

- Prior to installation, verify that the building official permits SPF insulation directly applied to the underside of the roof deck and/or allows unvented rafter spaces

RA3.5.5.2.3 Special Situations--Attics and Cathedral Ceilings

- Prior to installation verify that the building official permits SPF insulation to be directly applied to the underside of the roof.
- In vented and unvented attics where entry is made for the service of utilities, SPF applied in direct contact with the underside of the roof deck shall be protected from ignition in accordance with CBC, Part 2, Section 2603, and Part 2.5, Section R316.
- In unvented attics, where SPF is applied directly to the underside of the roof deck, all gable ends shall be insulated to the same R-value as the exterior walls and as specified in the compliance documentation.

- In unvented attics where SPF insulation is used to insulate roof and attic surfaces, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.5.2.4~~213~~ Special Situations--HVAC Platform

- A minimum of 3 inches of ccSPF insulation or 5.3 inches of ocSPF shall be placed below any platform or cat-walk access ways installed in vented attics for HVAC equipment or other needs. The overall assembly R-value shall meet the required R-values specified in the compliance documentation.

RA3.5.5.2.5~~314~~ Special Situations--Attic Access

- A minimum of 3 inches of ccSPF or 5.3 inches of ocSPF insulation shall be applied to the access door assuring good adhesion to the door surface. Alternatively, permanently attach rigid foam or batt insulation with adhesive or mechanical fastener. The overall assembly R-value shall meet the required values specified in the compliance documentation.

~~*2.4*~~RA3.5.5.~~16~~3 Raised Floors

- SPF insulation shall be spray-applied to fully adhere to the bottom side of the floor sheathing.
- SPF insulation ~~installation~~ shall uniformly cover the cavity side-to-side and end-to-end.

RA3.5.5.3.1 Homes w~~W~~ith~~and~~ Floors Over Garages~~~~

- SPF insulation shall be spray-applied to fully adhere to the bottom side of the floor sheathing.
- SPF insulation installation shall uniformly cover the cavity side-to-side and end-to-end.

RA3.5.5.3.2~~17~~ Homes with Conditioned Space Over Garage

- The floor over the garage shall be insulated by spraying SPF insulation to fully adhere to the subfloor of the conditioned space. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. SPF insulation shall cover any gaps between the header and the floor joist.

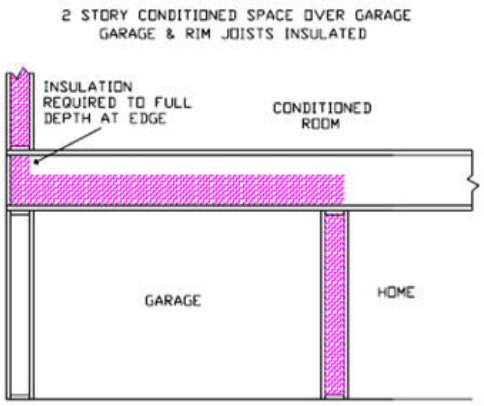

FIGURE 3

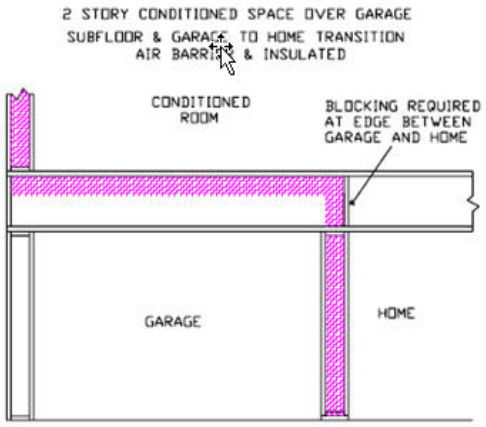

FIGURE 4

RA3.5.5.3.3~~18~~ Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

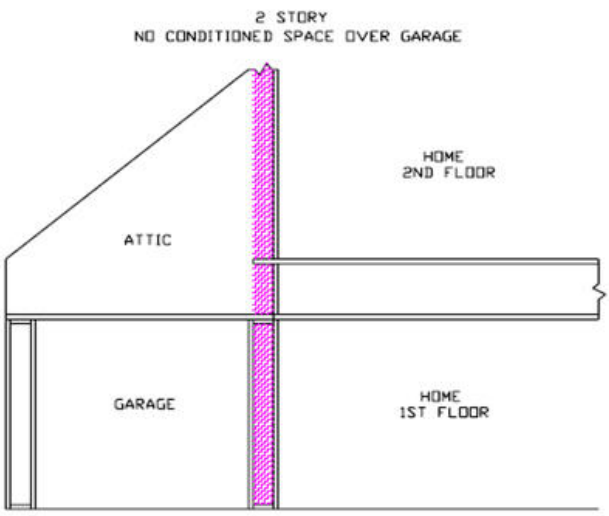

FIGURE 1

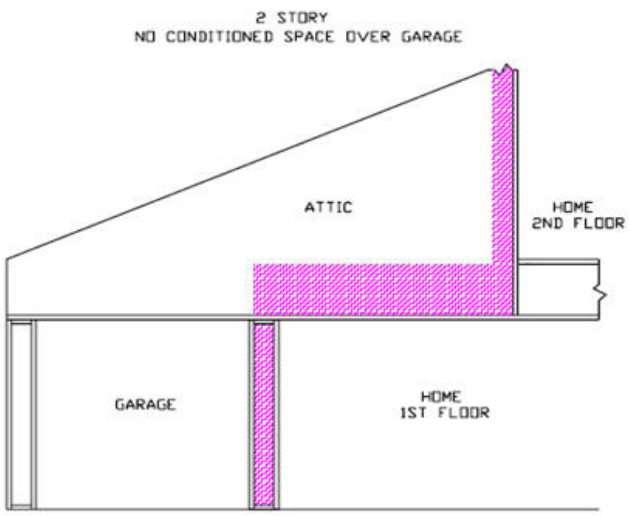

FIGURE 2

~~*RA3.5.53.19 R-value Measurement Equipment*~~

~~The HERS rater shall measure the installed thickness of insulation in at least 6 random locations on walls, roof/ceilings and floors (i.e., 6 measurements per opaque surface type: wall, roof/ceiling or floor) to ensure minimum thickness levels necessary to meet the R-value specified on the Certificate of Compliance, CF-1R and CR-6R have been met. Measurement areas shall include low and high areas of the SPF insulated surface.~~

~~Probes for inspection of installed thickness of SPF insulation. The insulation thickness shall be verified by using a probe, gauge or device capable of measuring the installed thickness of insulation. A pointed measurement probe or other gauge or device, capable of penetrating the full thickness of the insulation, shall be used having measurements marked by at least one-eighth inch increments. Insulation thickness measurement probes and gauges or devices shall be accurate to within ±1/8 inch and shall be designed and used in a manner to cause minimal damage to the insulation.~~

~~*RA3.5.5.20 Certificates*~~

~~All provisions of Residential Appendix RA2 shall be met. An Insulation Certificate (CF-6R) signed by the SPF applicator that states that the installation is consistent with the plans and specifications for which the building permit was issued shall be provided. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, and that the labeled installed nominal thickness, and installed R-value for SPF insulation meets those specified in Section 3, Thermal Specification. The SPF applicator shall also attach a manufacturer's coverage chart or Specification Sheet with insulation coverage information for every insulation material used.~~

~~*RA3.5.3.21 Certificates and Availability*~~

~~All provisions of Residential Appendix RA2 shall be met. The CF-6R with complete information, signed by the SPF applicator, and a measuring probe or similar device shall be available at the building site for the HERS rater's verification inspection. Note: The HERS rater shall not verify compliance credit without these completed forms.~~

RA3.5.2 Terminology

Air Barrier	An air barrier is needed in all thermal envelope assemblies to prevent air movement. Insulation, other than foam, is not designed to stop air movement. For insulation installed horizontally, such as in an attic, the insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-value. A wall or ceiling covering that has multiple leakage sites (such as 1 x 6 tongue and groove board ceilings) can not serve as an air barrier.
Air-tight	Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement can move unwanted heat and moisture through or into the assembly. For these procedures air-tight shall be defined as an assembly or air barrier with all openings greater than 1/8 inch caulked, or sealed with expansive or minimally expansive foam.
Excessive Compression	Batt insulation may be compressed up to 50 percent at obstructions such as plumbing vents and in non-standard cavities, but compression of more than 50 percent in any dimension is excessive and shall not be allowed. Where obstructions would cause the insulation to be compressed greater than 50 percent insulation shall be cut to fit around the obstruction.
Delaminated	Batts are often split or delaminated to fit around an obstruction. For example when an electrical wire runs through a wall cavity the insulation must still fill the area both in front of the wire and the area behind the wire. This is typically accomplished by delaminating the batt from one end and placing one side of the batt behind the wire and the other in front of the wire. The location of the delamination must coincide with the location of the obstruction. For example if the wire is one third of the distance from the front of the cavity the batt should be delaminated so that two thirds of the batt goes behind the wire and one third in front of the wire.
Draft Stops	Draft stops are installed to prevent air movement between wall cavities, other interstitial cavities - and the attic. They are typically constructed of dimensional lumber blocking, drywall or plywood. Draft stops become part of the attic air barrier and shall be air-tight. Fire blocks constructed of porous insulation materials cannot serve as draft stops since they are not air-tight.
Friction Fit	Friction fit batts are commonly used. Friction fit batts have enough side-to-side frictional force to hold the batt in place without any other means of attachment.
Gaps	A gap is an uninsulated area at the edge of or between batts. Gaps in insulation are avoidable and are not permitted.
Hard Covers	Hard covers shall be installed above areas where there is a drop ceiling. For example a home with 10 ft ceilings may have an entry closet with a ceiling lowered to 8 ft. A hard cover (usually a piece of plywood) is installed at the 10 ft. level above the entry closet. Hard covers become part of the ceiling air barrier and shall be air-tight.
Inset Stapling	In windy areas installers often staple the flanges of faced batts to the sides of the stud in order to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.
Net Free-Area	The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by the screen or louver. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.

~~Voids~~ ~~When batt insulation is pushed too far into a wall stud cavity a void is created between the front of the batt and the drywall. Batts shall be fully lofted and fill the cavity front to back. Small voids less than ¾ in. deep on the front or back of a batt shall be allowed as long as the total void area is not over 10 percent of the batt surface area. This definition shall not preclude the practice of inset stapling as long as the void created by the flange inset meets the specification in the definition of inset stapling. Improper spraying or blowing of insulation in ceilings and wall cavities can result in areas with insufficient insulation not meeting the specified installed density and R-value. Wall and cathedral ceiling cavity areas where cellulose insulation has fallen away shall be filled with insulation. Depressions in netting or material supporting blown insulation in walls and cathedral ceilings shall be filled with insulation.~~

RA3.5.6 STRUCTRUAL INSULATED PANEL (SIP)

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of Structural Insulated Panel (SIP) systems. These procedures must be field verified before the building construction permit is finalized in order to claim QII energy compliance.

These procedures are to be followed by the SIP installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c)13 and 110.7(a) and (b) of the Standards.

RA3.5.4.0.1 Thermal Specification

This insulation type is a composite building material manufactured with an internal insulating layer of rigid insulation of sheet or board material, or from cured spray polyurethane foam insulation material. The internal insulation is sandwiched between two layers of structural board, usually referred to as a "panel." The result is "panelized" construction versus traditional framed construction. SIPs combine several components of conventional building, such as studs and joists, insulation, vapor retarder and air barrier. They can be used for different applications, such as exterior walls, roofs, and floors. Examples of common SIP sizes are panels ranging in length from 4x8 feet to 4x24 feet and having core thickness of 3 1/2 inches to 11 1/5 inches, depending on the manufacturer. Panels are typically cut at the manufacturing facility to precisely fit the building's design characteristics. Openings for windows and doors are cut into one or more panels, and often small chases are provided within the internal insulation for electrical wiring and plumbing.

SIPs can be used for the entire building envelope or for individual assemblies, such as for just walls or just floors. In these situations, the SIP system will used in conjunction with other traditional insulation materials installed within cavities of framed assemblies. The R-value of a SIP is dependent on the type of material used internally for insulation and the overall thickness of the panel. Specific product R-values are readily available from the manufacturer and for the specific materials being installed. The R-value of the product is typically marked on the product. The installed insulation must meet the R-value stated on the compliance documentation.

RA3.5.4.0.2 Requirements for Walls, Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.

- Materials shall be installed according to manufacturer specifications and instructions.
- SIP systems are considered an air barrier; however extension of the air barrier shall be made across all interconnections of panels, at window and door openings, and at all adjoining surfaces of different panel areas (i.e., where SIP walls adjoin the floor and roof/ceiling).
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement if present (i.e., traditional framed attics). If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- In traditional framed attics, required eave ventilation shall not be obstructed for conventional attics - the net free-ventilation area of the eave vent shall be maintained. Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation of conventional attics.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.6.0.3 R-value Measurement Equipment

- The HERS raters shall verify the installed thickness of insulation in all SIP panels and locations on walls, roof/ceilings, and floors, and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CF-6R.

RA3.5.6.0.4 Certificates

- An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, SIP manufacturer's name and material identification, and the installed R-value. The SIP installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.

RA3.5.6.0.5 Certificates and Availability

- The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the SIP installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.5.6.1. Wall Insulation

- Connections of wall panels shall be sealed, caulked, foamed, or taped (i.e., SIP tape) to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. All plumbing and wiring penetrations through the top and bottom of panels, and electrical boxes that penetrate the SIP sheathing shall be sealed. All gaps in the air barrier shall be caulked, or sealed with minimally expansive foam or taped (i.e., SIP tape).
- Bottom connections of wall panels shall be sealed to the ground subfloor or slab, and above ground subfloor.
- Insulation shall uniformly fit across the plane of the wall and taping (i.e., SIPs tape), caulking or sealing of all joints and seams of panel joints (i.e., spline connections) shall be maintained to be considered as the air barrier.

RA3.5.6.1.1 Special Situations--Obstructions

- Penetrations and obstructions to the SIP shall be completely caulked and sealed.
- Insulation shall fill between the sheathing and the rear of electrical boxes and phone boxes.

RA3.5.6.1.2 Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-value as the adjacent walls.
- The insulation shall be installed without gaps and voids.

RA3.5.6.1.3 Special Situations--Kneewalls, Skylight Shafts and Gable Ends

- Framing for~~All~~ kneewalls, skylight shafts~~,~~ and gable ends that separate conditioned from unconditioned ~~shall~~space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- For steel-framed kneewalls, skylight shafts~~,~~, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of air permeable insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.

RA3.5.6.1.4 Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in compliance documentation.

RA3.5.6.1.5 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.6.1.6 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.6.1.7 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.6.2 Roof/Ceilings

- Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under the insulation. The required net free-ventilation shall be maintained.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.

RA3.5.6.2.1 Special Situations--Attics and Cathedral Ceilings

- In unvented attics, where SIPs are the insulated roof structure, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.

- In unvented attics, where SIPs are the insulated roof structure, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.6.2.2 Special Situations--HVAC Platform

- Insulation shall be placed below any platform or cat-walk for HVAC equipment installation and access.

RA3.5.6.2.3 Special Situations--Attic Access

- Permanently attach rigid board insulation, batt or blanket insulation, or SIP with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air leakage of conditioned air to the unconditioned attic.

RA3.5.6.3 Raised Floors

- SIPs air barrier shall be maintain through use of SIPs tape, or sealing and caulking between panels and at al spline joints.

RA3.5.6.3.1 Homes with Floors Over Garage

- On floors that are over garages, the rim joist shall be insulated.

RA3.5.6.3.2 Homes with Conditioned Space Over Garage

- The floor over the garage shall be insulated. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. All rim and band joists adjoining conditioned space shall be air tight and insulated.

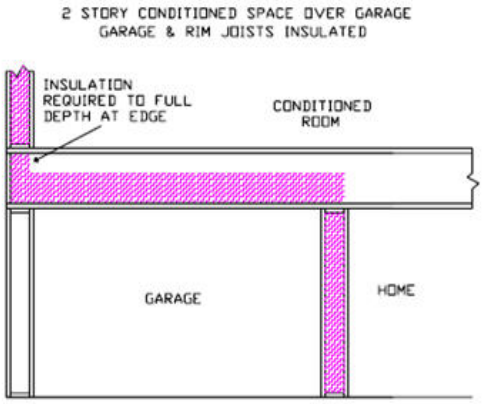

FIGURE 3

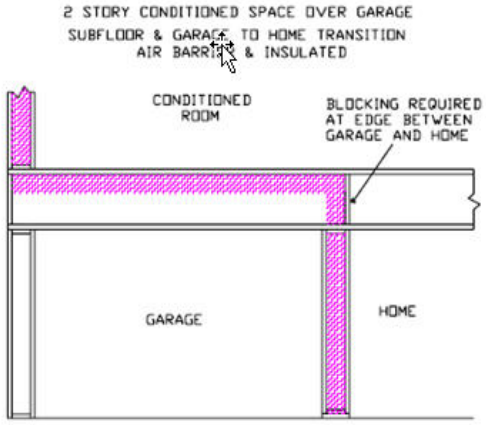

FIGURE 4

RA3.5.6.3.3 Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

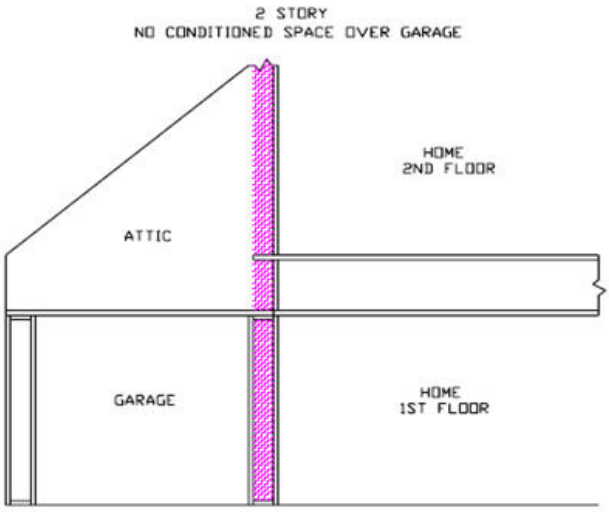

FIGURE 1

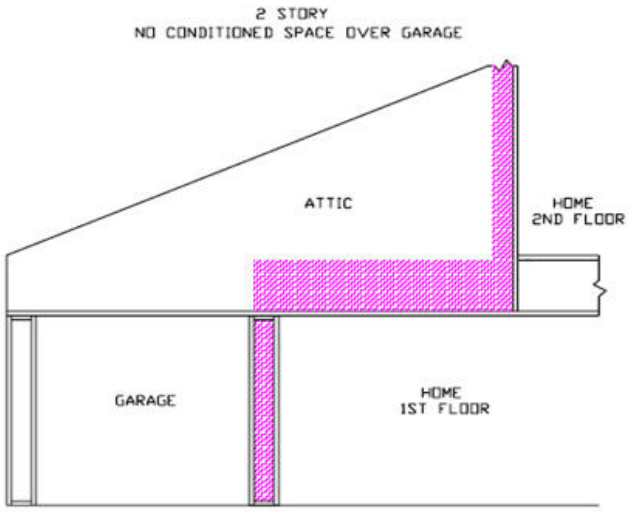

FIGURE 2

RA3.5.7 INSULATED CONCRETE FORM (ICF)

These procedures detail the installation and inspection protocols necessary to qualify for Quality Insulation Installation (QII) of insulated concrete forms (ICFs). These procedures must be field verified before the building construction permit is finalized in order to claim QII energy compliance.

These procedures are to be followed by the insulation installer and a qualified Home Energy Rating System (HERS) rater must verify its conformance for meeting the requirements of Sections 150.1(c)13 and 110.7(a) and (b) of the Standards.

RA3.5.7.0.1 Thermal Specification

Conventional concrete and concrete masonry unit (CMU) walls, floors and roofs can be insulated on the inside, on the outside, or have insulation between two layers of concrete (i.e., sandwich panel walls/block walls). ICFs are typically single forming masonry blocks with insulation to improve the thermal resistance of the material. ICFs are manufactured in conventional CMU dimensions of 6 inch, 8 inch, 10 inch, and larger widths. Insulated concrete forms (ICFs) typically haves a layer of ~~rigid foam i~~insulation located~~on~~: (1) within the inner core of the concrete masonry unit; or, (2) on one or all sides surrounding an inner core of concrete. ~~the outside, a layer of concrete in the middle, and a second layer of foam on the inside. Some ICF systems may have an integral layer of insulation within the core of the two outer layers of the concrete/masonry block. ICFs are typically single forming masonry blocks of rigid foam insulation material produced in 6 inch, 8 inch, 10 inch, and larger widths.~~

A similar type of insulated concrete form system is autoclaved aerated concrete (AAC) which has an air void matrix rather than sand and gravel commonly used in conventional concrete. The density range of AAC is 30 to 50 pounds per cubic foot (pcf) compared to conventional concrete used with ICFs with a density of approximately 80 to 140 pounds per cubic foot (pcf).

The R-value of ICFs is dependent on the type of insulation material used and its thickness. Insulation used within the inner core of ICFs can be: (1) poured-in-place vermiculite or perlite; (2) foamed-in-place spray polyurethane foam insulation material; or, (3) standard molded insulation inserts of rigid board insulation material. Insulation used to makeup one or more of the outer layers of the ICF is a rigid board insulation material. Specific product R-values are readily available from the manufacturer for the specific materials being installed. R-value of the product is typically marked on the product. The installed insulation must meet the R-value stated on the compliance documentation.

RA3.5.7.0.2 Requirements for Walls, Ceilings and Floors

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Part 12, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.
- ICF systems are considered an air barrier; however extension of the air barrier shall be made across all interconnections of window and door openings, and at all adjoining surfaces of exterior envelope assemblies of different materials (i.e., where ICF walls adjoin framed floors and roof/ceilings).
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement if present (i.e., traditional framed attics). If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- In traditional framed attics, required eave ventilation shall not be obstructed for conventional attics - the net free-ventilation area of the eave vent shall be maintained. Eave vent baffles shall be installed to prevent air movement under or into the ceiling insulation of conventional attics.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.7.0.3 R-value Measurement Equipment

- The HERS raters shall verify the installed type and thickness of insulation in the ICF system being used for walls, roof/ceilings, and floors, and to ensure that insulation levels and installation integrity meet the R-value specified on the Certificate of Compliance, CF-1R and CF-6R.

RA3.5.7.0.4 Certificates

- An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, ICF manufacturer's name and material identification, and the installed R-value. The ICF installer shall also complete the applicable sections of the Installation Certificate form and attach a product specification or data sheet for every insulation material used.

RA3.5.7.0.5 Certificates and Availability

- The Insulation Installation Certificate (CF-6R), with insulation material labels or specification/data sheets attached, signed by the SIP installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.5.7.1. Wall Insulation

- Connections of ICF walls shall be grouted and sealed meeting manufacturer's specifications. All plumbing and wiring penetrations through the top and bottom of the ICF, and electrical boxes that penetrate the plane of the ICF shall be sealed. All gaps between interconnecting envelope assemblies of different materials shall have air barrier caulked, or sealed with minimally expansive foam or taped (i.e., SIP tape).

- Bottom connections of ICFs shall be sealed to the ground subfloor or slab, and above ground subfloor.
- Insulation shall uniformly fit across the plane of the wall and taping, caulking or sealing of all joints and seams of the ICF shall be maintained to be considered as the air barrier.

RA3.5.7.1.1 Special Situations--Obstructions

- Penetrations and obstructions to the ICF shall be completely caulked and sealed.
- Insulation shall fill between the sheathing and the rear of electrical boxes and phone boxes.

RA3.5.7.1.2 Special Situations--Rim Joists

- All rim-joists shall be insulated to the same R-value as the adjacent walls.
- The insulation shall be installed without gaps and voids.

RA3.5.7.1.3 Special Situations--Kneewalls, Skylight Shafts and Gable Ends

- Framing for kneewalls, skylight shafts and gable ends that separate conditioned from unconditioned space shall be insulated to meet or exceed the wall R-value specified on the Certificate of Compliance, CF-1R and CF-6R.
- For steel-framed kneewalls, skylight shafts, and gable ends, external surfaces of steel studs shall be covered with batts or blankets, or rigid board insulation unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The backside of air permeable insulation exposed to the unconditioned attic space shall be completely covered with rigid board insulation or an air barrier.

RA3.5.7.1.4 Special Situations--HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls as specified in compliance documentation.

RA3.5.7.1.5 Special Situations--Double Walls and Framed Bump-Outs

- Insulation shall fill the entire cavity; or, an additional air barrier shall be installed inside the double wall or bump-out and in contact with the insulation so that the insulation fills the cavity formed with the additional air barrier.
- Entire double walls and framed bump-outs shall be air tight.

RA3.5.7.1.6 Special Situations--Structural Bracing, Tie-downs, Steel Structural Framing

- Framing and bracing used for structural purposes shall be identified on plan documents with diagrams and/or design drawings.
- Insulation shall be installed in a manner that restricts thermal bridging through the structural framing assembly.
- Insulation shall be applied to fully enclose and/or adhere to all sides and ends of structural assembly framing.
- The structural portions of assemblies shall be air-tight.

RA3.5.7.1.7 Special Situations--Window and Door Headers

- All window and door headers shall be insulated to a minimum of R-2 between the exterior face of the header and inside surface of the finish wall material.

RA3.5.7.2 Roof/Ceilings

- Baffles shall be placed at eaves or soffit vents of vented attics to keep insulation from blocking eave ventilation and prevent air movement under the insulation. The required net free-ventilation shall be maintained.

- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.

RA3.5.7.2.1 Special Situations--Attics and Cathedral Ceilings

- In unvented attics, where ICFs are the insulated roof structure, all gable ends shall be insulated to the same R-value as the exterior walls as specified in the compliance documentation.
- In unvented attics, where ICFs are the insulated roof structure, and fuel burning appliances are present (i.e., gas furnace, water heater), the HERS rater shall verify the appliance manufacturer's allowance for the equipment's use in unvented applications.

RA3.5.7.2.2 Special Situations--HVAC Platform

- Insulation shall be placed below any platform or cat-walk for HVAC equipment installation and access.

RA3.5.7.2.3 Special Situations--Attic Access

- Permanently attach rigid board insulation, batt or blanket insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air leakage of conditioned air to the unconditioned attic.

RA3.5.7.3 Raised Floors

- The outer and inner face, and all joints of the ICF air barrier shall be maintain through use of tape, or sealing and caulking as needed.

RA3.5.7.3.1 Homes with Floors Over Garage

- On floors that are over garages, the rim joist shall be insulated.

RA3.5.7.3.2 Homes with Conditioned Space Over Garage

- The floor over the garage shall be insulated. The garage and the adjacent conditioned space (house) shall be insulated up to the subfloor. All rim and band joists adjoining conditioned space shall be air tight and insulated.

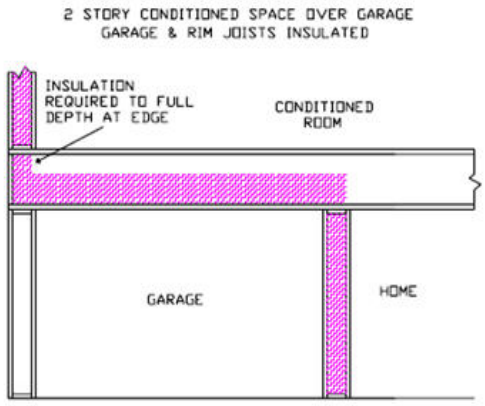

FIGURE 3

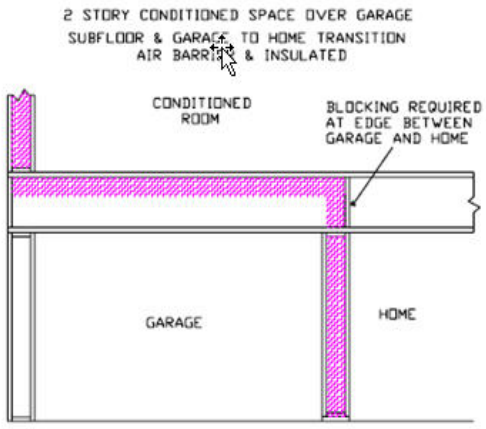

FIGURE 4

RA3.5.7.3.3 Homes with No Conditioned Space Over Garage

- The band joist where the garage transitions to an attic above conditioned space shall have an air barrier installed in contact with the edge of the attic insulation.

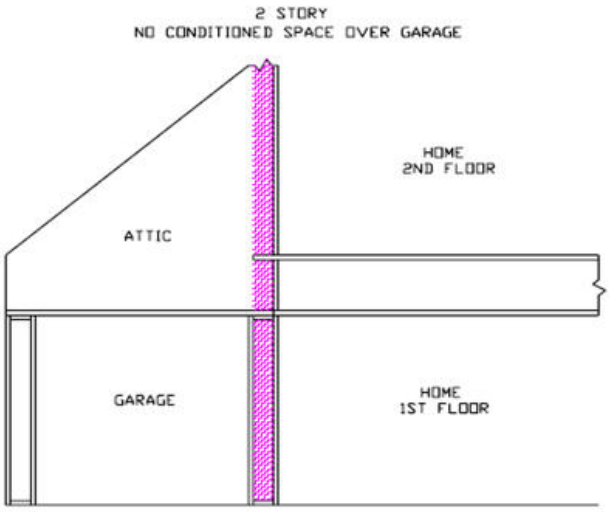

FIGURE 1

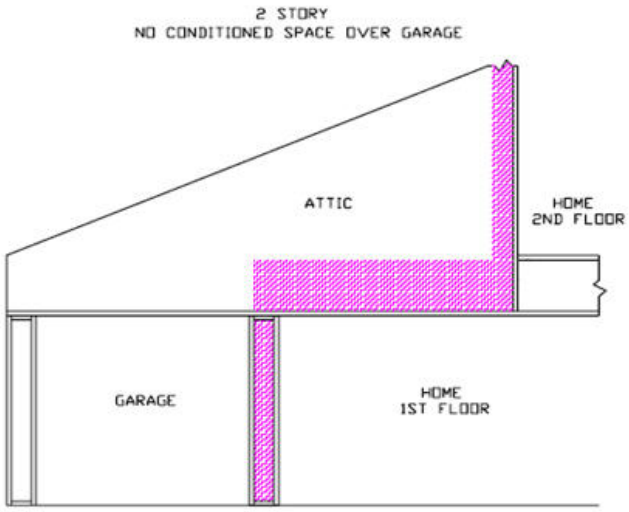

FIGURE 2

~~Core insulation refers to insulation placed into the inner cores of a concrete masonry unit. A variety of nsulationmaterials may be used for this purpose. Three types of insulation may be used to fill the concrete block core as follows:4 poured-in-place; 4 foamed-in-place; and 4 standard molded inserts.~~

~~Concrete/masonry construction and ICF systems are exclusively used for above and below grade wall systems. the buffering effect of the concrete helps to reduce and delay the onset of peak temperatures.~~

~~RA3.5.3 Ideally, insulation in external walls should be placed behind the concrete inner leaf (e.g. in the cavity), and the insulation in ground floors is located below the slab. Beyond this, the simple rule is that, as far as practicable, the surface of the concrete should be left thermally exposed by using finishes such as paint, tiles or wet plaster. A simple rule-ofthumb is that the mass must be 'visible' to the internal heat source to be effective.Raised Floors and Floors Over Garages~~

- **~~Batts shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.~~**
- **~~Batts shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.~~**
- **~~Insulation shall be in contact with an air barrier - usually the subfloor.~~**
- **~~On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.~~**
- **~~Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.~~**
- **~~If the insulation is faced, the facing shall be placed toward the living space and be in contact with the underside of the floor sheathing. Continuous support shall be provided to keep the facing in contact with the floor sheathing. Filling the entire cavity with insulation and providing support with netting at the bottom of the framing is one acceptable method.~~**
- **~~Insulation shall be properly supported to avoid gaps, voids, and compression.~~**

RA3.5.4 Wall Insulation

RA3.5.4.1 Batt Installation

- **Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate. All gaps in the air barrier greater then 1/8 inch shall be caulked, or sealed with expansive or minimally expansive foam.**
- **Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.**
- **The batt shall be friction fitted into the cavity unless another support method is used.**
- **Batt insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.**
- **Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.**
- **Non-standard-width cavities shall be filled with insulation fitted into the space without excessive compression.**
- **Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.**

RA3.5.4.2 Narrow-Framed Cavities

- **Non-standard width cavities ¼ inch or wider shall be filled by batt insulation cut to snuggly fit into the space or filled with loose fill insulation or expanding foam.**
- **Narrow spaces (two inches or less) at windows, between studs at the building's corners, and at the intersections of partition walls shall be filled with batt insulation snuggly fitted into the space (without excessive compression), loose fill insulation, or expansive or minimally expansive foam.**

RA3.5.4.3 Special Situations

RA3.5.4.3.1 Installations Prior to Exterior Sheathing or Lath

- **Hard to access wall stud cavities such as;0 corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. Special care shall be taken to insure the above cavities are air tight. This may have to be done prior to the installation of the exterior sheathing or the stucco lath.**

RA3.5.4.3.2 Obstructions

- **Insulation shall be cut to fit around wiring and plumbing without compression.**
- **Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.**
- **In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least 2/3 of the insulation between the water pipe and the outside. If the pipe is near the outside, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the inside.**

RA3.5.4.3.3 Rim Joists

- **All rim-joists shall be insulated to the same R-Value as the adjacent walls.**

- The insulation shall be installed without gaps or excessive compression.

RA3.5.4.3.4 Kneewalls and Skylight Shafts

- All kneewalls and skylight shafts shall be insulated to a minimum of R-19.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls and skylight shafts, external surfaces of steel studs shall be covered with batts or rigid foam unless otherwise specified on the Certificate of Compliance using correct U-factors from Joint Appendix JA4, Table 4.3.4 (or U-factors approved by the Commission Executive Director).
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either fitting to the framing, stapling in place with minimal compression, or using other support such as netting.

RA3.5.4.3.5 HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, which require combustion air venting, shall be insulated to the same R-value as the exterior walls.

RA3.5.4.3.6 Loose Fill Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate. All gaps in the air barrier greater then 1/8 inch shall be caulked, or sealed with expansive or minimally expansive foam.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- Loose fill insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Loose fill wall insulation shall be installed to fit around wiring, plumbing, and other obstructions.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.

RA3.5.5 Ceiling and Roof Insulation

RA3.5.5.1 Batt Insulation

RA3.5.5.1.1 General Requirements

- Batts shall be correctly sized to fit snugly at the sides and ends.
- Batts shall be installed so that they will be in contact with the air barrier.
- Where necessary, batts shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batts are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without excessive compression.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts that are taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.

- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RA3.5.5.1.2 Special Situations

RA3.5.5.1.2.1 ***Rafter Ceilings***

- An air space shall be maintained between the insulation and roof sheathing if required by California Building Code section 1203.2.
- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RA3.5.5.1.2.2 ***HVAC Platform***

- Appropriate batt insulation shall be placed below any plywood platform or cat-walks for HVAC equipment installation and access.
- Batts shall be installed so that they will be in contact with the air barrier.

RA3.5.5.1.2.3 ***Attic Access***

- Permanently attach rigid foam or batt insulation with the appropriate R-value to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be gasketed to prevent air movement.

RA3.5.5.2 *Loose-Fill Ceiling Insulation*

RA3.5.5.2.1.1 ***General Requirements***

- Baffles shall be placed at eaves or soffit vents to keep insulation from blocking eave ventilation. The required net free-ventilation shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the loose-fill insulation
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed or the entire drop area shall be filled with loose-fill insulation level with the rest of the attic.
- Attic rulers appropriate to the material installed shall be evenly distributed throughout the attic to verify depth: one ruler for every 250 square feet and clearly readable from the attic access. The rulers shall be scaled to read inches of insulation and the R-value installed.
- Insulation shall be applied underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.

- Insulation shall cover recessed lighting fixtures. If the fixtures are not rated for insulation cover (IC) and air tight, the fixtures shall be replaced.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.
- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and weight-per-square-foot.
- The installer shall certify on the Installation Certificate forms that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The HERS rater shall verify that the manufacturer's minimum weight-per-square-foot requirement has been met for attics insulated with loose-fill mineral-fiber insulation. Verification shall be determined using the methods of the Insulation Contractor's Association of America (ICAA) Technical Bulletin #17 except that only one sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record the weight-per-square-foot of the sample on the Certificate of Field Verification and Diagnostic Testing (CF-6R).
- The HERS rater shall verify that the manufacturer's minimum insulation thickness has been installed. For cellulose insulation this verification shall take into account the time that has elapsed since the insulation was installed. At the time of installation, the insulation shall be greater than or equal to the manufacturer's minimum initial insulation thickness. If the HERS rater does not verify the insulation thickness at the time of installation, and if the insulation has been in place less than seven days, the insulation thickness shall be greater than the manufacturer's minimum required thickness at the time of installation less 1/2 inch to account for settling. If the insulation has been in place for seven days or longer, the insulation thickness shall be greater than or equal to the manufacturer's minimum required settled thickness.

RA3.5.5.2.2 Special Situations

RA3.5.5.2.2.1 ***Kneewalls and Skylight Shafts:***

- Kneewalls and skylight shafts shall be insulated to a minimum of R-19. If loose fill insulation is used it shall be properly supported with netting or other support material.

RA3.5.5.2.2.2 ***HVAC Platform***

- Pressure-fill the areas under any plywood platform or walks for HVAC equipment installation and access or verify that appropriate batt insulation has been installed.

RA3.5.5.2.2.3 ***Attic Access***

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener. The bottom of the attic access shall be properly gasketed to prevent air movement.

RA3.5.6 Materials

- Materials shall comply with, and be installed in conformance with, all applicable building codes for building. California Building Code (including, but not limited to, California Electric Code Section 719) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.

- Materials shall comply with flame spread rating and smoke density requirements of Chapter 26 and Section 706 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.

RA3.5.7 Equipment

- Scales - The scales used to weigh density samples shall be accurate to within plus or minus 0.03 pounds and calibrated annually.

RA3.5.8 R-Value and U-Value Specifications

See the Certificate for Compliance (CF-1R) for minimum R-value requirements; Refer to Reference Joint Appendix JA4 for construction assemblies.

RA3.5.9 Certificates

An Insulation Installation Certificate (CF-6R) signed by the insulation installer shall be provided that states the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of loose-fill insulation, the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-Value, and the number of inches required to achieve the desired R-Value. The insulation installer shall also complete the applicable sections of the Installation Certificate form and attach a bag label or a manufacturer's coverage chart for every insulation material used.

RA3.5.10 Certificate Availability

The Insulation Installation Certificate (CF-6R), with insulation material bag labels or coverage charts attached), signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

RA3.6 Field Verification and Diagnostic Testing of Photovoltaic Systems

RA3.6.1 Purpose and Scope

The field verification and diagnostic testing procedures in this Appendix are intended to ensure that the:

- PV modules and inverters used in the expected performance calculations are actually installed at the applicable site;
- PV modules are minimally shaded, or if shaded, that the actual shading does not exceed the shading characteristics were included in the expected performance calculations; and
- Measured output power from the system matches that expected by the PV Calculator within the specified margin at the prevailing conditions at the time of field verification and diagnostic testing.

This is required to comply with the NSHP Compliance Option as explained in the Residential ACM Manual Appendix B. The actual protocol is included in Appendix 4 of the New Solar Homes Partnership Guidebook (most current version, available at http://www.gosolarcalifornia.ca.gov/documents/index.html).

RA3.7 Field Verification and Diagnostic Testing of Mechanical Ventilation Systems

RA3.7.1 Purpose and Scope

RA3.7 contains procedures for measuring the airflow in mechanical ventilation systems to confirm compliance with the requirements of ASHRAE 62.2.

RA3.7 applies to mechanical ventilation systems in low-rise residential buildings.

RA3.7 provides required procedures for installers, HERS raters and others who need to perform field verification of mechanical ventilation systems.

Table RA3.7-1 – Summary of Verification and Diagnostic procedures

Diagnostic	Description	Procedure
Whole-Building Mechanical Ventilation Airflow	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	RA7.4.1 Continuous Operation
Whole-Building Mechanical Ventilation Airflow	Verify that whole-building ventilation system complies with the airflow rate required by ASHRAE Standard 62.2.	RA7.4.2.Intermittent Operation

RA3.7.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RA3.7.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of plus or minus 1% of pressure reading or 0.2 Pa (whichever is greater). All pressure measurements within the duct system shall be made with static pressure probes Dwyer A303 or equivalent.

RA3.7.2.2 Airflow Measurements

All measurements of distribution fan airflows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 10% of reading.

RA3.7.2.3 Calibration

All instrumentation used for mechanical ventilation system airflow diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the accuracy requirement specified in Section RA3.7.2.2.

RA3.7.3 Diagnostic Apparatus for Measurement of Ventilation System Airflow

The apparatus for ventilation airflow measurements shall consist of a flow measurement device meeting the specifications in Section RA3.7.2.

RA3.7.3.1 Residential Mechanical Exhaust Airflow Measurement Device

A flowmeter that meets the applicable instrument accuracy specifications in RA3.7.2 shall be used to measure the mechanical ventilation airflow.

RA3.7.3.2 Powered Flow Capture Hood Airflow Measurement Device

A powered flow capture hood approved for use by the Energy Commission that has the capability to balance the flow capture inlet static pressure to 0 pa and meets the specifications in Section RA3.7.2 may be used to verify the fan flow at the return Grille(s) if the device has a flow capture area at least as large as the return grille in all dimensions. All supply registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RA3.7.4 Procedures

This section describes the procedures used to verify Mechanical ventilation system airflow.

RA3.7.4.1 Whole-Building Mechanical Ventilation Airflow - Continuous Operation

RA3.7.4.1.1 Exhaust Ventilation Systems

A flow measuring device that meets the applicable requirements of Section RA3.7.2 shall be used. If the measured airflow is equal to or greater than the value for whole-building ventilation airflow rate required by Section 4 of ASHRAE Standard 62.2, the mechanical ventilation system complies with the requirement for whole-building mechanical ventilation airflow. If the measured airflow is less than the required whole-building ventilation airflow rate, the mechanical ventilation system does not comply, and corrective action shall be taken.

RA3.7.4.1.2 Supply Ventilation Systems

The Executive Director may approve supply mechanical ventilation systems, devices, or controls for use for compliance with the HERS Rater field verification and diagnostic testing requirement for whole-building mechanical ventilation airflow, subject to a manufacturer providing sufficient evidence to the Commission that the installed mechanical ventilation systems, devices, or controls will provide at least the minimum whole-building ventilation airflow required by ASHRAE Standard 62.2, and subject to consideration of the manufacturer's proposed field verification and diagnostic test protocol for these ventilation system(s).

Approved systems, devices, or controls, and field verification and diagnostic test protocols for Supply Ventilation Systems shall be listed in directories published by the Energy Commission.

RA3.7.4.2 Whole-Building Mechanical Ventilation Airflow - Intermittent Operation

The Executive Director may approve intermittent mechanical ventilation systems, devices, or controls for use for compliance with the HERS Rater field verification and diagnostic testing requirement whole-building mechanical ventilation airflow, subject to a manufacturer providing sufficient evidence to the Commission that the installed mechanical ventilation systems, devices, or controls will provide at least the minimum whole-building ventilation airflow required by ASHRAE Standard 62.2, and subject to consideration of the manufacturer's proposed field verification and diagnostic test protocol for the ventilation system(s).

Approved systems, devices, or controls, and field verification and diagnostic test protocols for intermittent mechanical ventilation systems shall be listed in directories published by the Energy Commission.

RA3.8 Field Verification and Diagnostic Testing of Building Air Leakage

RA3.8.1 Purpose and Scope

The purpose of this test procedure is to measure the air leakage rate through a building enclosure measured in cubic feet per minute at a 50 Pa pressure difference (CFM50). The measurement procedure described in this section is derived from RESNET Mortgage Industry National Home Energy Rating Standards, Standard 800, which is based on ASTM E779 air tightness measurement protocols. This procedure requires the use of ASTM E779. This test method is intended to produce a measure of the air tightness of a building envelope for determining the energy credit allowance for reduced building air leakage.

These procedures shall be used to verify the building air leakage rate before the building construction permit is finalized when an energy credit for reduced air leakage is being claimed on compliance documentation.

- The HERS rater shall measure the building air leakage rate to ensure measured air leakage is less than or equal to the building air leakage rate stated on the Certificate of Compliance, CF-1R and CF-6R. HERS verified building air leakage shall be documented on form CF-4R-ENV-20.

RA3.8.2 On-Site Inspection Protocol

There are three acceptable air leakage test procedures:

RA3.8.2.1 Single-Point Test: Measuring air leakage one time at a single pressure difference as described in Section RA3.8.6.

RA3.8.2.2 Multi-Point Test: Measuring air leakage at multiple induced pressures differences as described in Section RA3.8.7.

RA3.8.2.3 Repeated Single-Point Test: This test is similar to the single-point test, but the test is done multiple times for improved accuracy and estimating uncertainty as described in Section RA3.8.8.

The building may be tested by applying a positive or negative pressure. Follow all manufacturers' instructions for set up and operation of all equipment. If certain requirements of this standard cannot be met, then all deviations from the standard shall be recorded and reported.

Note: Use caution when deciding how and whether to test homes with potential airborne contaminants (e.g. fireplace ash, mold or asbestos) and refer to local, state and national protocols/standards for methods to deal with these and other contaminants.

RA3.8.3 Protocol for Preparing the Building Enclosure for Testing

RA3.8.3.1 Doors and windows that are part of the conditioned space boundary shall be closed and latched.

RA3.8.3.2 Attached garages: All exterior garage doors and windows shall be closed and latched unless the blower door is installed between the house and the garage, in which case the garage shall be opened to outside by opening at least one exterior garage door.

RA3.8.3.3 Crawlspaces: If a crawlspace is inside the conditioned space boundary, interior access doors and hatches between the house and the crawlspace shall be opened and exterior crawlspace access doors, vents and hatches shall be closed. If a crawlspace is outside the conditioned space boundary, interior access doors and hatches shall be closed. For compliance testing purposes, crawl-space vents shall be open.

RA3.8.3.4 Attics: If an attic is inside the conditioned space boundary, interior access doors and hatches between the house and the conditioned attic shall be opened; and attic exterior access doors and windows shall be closed. If an attic is outside the conditioned space boundary, interior access doors and hatches shall be closed and exterior access doors, dampers or vents shall be left in their as found position and their position during testing shall be recorded on the test report.

RA3.8.3.5 Interior Doors: S hall be open within the Conditioned Space Boundary. See the definition of "Conditioned Space Boundary" for clarification.

RA3.8.3.6 Chimney dampers and combustion-air inlets on solid fuel appliances: Dampers shall be closed. Take precautions to prevent ashes or soot from entering the house during testing. Although the general intent of this standard is to test the building in its normal operating condition, it may be necessary to temporarily seal openings to avoid drawing soot or ashes into the house. Any temporary sealing shall be noted in the test report.

RA3.8.3.7 Combustion appliance flue gas vents: Shall be left in their normal appliance-off condition.

RA3.8.3.8 Fans: Any fan or appliance capable of inducing airflow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, outdoor air ventilation fans, air handlers, and crawl space and attic ventilation fans. Continuously operating ventilation systems shall be turned off and the air openings sealed, preferably at the exterior terminations.

RA3.8.3.9 Non-motorized dampers which connect the conditioned space to the exterior or to unconditioned spaces: Dampers shall be left as found. If the damper will be forced open or closed by the induced test pressure, that fact shall be reported in the test report. Clothes dryer exhaust openings should not be sealed off even if there is no dryer attached but this fact should be noted in the test report.

RA3.8.3.10 Motorized dampers which connect the conditioned space to the exterior (or to unconditioned spaces): The damper shall be placed in its closed position and shall not be further sealed.

RA3.8.3.11 Undampered or fixed-damper intentional openings between conditioned space and the exterior or unconditioned spaces: Shall be left open or fixed position; however, temporary blocking shall be removed. For example: fixed-dampered ducts supplying outdoor air for intermittent ventilation systems (including central-fan-integrated distribution systems) shall be left in their fixed-damper position. Exception: Undampered supply-air or exhaust-air openings of continuously operating mechanical ventilation systems shall be sealed (preferably seal at the exterior of enclosure) and ventilation fans shall be turned off as specified above.

RA3.8.3.12 Whole building fan louvers/shutters: Shall be closed. If there is a seasonal cover, it shall be installed.

RA3.8.3.13 Evaporative coolers: The opening to the exterior shall be placed in its off condition. If there is a seasonal cover, it shall be installed.

RA3.8.3.14 Operable window trickle-vents and through-the-wall vents: Shall be closed and/or sealed.

RA3.8.3.15 Supply registers and return grilles: Shall be left open and uncovered.

RA3.8.3.16 Plumbing drains with P-traps: Shall be sealed, or filled with water if empty.

RA3.8.3.17 Combustion appliances: Shall remain off during the test.

Maintain the above conditions throughout the test. If during the test, induced pressures affect operable dampers, seasonal covers, etc., reestablish the set-up and consider reversing direction of fan flow.

After testing is complete, return the building to its as found conditions prior to the test. For example, make sure that any combustion appliance pilots that were on prior to testing remain lit after testing.

RA3.8.4 Accuracy Levels for Enclosure Leakage Testing

RA3.8.4.1 Standard level of accuracy: level of accuracy that produces test results that can be used in approved modeling software to determine performance compliance with the Standards.

RA3.8.5 Installation of the Blower Door Air Tightness Testing System and Preliminary Recordings

RA3.8.5.1 Install the blower door system in an exterior doorway or window that has unrestricted access to the building and no obstructions to airflow within five feet of the fan inlet and two feet of the fan outlet. Avoid installing the system in a doorway or window exposed to the wind.

RA3.8.5.1.2 It is permissible to use a doorway or window between the conditioned space and unconditioned space as long as the unconditioned space has an unrestricted air pathway to the outdoors. For example, an attached garage or porch can be used as the unconditioned space. In this case, be sure to open all exterior windows and doors of the unconditioned space to the outdoors.

RA3.8.5.1.3 Install the pressure gauge(s), fans and tubing connections according to the equipment manufacturer's instructions.

RA3.8.5.1.4 Record the indoor and outdoor temperatures in degrees F to an accuracy of 5 degrees F.

RA3.8.5.1.5 Record the elevation of the building site with an accuracy of 200 feet.

RA3.8.5.1.6 For ACH50 (i.e., air changes per hour @ 50 Pa), record the *building volume*.

RA3.8.6 Procedure for Conducting a Single-Point Air Tightness Test

RA3.8.6.1 Choose and record a *time averaging period* of at least 10 seconds to be used for measuring pressures. With the blower door fan sealed and off, measure and record five (5), independent, *average baseline building pressure readings* with respect to outside to a resolution of 0.1 Pa.

RA3.8.6.2 Subtract the smallest baseline measurement from the largest recorded in Step RA3.8.6.1 and record this as the *baseline range*.

RA3.8.6.3 Air tightness tests with a baseline range less than 5.0 Pa, will be considered a *Standard Level of Accuracy Test*. A Single-Point test cannot be performed under this standard if the baseline range is greater than 10.0 Pa. Record the level of accuracy for the test as *Standard*. The baseline test may be repeated employing a longer time averaging period in order to meet the desired level of accuracy.

RA3.8.6.4 Re-measure the baseline building pressure using the same time averaging period recorded in Section RA3.8.6.1 or use the average of the baseline pressures measured in Section RA3.8.6.1. This measurement is defined as the *Pre-Test Baseline Building Pressure*. If desired for greater accuracy, a longer time averaging period may be used. Record the *Pre-Test Baseline Building Pressure*.

RA3.8.6.5 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 50 Pa. Induced building pressure shall be defined as the (unadjusted) building pressure minus the pre-test baseline building pressure. If a 50 Pa induced building pressure cannot be achieved because the blower door fan does not have sufficient flow capacity, then achieve the highest induced building pressure possible with the equipment available.

RA3.8.6.6 A single-point test may only be performed if the maximum induced building pressure is at least 15 Pa and greater than four times the baseline pressure. If the maximum induced building pressure is less than 15 Pa, recheck that the house set up is correct and determine if any basic repairs are needed prior to further testing. A multi-point test may be attempted, or multiple fans may be used. If using multiple fans, follow the manufacturer's instruction for measurement procedures.

RA3.8.6.7 Measure and record the unadjusted building pressure and nominal (not temperature and altitude corrected) fan flow using the same averaging period used in Section RA3.8.6.4. Record the unadjusted building pressure (with 0.1 Pa resolution), nominal fan flow (with 1 CFM resolution), fan configuration (i.e., rings, pressurization or depressurization, etc), fan and manometer models and serial numbers.

RA3.8.6.8 Turn off the fan.

RA3.8.6.9 If the equipment's pressure gauge has the capability to display the induced building pressure (i.e., "baseline adjustment" feature) and adjust the fan flow value to an induced building pressure of 50 Pa (i.e., "@50 Pa" feature), then follow the manometer manufacturer's procedures for calculating the results of a single-point test and record the following values: induced building pressure, nominal CFM50, fan configuration, fan and manometer model and serial numbers. If needed calculate the following values:

- *Induced Building Pressure* = measured building pressure minus the *Pre-Test Baseline Building Pressure*

Note: If a "baseline adjustment" feature of the manometer was used, the induced building pressure is displayed on the pressure gauge.

- *Nominal CFM50* = (50 / induced building pressure)$^{0.65}$ x recorded fan flow

Note: If both a "baseline adjustment" feature and an "@50 Pa" feature were used, the nominal CFM50 is displayed directly on the pressure gauge.

If the altitude is above 5,000 feet or the difference between the inside and outside temperature is more than 30 degrees F, calculate the corrected CFM50 as defined below:

- *Corrected CFM50* = nominal CFM50 x altitude correction factor x temperature correction factor

Where: *Altitude correction factor* = 1 + .000006 x altitude. Note: altitude is in feet, temperature correction factors are listed in Tables RA3.8B and RA3.8C.

RA3.8.7 Procedure for Conducting a Multi-Point Air Tightness Test

RA3.8.7.1 Equipment that can automatically perform a Multi-Point Test may be used to perform the steps below.

RA3.8.7.2 With the blower door fan sealed and off, measure and record the pre-test baseline building pressure reading with respect to outside. This measurement shall be taken over a time-averaging period of at least 10 seconds and shall have a resolution of 0.1 Pa. Record the pre-test baseline building pressure measurement.

RA3.8.7.3 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 60 Pa. If a 60 Pa induced building pressure cannot be achieved because the blower door fan does not have sufficient flow capacity, then adjust the fan to achieve the highest induced building pressure possible.

RA3.8.7.4 Measure the *unadjusted building pressure* (not baseline adjusted) and nominal fan flow (neither temperature nor altitude corrected) using the same time-averaging period used in Section RA3.8.7.2. Record the unadjusted building pressure (with 0.1 Pa resolution), nominal fan flow (with 1 CFM resolution), fan configuration, fan model and fan serial number. Assure that the fan is being operated according to the manufacturer's instructions.

Note: Since both pre- and post-test baseline measurements are required, do not use any baseline-adjustment feature of the manometer. In addition, do not use an "@50 Pa" feature because the nominal fan flow shall be recorded.

RA3.8.7.5 Take and record a minimum of seven (7) additional unadjusted building pressure and nominal fan flow measurements at *target induced pressures* which are approximately equally-spaced between 60 Pa (or the highest achievable induced building pressure) and 15 Pa. In very leaky buildings, the low end of this range may be reduced to as little as 4 Pa plus the absolute value of the baseline pressure.

RA3.8.7.6 Turn off and seal the blower door fan.

RA3.8.7.7 Measure and record the *post-test baseline building pressure* reading with respect to outside. This measurement shall be taken over the same time-averaging period used in Step 802.6.2 and shall have a resolution of 0.1 Pa. Record the post-test baseline building pressure measurement.

RA3.8.7.8 Enter the recorded test values, temperatures and altitude into software that can perform the necessary calculations in accordance with ASTM E779-10, Section 9.

- The software program shall calculate and report: corrected CFM50 and the percent uncertainty in the corrected CFM50, at the 95% confidence level, as defined in ASTM E779-10, Section 9.

Note: To avoid a higher percent uncertainty than desired, the HERS rater may choose a larger, time-averaging period and start over at Section RA3.8.7.2.

RA3.8.7.9 If the reported uncertainty in the corrected CFM50 is less than or equal to 10.0%, the air tightness test shall be classified as a *Standard Level of Accuracy Test*.

RA3.8.8 Procedure for Conducting a Repeated Single-Point Test

RA3.8.8.1 With the blower door fan sealed and off, measure and record the pre-test baseline building pressure reading with respect to outside. This measurement shall be taken over a time-averaging period of at least 10 seconds and shall have a resolution of 0.1 Pa. Record this value as the pre-test baseline building pressure measurement.

RA3.8.8.2 Unseal the blower door fan. Turn on and adjust the fan to create an induced building pressure of approximately 50 Pa. If a 50 Pa induced building pressure cannot be achieved because the blower door fan

does not have sufficient flow capacity, then achieve the highest induced building pressure possible with the equipment available.

RA3.8.8.3 If during any single repeat of this test, the induced building pressure is less than 15 Pa, recheck that the house set up is correct and determine if any basic repairs are needed prior to further testing or modeling of the building. Following any repairs or changes to the set up, the test shall be restarted from the beginning. If at least 15 Pa cannot be reached every time, then use the procedures in Sections RA3.8.6 or RA3.8.7.

RA3.8.8.4 Measure and record the *unadjusted building pressure* and nominal (not temperature and altitude corrected) *fan flow* using the same time-averaging period used in Section RA3.8.7.2. Record the *unadjusted building pressure* (with 0.1 Pa resolution), *nominal fan flow* (with 1 CFM resolution), *fan configuration* (i.e., *rings*, *pressurization* or *depressurization*, etc), *fan model* and fan *serial number*.

RA3.8.8.5 If the pressure gauge has the capability to display the induced building pressure (i.e., baseline adjustment feature) and the capability to adjust the fan flow value to an induced building pressure of 50 Pa (i.e., "@50 Pa" feature), then follow the manufacturer's procedures for calculating the results of a single-point test and record the following values: induced building pressure, nominal CFM50, fan configuration, fan model and fan serial number.

Note: If the equipment's pressure gauge has the capability to display the induced building pressure (i.e. baseline adjustment feature) and the capability to adjust the fan flow value to an induced building pressure of 50 Pa (i.e. "@50 Pa" feature), then follow the manufacturer's procedures for calculating the results of a Single-Point Test and record the following values: *induced building pressure*, *nominal CFM50*, *fan configuration*, *fan model* and *fan serial number*.

RA3.8.8.6 Turn off the fan.

RA3.8.8.7 Calculate the following values:

- *Induced Building Pressure* = unadjusted building pressure (Pa) minus pre-test baseline building pressure (Pa).

Note: If a baseline adjustment feature was used, then the induced building pressure is displayed on the pressure gauge.

- *Nominal CFM50* = (50 Pa / Induced building pressure)$^{0.65}$ x nominal fan flow.

Note: If both a baseline adjustment feature and an "@50 Pa" feature were used, the nominal CFM50 is displayed directly on the pressure gauge.

RA3.8.8.8 Repeat Sections RA3.8.8.1 through RA3.8.8.7 until a minimum of 5 nominal CFM50 estimates have been recorded. The same fan configuration shall be used for each repeat.

RA3.8.8.9 Calculate the *Average Nominal CFM50* by summing the individual nominal CFM50 readings and dividing by the number of readings.

RA3.8.8.10 If the altitude is above 5,000 feet or the difference between the inside and outside temperature is more than 30 degrees F, calculate the corrected CFM50 as defined below:

- *Average Corrected CFM50 = Average Nominal CFM50* x altitude correction factor x temperature correction factor

Where: *Altitude correction factor* = 1 + .000006 x altitude. Note: altitude is in feet, temperature correction factors are listed in Tables RA3.8B and RA3.8C.

RA3.8.9 Estimate the precision uncertainty using one of the two following methods

RA3.8.9.1 Standard Statistical Process – Use a calculator or computer to compute the Standard Deviation of the repeated Nominal CFM50 readings. Divide this Standard Deviation by the square root of the number of readings. Multiply the result by the t-statistic in Table RA3.8A corresponding to the number of readings taken. Convert this result to a percentage of the Average Nominal CFM50.

Table 3.8A Precision Uncertainty: Values of t-statistic

Number of Readings	t-statistic
5	2.78
6	2.57
7	2.45
8	2.37
9	2.31

RA3.8.8.10 If a software program is used, it shall at a minimum calculate and report:

RA3.8.8.10.1 Average CFM50, corrected for altitude and temperature.

RA3.8.8.10.2 Record the percent uncertainty of the measured CFM50 at the 95% confidence level, as calculated in Section RA8.8.9.

RA3.8.8.10.3 ACH50 (air changes per hour @ 50 Pa) = (CFM50 x 60) / building volume (in cubic feet).

RA3.8.8.11 If the reported uncertainty of the CFM50 is less than or equal to 10.0%, then the air tightness test shall be classified as a *Standard Level of Accuracy Test* as defined in Section RA3.8.4.1.

RA3.8.8.12 Other Leakage Metrics:

ELA may be calculated by: *ELA* = 0.055 x CFM50

Where: ELA is in square inches

ACH50 = corrected CFM50 x 60 / building volume (in cubic feet)

Specific Leakage Area may be calculated by: *SLA* = 69.4 x ELA/ building floor area (square feet)

Where: ELA is in square inches

Normalized Leakage Area may be calculated by: $NLA = SLA \times (S)^{0.3}$

Where: S is the number of stories above grade

RA3.8.8.13 Equipment Accuracy and Requirements

Blower door fans used for building air leakage testing shall measure airflow (after making any necessary air density corrections) with an accuracy of +/- 5%. Pressure gauges shall measure pressure differences with a resolution of 0.1 Pa and have an accuracy of +/- 1% of reading or 0.5Pa, whichever is greater.

Blower door and associated pressure testing instruments shall be tested annually for calibration by the HERS Provider or HERS Rater. The HERS Provider or HERS Rater shall use a standard for field testing of calibration provided by the equipment manufacturer. Magnehelic Gauges cannot be field tested and shall be recalibrated by the Blower Door manufacturer annually. Fan and flow measuring systems for shall be regularly field checked for defects and maintained according to manufacturers' recommendations. The HERS Provider or HERS Rater shall maintain a written log of the annual calibration check to verify all equipment accuracy for a period of three (3) years. These records shall be made available to the Commission.

RA3.8.8.14 Air Leakage Reporting

The HERS rater shall measure the building air leakage rate to ensure measured air leakage is less than or equal to the building air leakage rate stated on the Certificate of Compliance, CF-1R and CF-6R. HERS verified building air leakage shall be documented on form CF-4R-ENV-20.

Table RA3.8B Temperature Correction Factors for Pressurization Testing- Calculated according to ASTM E779-10

		Inside Temperature (F)								
		50	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**
Outside Temp (F)	**-20**	1.062	1.072	1.081	1.090	1.099	1.108	1.117	1.127	1.136
	-15	1.056	1.066	1.075	1.084	1.093	1.102	1.111	1.120	1.129
	-10	1.051	1.060	1.069	1.078	1.087	1.096	1.105	1.114	1.123
	-5	1.045	1.054	1.063	1.072	1.081	1.090	1.099	1.108	1.117
	0	1.039	1.048	1.057	1.066	1.075	1.084	1.093	1.102	1.111
	5	1.033	1.042	1.051	1.060	1.069	1.078	1.087	1.096	1.105
	10	1.028	1.037	1.046	1.055	1.064	1.072	1.081	1.090	1.099
	15	1.023	1.031	1.040	1.049	1.058	1.067	1.076	1.084	1.093
	20	1.017	1.026	1.035	1.044	1.052	1.061	1.070	1.079	1.087
	25	1.012	1.021	1.029	1.038	1.047	1.056	1.064	1.073	1.082
	30	1.007	1.015	1.024	1.033	1.041	1.050	1.059	1.067	1.076
	35	1.002	1.010	1.019	1.028	1.036	1.045	1.054	1.062	1.071
	40	0.997	1.005	1.014	1.023	1.031	1.040	1.048	1.057	1.065
	45	0.992	1.000	1.009	1.017	1.026	1.035	1.043	1.051	1.060
	50	0.987	0.995	1.004	1.012	1.021	1.029	1.038	1.046	1.055
	55	0.982	0.990	0.999	1.008	1.016	1.024	1.033	1.041	1.050
	60	0.997	0.986	0.994	1.003	1.011	1.019	1.028	1.036	1.045
	65	0.973	0.981	0.989	0.998	1.006	1.015	1.023	1.031	1.040
	70	0.968	0.976	0.985	0.993	1.001	1.010	1.018	1.026	1.035
	75	0.963	0.972	0.980	0.988	0.997	1.005	1.013	1.022	1.030
	80	0.959	0.967	0.976	0.984	0.992	1.000	1.009	1.017	1.025
	85	0.955	0.963	0.971	0.979	0.988	0.996	1.004	1.012	1.020
	90	0.950	0.958	0.967	0.975	0.983	0.991	0.999	1.008	1.016
	95	0.946	0.954	0.962	0.970	0.979	0.987	0.995	1.003	1.011
	100	0.942	0.950	0.958	0.966	0.970	0.982	0.990	0.998	1.007
	105	0.938	0.946	0.954	0.962	0.970	0.978	0.986	0.994	1.002
	110	0.933	0.942	0.950	0.952	0.966	0.974	0.982	0.990	0.998

Table RA3.8C Temperature Correction Factors for Depressurization Testing- Calculated according to ASTM E779-10

		Inside Temperature (F)								
		50	55	60	65	70	75	80	85	90
Outside Temp (F)	-20	0.865	0.861	0.857	0.853	0.849	0.845	0.841	0.837	0.833
	-15	0.874	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.842
	-10	0.883	0.879	0.874	0.870	0.866	0.862	0.858	0.854	0.850
	-5	0.892	0.887	0.883	0.879	0.875	0.871	0.867	0.863	0.859
	0	0.900	0.896	0.892	0.887	0.883	0.879	0.875	0.871	0.867
	5	0.909	0.905	0.900	0.896	0.892	0.888	0.883	0.879	0.875
	10	0.918	0.913	0.909	0.905	0.900	0.896	0.892	0.888	0.884
	15	0.927	0.922	0.918	0.913	0.909	0.905	0.900	0.896	0.892
	20	0.935	0.931	0.926	0.922	09.17	0.913	0.909	0.905	0.900
	25	0.944	0.939	0.935	0.930	0.926	0.922	0.917	0.913	0.909
	30	0.952	0.948	0.943	0.939	0.934	0.930	0.926	0.921	0.917
	35	0.961	0.956	0.952	0.947	0.943	0.938	0.934	0.930	0.926
	40	0.970	0.965	0.960	0.956	0.951	0.947	0.942	0.938	0.934
	45	0.978	0.974	0.961	0.964	0.960	0.955	0.951	0.946	0.942
	50	0.987	0.982	0.977	0.973	0.968	0.963	0.959	0.955	0.950
	55	0.995	0.990	0.986	0.981	0.976	0.972	0.967	0.963	0.958
	60	1.004	0.999	0.994	0.998	0.985	0.980	0.976	0.971	0.967
	65	1.012	1.008	1.003	0.998	0.993	0.988	0.984	0.979	0.975
	70	1.021	1.016	1.011	1.006	1.001	0.997	0.992	0.988	0.983
	75	1.029	1.024	1.019	1.015	1.010	1.005	1.000	0.996	0.991
	80	1.038	1.033	1.028	1.023	1.018	1.013	1.009	1.004	0.999
	85	1.046	1.041	1.036	1.031	1.026	1.022	1.017	1.012	1.008
	90	1.055	1.050	1.045	1.040	1.035	1.030	1.025	1.020	1.016
	95	1.063	1.058	1.053	1.048	1.043	1.038	1.033	1.028	1.024
	100	1.072	1.066	1.061	1.056	1.051	1.046	1.041	1.037	1.032
	105	1.080	1.075	1.070	1.064	1.059	1.054	1.050	1.045	1.040
	110	1.088	1.083	1.078	1.073	1.068	1.063	1.058	1.053	1.048

50 55 60 65 70 75 80 85 90 -20 1.062 1.072 1.081 1.090 1.099 1.108 1.117
1.127 1.136 -15 1.056 1.066 1.075 1.084 1.093 1.102 1.111 1.120 1.129 -10
1.051 1.060 1.069 1.078 1.087 1.096 1.105 1.114 1.123 -5 1.045 1.054 1.063
1.072 1.081 1.090 1.099 1.108 1.117 0 1.039 1.048 1.057 1.066 1.075 1.084
1.093 1.102 1.111 5 1.033 1.042 1.051 1.060 1.069 1.078 1.087 1.096 1.105 10
1.028 1.037 1.046 1.055 1.064 1.072 1.081 1.090 1.099 OUTSIDE 15 1.023
1.031 1.040 1.049 1.058 1.067 1.076 1.084 1.093 TEMP 20 1.017 1.026 1.035
1.044 1.052 1.061 1.070 1.079 1.087 (F) 25 1.012 1.021 1.029 1.038 1.047
1.056 1.064 1.073 1.082 30 1.007 1.015 1.024 1.033 1.041 1.050 1.059 1.067
1.076 35 1.002 1.010 1.019 1.028 1.036 1.045 1.054 1.062 1.071 40 0.997
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1.046 1.055 55 0.982 0.990 0.999 1.008 1.016 1.024 1.033 1.041 1.050 60
0.977 0.986 0.994 1.003 1.011 1.019 1.028 1.036 1.045 65 0.973 0.981 0.989
0.998 1.006 1.015 1.023 1.031 1.040 70 0.968 0.976 0.985 0.993 1.001 1.010
1.018 1.026 1.035 75 0.963 0.972 0.980 0.988 0.997 1.005 1.013 1.022 1.030
80 0.959 0.967 0.976 0.984 0.992 1.000 1.009 1.017 1.025 85 0.955 0.963
0.971 0.979 0.988 0.996 1.004 1.012 1.020 90 0.950 0.958 0.967 0.975 0.983
0.991 0.999 1.008 1.016 95 0.946 0.954 0.962 0.970 0.979 0.987 0.995 1.003
1.011 100 0.942 0.950 0.958 0.966 0.970 0.982 0.990 0.998 1.007 105 0.938
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0.966 0.974 0.982 0.990 0.998