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desirable and should be eliminated. When performing the leakage to outside test, it is only necessary to pressurize the dwelling unit served by the duct system being tested.

§150.0(m)1 Exception to §150.0(m)1

Ducts and fans integral to a wood heater or fireplace are exempt from Standards Section 150.0(m)1.

§150.0(m)5

For the purpose of determining installed R-value of duct insulation based on thickness, when not an integral part of a manufacturer-labeled, insulated duct product such as vinyl flex duct, the following shall be used:

1. For duct wrap, the installed thickness of insulation must be assumed to be 75 percent of the nominal thickness due to compression.
2. For duct board, duct liner and factory-made rigid ducts not normally subjected to compression, the nominal insulation thickness shall be used.

B. Connections and Closures

§150.0(m)1, §150.0(m)2, §150.0(m)3

Note: Duct installation requirements are discussed in more detail in Duct Installation Standards Section 4.4.3

The Standards set a number of mandatory measures related to duct connections and closures. These measures address both the materials and methods used for duct sealing. The following is a summary. Refer to the sections of the Standards listed above for additional details.

C. Factory-fabricated Duct Systems

Factory fabricated duct systems must comply with the following requirements:

1. All factory-fabricated duct systems must comply with UL 181 for ducts and closure systems, including collars, connections, and splices, and be labeled as complying with UL 181. UL181 testing may be performed by UL laboratories or a laboratory approved by the Executive Director.
2. All pressure-sensitive tapes, heat-activated tapes, and mastics used in the manufacture of rigid fiberglass ducts must comply with UL 181 and UL 181A and be labeled UL181A-P, UL181A-H, or UL181A-M respectively.
3. All pressure-sensitive tapes and mastics used with flexible ducts must comply with UL 181 and UL 181B and be labeled UL181B-FX or UL181B-M respectively.
4. Joints and seams of duct systems and their components cannot be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands: or
5. It has on its backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums and junction box joints.

D. Field-fabricated Duct Systems

Field –fabricated duct systems must comply with the following requirements:

1. Factory-made rigid fiberglass and flexible ducts for field-fabricated duct systems must comply with UL 181. All pressure-sensitive tapes, mastics, aerosol sealants, or other closure systems used for installing field-fabricated duct systems shall meet the applicable requirements of UL 181, UL 181A, and UL 181B.
2. Mastic sealants and mesh:
   a. Sealants must comply with the applicable requirements of UL 181, UL 181A, and/or UL 181B, and be labeled UL181A-M or UL181B-M as applicable, and be nontoxic and water resistant.
   b. Sealants for interior applications must be tested in accordance with ASTM C731 and D2202.
   c. Sealants for exterior applications must be tested in accordance with ASTM C731, C732, and D 2202.
   d. Sealants and meshes must be rated for exterior use.
3. Pressure-sensitive tapes must comply with the applicable requirements of UL 181, UL 181A, and UL 181B and be labeled UL181A-P, UL181A-H, or UL181B-FX as applicable.
4. Joints and seams of duct systems and their components must not be sealed with cloth back rubber adhesive duct tapes unless such tape is used in combination with mastic and draw bands: or
5. It has on its backing the phrase "CEC approved," a drawing of a fitting to plenum joint in a red circle with a slash through it (the international symbol of prohibition), and a statement that it cannot be used to seal fittings to plenums or junction box joints.

E. Draw Bands Used With Flexible Duct

1. Draw bands must be either stainless-steel worm-drive hose clamps or UV-resistant nylon duct ties. Non-metallic mechanical fasteners (plastic duct ties) must comply with the applicable requirements of UL181B and be labeled UL181B-C.
2. Draw bands must have a minimum tensile strength rating of 150 pounds.
3. Draw bands must be tightened as recommended by the manufacturer with an adjustable tensioning tool.

F. Aerosol-sealant Closures

1. Aerosol sealants shall meet the requirements of Class 1 when tested to UL 723 and be applied according to manufacturer specifications.
2. Tapes or mastics used in combination with aerosol sealing shall meet the requirements of this Section.

If mastic or tape is used to seal openings greater than 1/4 inch, the combination of mastic and either mesh or tape must be used.

Building spaces such as cavities between walls, support platforms for air handlers, and plenums defined or constructed with materials other than sealed sheet metal, duct board, or flexible duct must not be used for conveying conditioned air including return air and supply air. The practice of using drywall materials as the interior surface of a return plenum is not allowed. Building cavities and support platforms may contain ducts. Ducts installed in cavities and support platforms must not be compressed to cause reductions in the cross-sectional area of the ducts. Although a HERS rater may examine this as a part of his or her responsibilities when involved in a project, the enforcement of these minimum standards for ducts is the responsibility of the building official.

§150.0(m)2D, §150.0(m)3D

Duct systems may not use cloth-back, rubber-adhesive duct tape (typical, "old fashion", non-rated duct tape) unless it is installed in combination with mastic and draw bands. Note: mastic and drawbands alone are adequate for sealing most connections. Cloth back rubber adhesive duct tape would then only be used to hold the outer vapor barrier in place or for some other superfluous purpose. It alone is not adequate to serve as an air sealing method or as a mechanical connection.

The enforcement of these minimum standards is normally the responsibility of the building official; however HERS raters will also verify compliance with this requirement in conjunction with duct leakage verification.

G. Product Markings

§150.0(m)2A, §150.0(m)6

All factory-fabricated duct systems must meet UL 181 for ducts and closure systems and be labeled as complying with UL 181. Collars, connections and splices are considered to be factory-fabricated duct systems and must meet the same requirement.

Insulated flexible duct products installed to meet this requirement must include labels, in maximum intervals of 3 ft, showing the R-value for the duct insulation (excluding air films, vapor barriers, or other duct components), based on the tests and thickness specified in §150.0(m)4 and §150.0(m)5C.

H. Dampers to Prevent Air Leakage

§150.0(m)7

Fan systems that exhaust air from the building to the outside must be provided with back draft or automatic dampers.

§150.0(m)8

Gravity ventilating systems must have an automatic or readily accessible, manually operated damper in all openings to the outside, except combustion inlet and outlet air openings and elevator shaft vents. This includes clothes dryer exhaust vents when installed in conditioned space.

I. Protection of Insulation

§150.0(m)9

Insulation must be protected from damage, including that due to sunlight, moisture, equipment maintenance, and wind but not limited to the following:

- Insulation exposed to weather must be suitable for outdoor service; for example, protected by aluminum, sheet metal, painted canvas, or plastic cover.
- Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

J. Ducts in Concrete Slab

Ducts located in a concrete slab must have R-6 insulation but other issues will come into play. If ducts are located in the soil beneath the slab or embedded in the slab, the insulation material should be designed and rated for such installation. Insulation installed in below-grade applications should resist moisture penetration (closed cell foam is one moisture-resistant product). Common pre-manufactured duct systems are not suitable for below-grade installations. If concrete is to be poured directly over the ducts, then the duct construction and insulation system should be sturdy enough to resist the pressure and not collapse. Insulation should be of a type that will not compress, or it should be located inside a rigid duct enclosure. The only time that common flex ducts are suitable in a below-grade application is when a channel is provided in the slab.

K. Porous Inner Core Flex Duct

§150(m)10

Over time the outer vapor barrier of flex duct can be compromised. Therefore porous inner core flex duct is not allowed.

L. Duct System Sealing and Leakage Testing

§150(m)11

Duct system sealing and leakage testing is mandatory in all climate zones. Duct systems in newly constructed single family dwellings, townhouses, and multifamily dwellings are required to comply with the requirements. Alterations and additions to ducted systems in existing buildings in all climate zones are also required to comply with applicable maximum leakage criteria. Refer to Chapter 9 for more information on duct sealing and leakage testing for existing buildings.

Duct Leakage Testing For Multiple Duct Systems With Common Return Ducts

If there are two or more duct systems in a building that are tied together at a common return duct, then each duct system should be tested separately, including the shared portion of the return duct system in each test. Under this scenario, the portions of the second duct system that is not being tested must be completely isolated from the portions of the ducts that are being tested, so the leakage from second duct system does not affect the leakage rate from the side that is being tested.

The diagram below represents the systems that are attached to a shared return boot or remote return plenum. In this case, the point in the return system that needs to be blocked off is readily accessible through the return grille.

The “duct leakage averaging” where both system are tested together as though it is one large system and divide by the combined tonnage to get the target leakage may not be used as it allows a duct system with more the 6% leakage to pass if the combined system’s leakage is 6% or less.

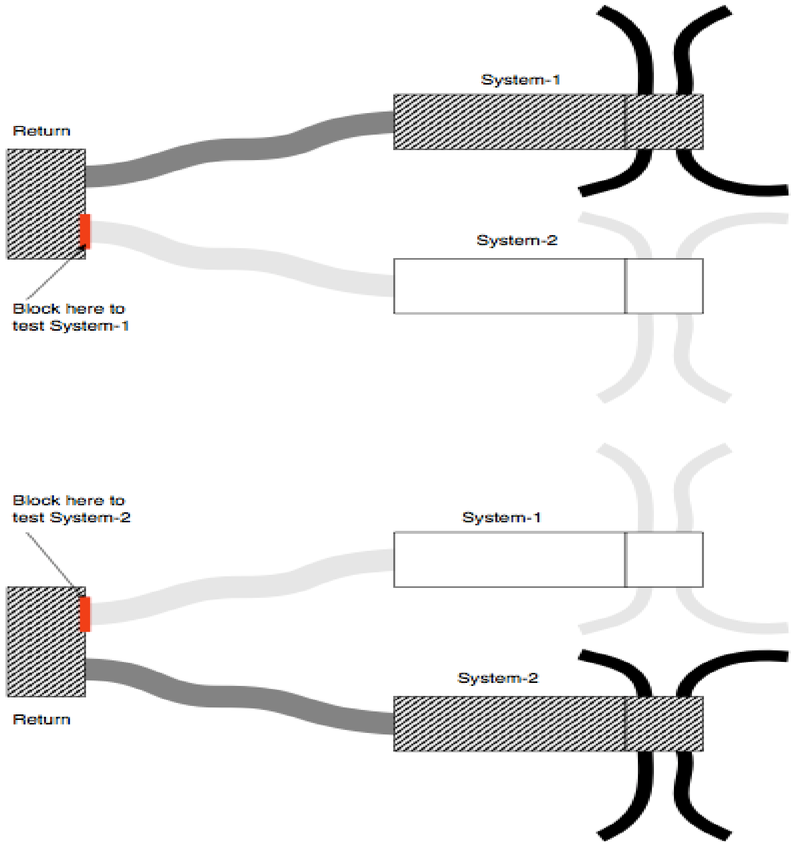

Figure 4–3- Two Duct Systems with a Common Return Duct
Source: California Energy Commission

M. Air Filtration

§150.0(m)12

Air filtration is present in forced air systems to protect the equipment and may provide health benefits to occupants of the building. In addition to filtering particulates from the airstream filters add flow resistance to the forced air system, potentially lowering the efficiency of the heating/cooling equipment. Flow resistance is measured as a pressure drop at a specific airflow.

Except for evaporative coolers, any mechanical forced air heating and/or cooling system with more than 10 feet of duct must meet four sets of criteria:

1. System Design Criteria:
   a) All recirculated and outdoor air passing through the heating/cooling device must first pass through the filter.
   b) The system design must accommodate the pressure drop through the filter at the designed airflow. In order to accomplish this, the design airflow and the design pressure drop through the filter must be determined by the designer. The design pressure drop will determine the size and depth of the filter media required for the device (return filter grill or filter rack).

c) If the system design elects compliance utilizing the Return Duct Design alternative specified in Tables 150.0-C and D, then the designer must assume a design filter pressure drop of 0.05 IWC at the applicable design airflow rate.

d) Replacing the filters, like for like, when they become dirty brings their resistance to airflow back to the design condition. Therefore, the filters must be located to allow access for regular service by the occupants.

e) To maintain the energy efficiency of the system it is necessary for the occupants to know which filters to select that will provide the designed airflow. Therefore, a clearly legible label, such as shown in Figure 4-6 shall be permanently placed in a location visible to a person changing the filter. As shown in Figure 4-6, the label shows the allowable maximum resistance at the airflow rate closest to the design airflow for that filter location. Figure 4-6 is an example of label for a filter location designed for 400 CFM at 0.03 IWC. Note that the standard AHRI 680 airflow values are given in 400 CFM increments. The filter media pressure drop specifications at the design airflow rates that fall between the 400 cfm increments must be determined by interpolation of the Standard 680 rating values, or by lookup methods made available by the filter media vendor or manufacturer.

AHRI 680 Standards Rating		Maintenance Instructions
Airflow (CFM)	Initial Resistance (inch WC)	USE ONLY REPLACEMENT FILTERS WITH AN INTIAL RESISTANCE LESS THAN 0.032 AT 400 CFM AIRFLOW RATE
400	0.03	

Figure 4-4 – Example of Filter Location Label

1. Air Filter Media Efficiency Criteria: The filter media shall be MERV 6 or better to provide protection to the equipment and to potentially provide health benefits. Filter media that provide at least 50% particle efficiency in the 3.0–10 μm range in AHRI 680 are considered to meet the MERV 6 criterion.
2. Air Filter Media Pressure Drop Criteria: To ensure airflow for efficient heating and cooling equipment operation, the installed filter media must conform to the design pressure drop specification shown in the Filter Location Label described in item 1e above.
3. Air Filter Media Labeling Criteria: The filter device must be provided with a filter media product that has been labeled by the manufacturer to disclose performance ratings that meet both the Efficiency and Pressure drop criteria described in 2, and 3 above and as shown in the Filter Location Label described in item 1e above.

N. Forced Air System Duct Sizing, Airflow Rate and Fan Efficacy

§150.0(m)13

Adequate airflow is critical for heating and cooling equipment efficiency. Simultaneously, the watt draw of the fan producing the airflow is a portion of the efficiency. It is important to maintain adequate airflow without expending excessive fan watts to achieve the airflow. The airflow and watt draw must be HERS verified. See Reference Residential Appendices RA3.3 for the HERS verification procedures. The prescriptive return system does not have to be HERS verified.

Except for heating only systems, systems must comply with one of the following two methods:

1. Airflow and Watt Draw measurement and determination of Fan Efficacy:

   When using the Airflow (cfm/ton) and Fan Efficacy (Watt/cfm) method the following criteria must be met:

   a) Provide airflow through the return grilles that is equal to or greater than 350 CFM per ton of nominal cooling capacity.

   b) At the same time the fan watt draw must be less than or equal to 0.58 Watts per CFM.

   The methods of measuring the watt draw are described in Reference Residential Appendix RA3.3. Three acceptable apparatuses are:

   a) a portable watt meter,

   b) an analog utility revenue meter, or

   c) a digital utility revenue meter.

   There are three acceptable methods to determine compliance with the system airflow requirement. They are described in Reference Residential Appendix RA3.3 and use an:

   a) active or passive flow capture hood to measure the total airflow through the return grill(s), or

   b) flow grid device(s) at the return grill(s) or other location where all the central fan airflow passes through the flow grid, or

   c) fan flow meter device to perform the plenum pressure matching procedure.

   The flow grid measurement device and the fan flow meter measurement device both require access to static pressure measurements of the airflow exiting the cooling coil, which utilizes a HSPP or PSPP (Section RA3.3.1.1).

   The contractor must install either a hole for the placement of a static pressure probe (HSPP) or provide a permanently installed static pressure probe (PSPP) as shown in Figure 4-7 below and Reference Residential Appendix RA3.3

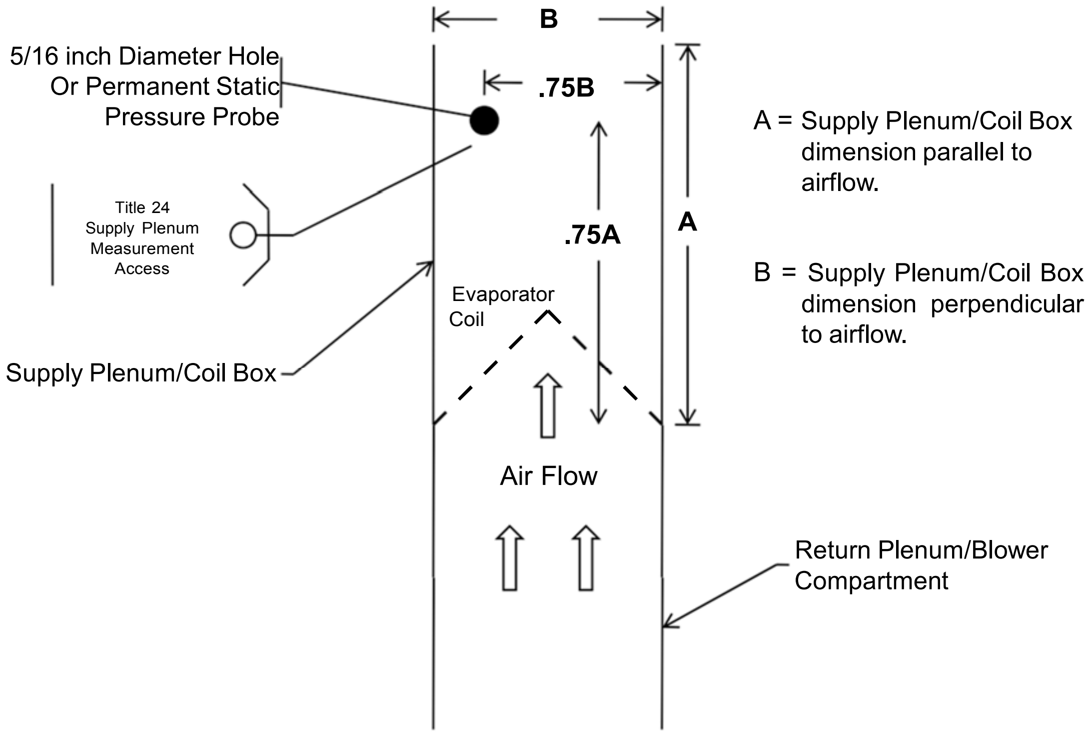

Figure 4–5 - Location of the Static Pressure Probe
Source: California Energy Commission

The HSPP or PSPP facilitates cooling coil airflow measurement when using devices/procedures that depend on supply plenum pressure measurements.

2. Return Duct System Design Method – This method allows the designer to specify, and the contractor to install, a system that does not have to be tested for airflow and fan watt draw. This method can be used for return systems with two returns. Each return shall be no longer than 30 feet from the return plenum to the filter grille. When bends are needed, metal elbows are desirable. Each return can have up to 180 degrees of bend and no more 90 degrees of bend can be flex duct. To use this method, the designer and installer must provide return system sizing that meets the appropriate criteria in Table 150.0-C or D.

O. Airflow and Fan Efficacy Testing Versus Return Duct Sizing

Studies have shown that adequate airflow is critical to the efficient operation of air conditioning systems. Section 150.0(m)13B establishes mandatory requirements that are intended to ensure adequate cooling airflow through properly sized ducts and efficient fan motors.

There are two options allowed to ensure adequate air flow; option one is to design and install the systems using standard design criteria and then have the systems airflow and fan efficacy (AF/FE) tested and third-party verified in the field. The second option is to use size the return ducts according to Tables 150.0-C and D. These tables are very simplified and very conservative (the return ducts are much larger than would normally be used). They should only be used in situations where there is a serious concern that the system will not pass the diagnostic tests for airflow and fan efficacy, such as in alterations where duct modification opportunities are limited. The first option, AF/FE testing, is always preferable, especially in new construction.

The California Green Code and the California Mechanical Code both require that residential duct systems be designed according to ACCA Manual D, or equivalent. If reasonable care and judgment is used in designing the duct system (both return and supply ducts) and the system is designed to reasonable parameters for airflow per ton, static pressure across the fan and friction rate, these systems should have no problem passing the diagnostic tests. Return ducts should not be sized according to Tables 150.0- C and D purely as a way to avoid the diagnostic testing. While undersized return ducts are very often the cause of poor airflow in many systems, they are only part of the overall system.

The following design guidelines will increase the chances of the system passing the AF/FE testing without sizing the return ducts according to Table 150.0-Cand D:

1. Right-size the HVAC system; if a 3-ton unit is enough to satisfy the cooling load, do not install a 4-ton unit "just to be safe". Oversizing equipment can cause comfort problems in addition to excessive energy use.
2. The HVAC designer must coordinate closely with the architect and structural engineer to make sure that the ducts will fit into the home as designed.
3. Prepare a detailed mechanical plan that can be followed in the field. If deviations must occur in the field, make sure that they are coordinated with the designer and that the design is adjusted as needed.
4. Follow Manual D for duct sizing:
   a. Make sure that the correct duct type is being used (vinyl flex, sheet metal, rigid fiberglass, etc.).
   b. Make sure that all equivalent lengths and pressure drops are correctly accounted for (bends, plenum start collars, t-wyes, filters, grilles, registers, etc).
   c. Select a furnace that will provide at least 400 cfm/ton at the desired static pressure of 125 to 150 Pa (0.5 to 0.6 inches w.c.).
   d. Design the duct system to a static pressure across the fan of no more than 150 Pa (0.6 inches w.c.).
   e. Consider upsizing the evaporator coil relative to the condenser to reduce the static pressure drop. This results in better airflow and slightly better capacity and efficiency. Manufacturers commonly provide performance data for such condenser coil combinations.
   f. Consider specifying an air handler with a better quality fan motor.
5. Install a large grill area and use proper filter for the system; using a higher MERV filter than needed unnecessarily increases the static pressure.
6. Locate registers and equipment to make duct runs as short as possible.
7. Make all short-radius 90 Degree bends out of rigid ducting.
8. Install flex duct properly by: stretching all flex duct tight and cut off excess ducting, ensure the duct is not kinked or compressed, ensure flex duct is properly supported every four feet or less using minimum one-and-one-half (1-1/2) inch strapping having less than ~~two~~ one-half inche~~s~~ of sag per lineal feet between supports. Flex duct vertical risers should be supported at six feet maximum spacing.

Consider using better quality supply and filter grills. "Bar-type" registers have considerably better airflow performance than standard stamped-face" registers. Refer to manufacturer's specifications and select accordingly.

Note that Standards Tables 150.0-C and D (Tables 4-10, 4-11, 4-12) only allow for one or two returns. There may be times where three returns are necessary on a single system.