



CALIFORNIA CONVENTIONAL HOME WEATHERIZATION INSTALLATION STANDARDS

for use in

California's Low Income Energy Efficiency Programs

administered by

**San Diego Gas and Electric Company
Southern California Edison
Southern California Gas Company
Pacific Gas and Electric Company**

PART 1

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ABBREVIATIONS AND ACRONYMS

AAMA	American Architectural Manufacturers Association
ACCA	Air Conditioning Contractors of America
ACDD	Annual Cooling Degree Days (also see CDD)
AFUE	Annual Fuel Utilization Efficiency
AGA	American Gas Association
AHDD	Annual Heating Degree Days (also see HDD)
ANSI	American National Standards Institute
ARI	Air Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWG, awg	American Wire Gage
BEAR	Bureau of Electronic and Appliance Repair
BEF	Ballast Efficacy Factor
BOCA	Building Officials and Code Administrators
Btu	British Thermal Unit
Btu/hr	British Thermal Units per Hour
°C	Degrees Centigrade
CABO	Council of American Building Officials
Cal OSHA	California Occupational Safety and Health Administration
CAS	Combustion Appliance Safety

ABBREVIATIONS AND ACRONYMS

CASIF	Combustion Appliance Safety Inspection Form
CAZ	Combustion Appliance Zone
CBC	California Building Code
CBM	Certified Ballast Manufacturers
CBO	Community Based Organization
CCR	California Code of Regulations
CDD	Cooling Degree Days (also see ACDD)
CEC	California Energy Commission <u>and</u> California Electrical Code
CFL	Compact Fluorescent Lamp
CFM, cfm	Cubic Feet per Minute
CFM₂₅	Cubic Feet per Minute of Air Flow at 25 Pascals of Pressure
CFM₅₀	Cubic Feet per Minute of Air Flow at 50 Pascals of Pressure
CFR	Code of Federal Regulations
CMC	California Mechanical Code
CO	Carbon Monoxide
COP	Coefficient of Performance
CPSC	Consumer Products Safety Commission
CSD	(California Department of) Community Services and Development
DOE	(United States) Department of Energy
DV	Direct Vent (Furnace/Heater)
EER	Energy Efficiency Ratio

ABBREVIATIONS AND ACRONYMS

EPA	Environmental Protection Agency
ESP	Economic Stop Parameters/Economic Stop Policy
°F	Degrees Fahrenheit
F.S.	Federal Specifications
FAU	Forced Air Unit
fpm	Feet per Minute
GFCI	Ground Fault Circuit Interrupter
HCD	(California Department of) Housing and Community Development
HDD	Heating Degree Days (also see AHDD)
HDL	House Depressurization Limit
HPD	Heat Producing Device
HUD	(U.S. Department of) Housing and Urban Development
HVAC	Heating Ventilation and Air Conditioning
Hz	Hertz
ICBO	International Conference of Building Officials
ID	Inside Diameter
IWC, iwc	Inches of Water Column (Same as IWG, Inches of Water Gauge)
IWG, iwg	Inches of Water Gauge (Same as IWC, Inches of Water Column)
KHz	Kilohertz
MVR	Minimum Ventilation Requirement

ABBREVIATIONS AND ACRONYMS

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NFVA, NFV Area	Net Free Venting Area: Total vent opening area minus the blocking effect of louvers, grilles, and screens
OC	On Center
OD	Outside Diameter
OSHA	Occupational Safety and Health Administration
P&P	Policies & Procedures
Pa	Pascal (See Definitions)
PPM, ppm	Parts per Million
psf	Pounds per Square Foot
psi	Pounds per Square Inch
RTV	Room Temperature Vulcanization (e.g., RTV Silicone)
SEER	Seasonal Energy Efficiency Ratio
T&P Valve	Temperature and Pressure Relief Valve
TPE	Thermoplastic Elastomer
UBC	Uniform Building Code
UL	Underwriters Laboratories
UMC	Uniform Mechanical Code
UPC	Uniform Plumbing Code

ABBREVIATIONS AND ACRONYMS

UV	Ultraviolet
WC, wc	Water Column (Same as Water Gauge)
WG, wg	Water Gauge (Same as Water Column)
WIS	Weatherization Installation Standards
Wx	Weatherization

DEFINITIONS

Abandoned Appliance

An appliance which is no longer used and has been removed from service and ~~by the following actions:~~ (1) the flexible gas connector has been disconnected ~~and/or removed,~~ and (2) the gas line shut-off valve has been capped, or the valve has been removed and the pipe capped.

Backdrafting

The reverse flow of combustion gases down the vent pipe and out the draft hood of a natural vent open combustion appliance. Intermittent backdrafting can be caused by wind gusts. Ongoing backdrafting can be the result of a negative pressure in the combustion appliance zone (CAZ) caused by (a) duct system return leaks in the vicinity of the appliance, and/or (b) the excessive influence of mechanical systems exhausting air from the structure (e.g., bathroom and utility room exhaust fans, range hood fan, clothes dryer, built-in vacuum system, etc.).

Built-up Roof (Low-Slope)

A low-slope roof that is “built up” with roofing felt laminated in overlapping layers to form a membrane that is two to four plies thick. To protect the membrane from sunlight and physical wear, a layer of aggregate (crushed stone or other mineral granules) is embedded in the surface.

Closure System

The sum total of components utilized to secure and seal a duct system joint or seam against air leakage (e.g., pressure sensitive tape, or heat activated tape, or mastic with fiberglass mesh reinforcement). Closure systems for non-metallic flexible ducts also include one or more drawbands.

Combustion Air

The total amount of air provided to the space, which contains fuel-burning equipment; it includes air for fuel combustion, for draft hood dilution, and for ventilation of the equipment enclosure. (Reference ~~1997-2001~~ UMC, Section 205-~~C,~~ ~~page 8~~).

Combustion Appliance Zone(CAZ)

The room or area of a home in which an open combustion natural draft appliance (typically a furnace, water heater, wood burning stove or fireplace) is located. It

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could be a living room containing a wood burning stove, a kitchen or utility porch containing a water heater, or an appliance enclosure. Excessive depressurization of the CAZ causes backdrafting and spillage of combustion gases into the room.

Conditioned Space	An area, room, or space normally occupied and being heated or cooled by any equipment for human habitation. (Reference 1998-2001 CMC, Section 205- C .)
Confined Space	A room or space having a volume less than 50 cubic feet per 1,000 Btu/h of aggregated input rating of all-fuel burning appliances installed in that space. (Reference 1998-2001 CMC, Section 205- C .)
Drawband	A device which encircles a duct and mechanically secures the core-to-fitting attachment (i.e., a synthetic duct tie or a worm drive stainless steel clamp). Duct ties are also used to secure fiberglass duct wrap and to seal jacket overlaps at flexible duct splices.
Duct Systems	All ducts, duct fittings, plenums, and fans assembled to form a continuous passageway for the distribution of air. (Reference 1998-2001 CMC, Section 206- D .)
<i>Enclosed Cavity</i>	<i>A building cavity that is totally enclosed and inaccessible for installation of measures. An example is a low-profile section of attic that is closed off by drywall, plywood or other sheathing. Because of inadequate crawl clearance, proper installation of insulation would not be feasible even if an access hole were cut.</i>
FAU	Forced air unit, which is that portion of a central heating and/or air conditioning (A/C) system which contains the air handler (blower section). In a "Split System," it is the furnace. In a "Package System," the entire heating and A/C "Package Unit" may be referred to as the FAU.
Heat Activated Tape	Metallic tape with an adhesive coating that is activated and cured by the application of heat and pressure.

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Inaccessible Appliance

A combustion appliance that cannot be accessed for NGAT testing, due to a locked passage or a physical impediment. Examples include a water heater in a locked room/enclosure for which a key is not available, an attic-mount furnace that requires entry through an inaccessible MUD unit, and a floor furnace in a crawl space with inadequate crawl clearance. A floor furnace may also be inaccessible because it has been covered over by plywood or attached floor covering (e.g., wall-to-wall carpet or vinyl). A floor or wall furnace may be inaccessible because it has been turned off and blocked by heavy furniture (e.g., a hutch or cabinet).

Labeled

Equipment or materials to which has been attached a label of a nationally recognized testing agency that maintains periodic inspection of the production of labeled equipment or materials. Labeling indicates compliance with nationally recognized standards. (Also see "Listed" and "UL Classified, Labeled, Listed".)

Lapped Seam

The seam (joint) formed where two pieces of material (usually sheet metal) are overlapped.

Listed

Equipment or materials included in a list published by a nationally recognized testing agency (e.g., UL, CSA, ITS, ETL, etc.) that maintains periodic inspection of the production of listed equipment or materials. Listing indicates compliance with nationally recognized standards. (Also see "Labeled" above and "UL Classified, Labeled, Listed" below.)

Longitudinal Joint

Lengthwise joint along a piece of duct (e.g., the joint running the full length of a snap-together sheet metal duct). [Note: *longitudinal* means "lengthwise"...in contrast with *transverse*, which means "across".]

NFPA 90B

Standards governing installation of "Warm Air Heating and Air Conditioning Systems" in one- or two-family dwellings and structures not exceeding 25,000 cu. ft. Provides specifications for the manufacture and

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installation of rigid metal ductwork and references UL 181 regarding factory made air ducts (e.g., flexible ducts). Installations in larger structures are addressed by NFPA 90A.

NFV, NFVA

NFV stands for “net free venting.” NFVA is “net free venting area,” the net amount of venting area provided by a vent after the blocking effect of mesh and/or louvers has been subtracted from the gross area of the vent opening(s).

Package Unit

A combination heating and air conditioning system contained within one housing unit, which is installed outdoors (on the roof or on a slab next to the house). (Also see “Split System.”)

Pascal (Pa)

A small unit of pressure equivalent to 0.004 inches of water column (IWC). 1 Pa = 0.004 IWC, and 1 IWC = 250 Pa. 25 Pa, the pressure typically used to test duct systems for leakage, is equivalent to 0.1 IWC. Conversion formulas are: $[Pa = IWC \div 0.004]$ and $[IWC = Pa \times 0.004]$.

Perm

A unit of permeance, which refers to how permeable a material is (e.g., how well moisture will pass through a vapor barrier).

Plenum

An air compartment or chamber, including uninhabited crawl spaces, areas above a ceiling or below a floor, to which one or more ducts are connected and which forms part of either the supply-air or return-air system. Typically on residential HVAC systems, the supply and return plenums are the large rectangular boxes/chambers that connect the FAU to the supply duct system and the return-air system. (Reference 1998 CMC, Section 215-P.)

Pressure Sensitive Tape

Duct tape with a tacky adhesive coating (e.g., butyl, acrylic, etc.) which will adhere to a surface with the application of pressure (heat not required). Duct tapes must be listed and marked per UL 181A and 181B

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standards.

Repair

Corrective work performed by a qualified technician, intended to make a natural gas appliance operate properly, when correction is beyond the scope of “Service/Adjustment”. ~~Repair may include, but is not limited to, diagnostics, cleaning, adjustments, and replacement of defective or missing parts and components. (Also see “Replacement” and “Service/Adjustment”.)~~

Replacement

Complete replacement of a defective natural gas appliance, when repair is not feasible: i.e., the cost to repair the appliance exceeds program guidelines, or parts required to make the appliance safely operable cannot be obtained. ~~Replacement must be performed by a properly-licensed contractor (e.g., C-20 for HVAC), with a permit and final inspection obtained. (Also see “Repair” and “Service/Adjustment”.)~~

Service/Adjustment

Minor corrective work, within the normal scope of service, performed by utility gas service personnel, or designated representative, intended to make a natural gas appliance operate properly without repair or replacement. ~~replacing parts. (Also see “Repair” and “Replacement”.)~~

Spillage

In a natural draft open combustion appliance, the unwanted outflow of combustion gases from the draft hood into the atmosphere of the room or area where the appliance is located. Spillage occurs when the vent system draft is inadequate to carry combustion gasses up through the vent pipe and outdoors. Spillage occurs briefly when combustion first begins in a cold appliance, because cold air in the vent pipe impedes exhaust flow until the systems warms up. Continuous spillage may result when the vent pipe is blocked by an obstruction or is improperly constructed (too many elbows, improper slope, inadequate diameter, etc.).

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Split System	A heating and cooling system in which the air conditioning evaporator coil is attached to the furnace, which is located indoors (typically in the garage, attic, or interior closet), and the condenser unit (with coil, compressor, and fan) is installed outdoors, usually on a slab next to the house. (Also see “Package Unit.”)
Transverse Joint	The joint formed when two pieces of duct are spliced together (e.g., the joint around the circumference where two round ducts are joined together, and the joint around the perimeter where two rectangular ducts are joined together). [Note: <i>transverse</i> means “across”...in contrast with <i>longitudinal</i> , which means “lengthwise”.]
UL 181	UL “Standard for Factory-Made Air Ducts and Connectors”.
UL 181A	UL standard for pressure sensitive aluminum tapes, heat activated aluminum tapes, and mastic closure systems for use with rigid fiberglass air ducts.
UL 181B	UL standard for pressure sensitive tapes and mastic closure systems for use with flexible air ducts.
UL Class 0 Duct	Air duct materials having a fire hazard classification of zero (flame spread and smoke developed).
UL Class 1 Duct	Air duct materials having a flame-spread rating not over 25 without evidence of continued progressive combustion and a smoke-developed rating not over 50.
UL Classified, Labeled, Listed, Recognized	<ul style="list-style-type: none">• UL Classified means that UL testing was limited to examination of one potential hazard.• UL Labeled means that a product is either UL Listed or UL Classified. Note that a product can be certified and “listed” without involving UL. Other accredited laboratories (e.g., CSA International, ITS Intertek Services, ETL SEMKO, etc.) can test products and certify conformance with established standards. Such products can thus be “listed and labeled” without reference to UL. (See “Listed” and “Labeled” above.)

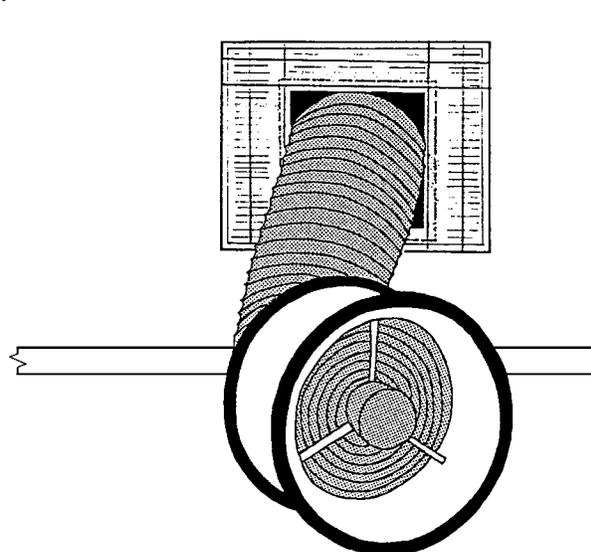
DEFINITIONS

- **UL Listed** means that UL testing included examination of *all* foreseeable hazards.
- **UL Recognized** means that a component (such as a motor) is approved for use in a UL Listed product (such as an evaporative cooler). The complete cooler is UL Listed, but the tested and approved components used in it are “UL Recognized components.” Each UL Recognized component is tested to a UL standard applicable to that component, and it is “recognized” for use in a UL Listed product.

DUCT TESTING STANDARDS

1. EQUIPMENT

- **Instrumentation Minimum Specifications**
 - Pressure Measurements
 - Measurement systems shall have an accuracy of ± 0.2 Pa or 1% of reading, whichever is greater, and
 - Shall utilize static pressure probes specified by the measurement equipment manufacturer.
 - Duct Leakage Measurements
 - Duct leakage testing shall have an accuracy of $\pm 3\%$ of measured flow, and
 - Shall utilize digital gauges specified by the measurement equipment manufacturer.
 - Airflow Measurements
 - Airflow testing shall have an accuracy of $\pm 7\%$ of measured flow, and
 - Shall utilize digital gauges specified by the measurement equipment manufacturer.
- **Approved Leakage Measurement Equipment**
 - Equipment shall meet the Title 24 requirements specified in the 2005 Residential ACM Manual, Appendices RC and RE.
 - May include, but is not limited a Duct pressurization system, e.g., Duct Blaster™.

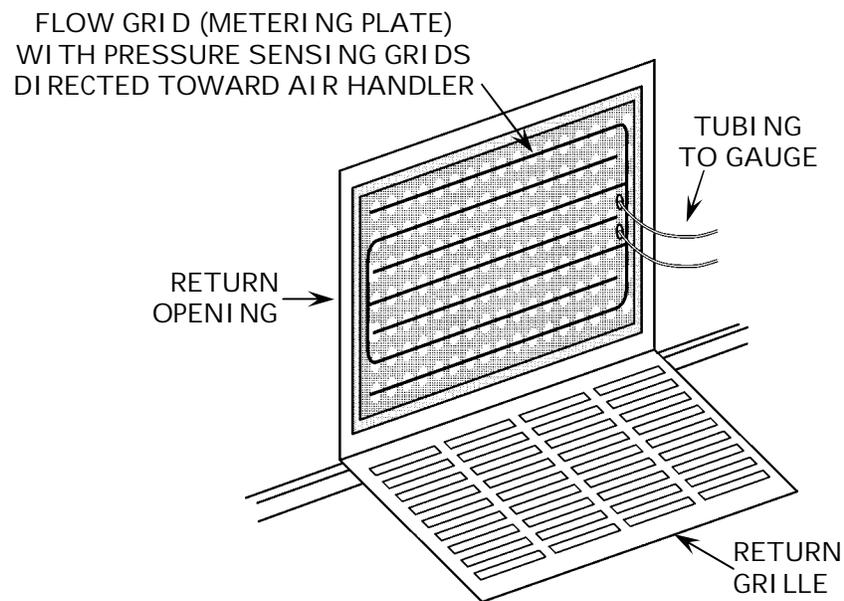


DUCTS PRESSURIZED WITH DUCT TESTER FAN

2. HVAC SYSTEM AIRFLOW (FAN FLOW) (continued)

- Flow Grid Measurement

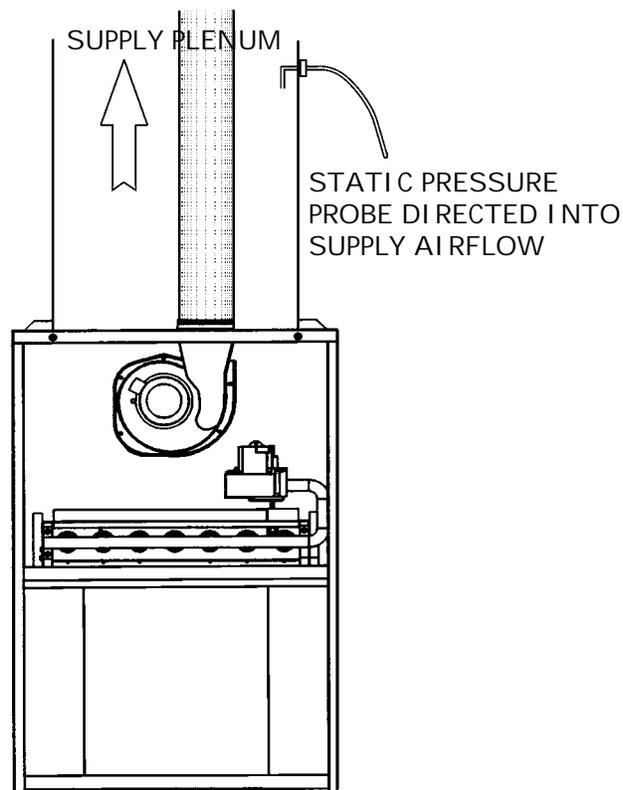
- Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.3, “Flow Grid Measurement.”
- Measurements shall be in accordance with manufacturer’s instructions, which take precedence, and Conventional WIS Appendix -D-.



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2. HVAC SYSTEM AIRFLOW (FAN FLOW) (continued)

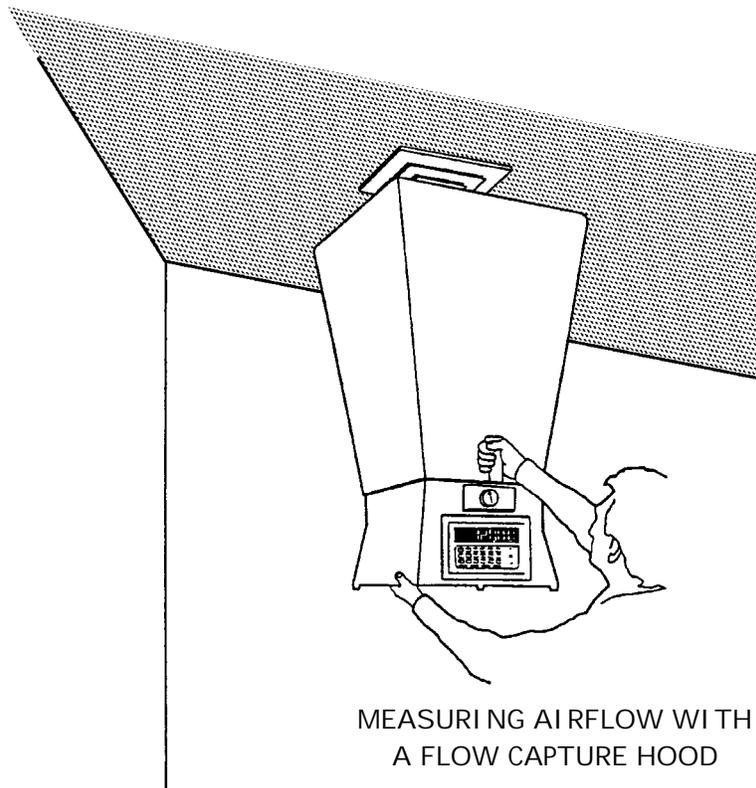
- **Plenum Pressure Matching Measurement (Duct Tester Used as a Powered Capture Hood)**
 - Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.1, "Plenum Pressure Matching Measurement."
 - Measurements shall be in accordance with manufacturer's instructions, which take precedence, and Conventional WIS Appendix -D-.



2. HVAC SYSTEM AIRFLOW (FAN FLOW) (continued)

- Flow Capture Hood

- Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.2, "Flow Capture Hood Measurement."
- Measurements shall be in accordance with manufacturer's instructions, which take precedence, and Conventional WIS Appendix -D-.



MEASURING AIRFLOW WITH
A FLOW CAPTURE HOOD

Section 10

3. TEST CONDITIONS FOR ALL DUCT LEAKAGE TESTS

- Equipment Operation

- The HVAC system must be operated briefly to determine that the FAU functions properly prior to performing any duct tests.
- Duct Testing shall not be performed if:
 - The FAU is inoperable, or
 - A hazardous conditions exists (e.g., burner/flame abnormality, high CO, cracked heat exchanger) that requires service/adjustment or repair/replacement per NGAT standards/policy.

- Air filters

- Filter(s) shall be removed from the duct system.
- Opening (slots) for slide-in filters in the plenum shall be sealed (e.g., with temporary duct tape).

- Ventilation Air Intakes

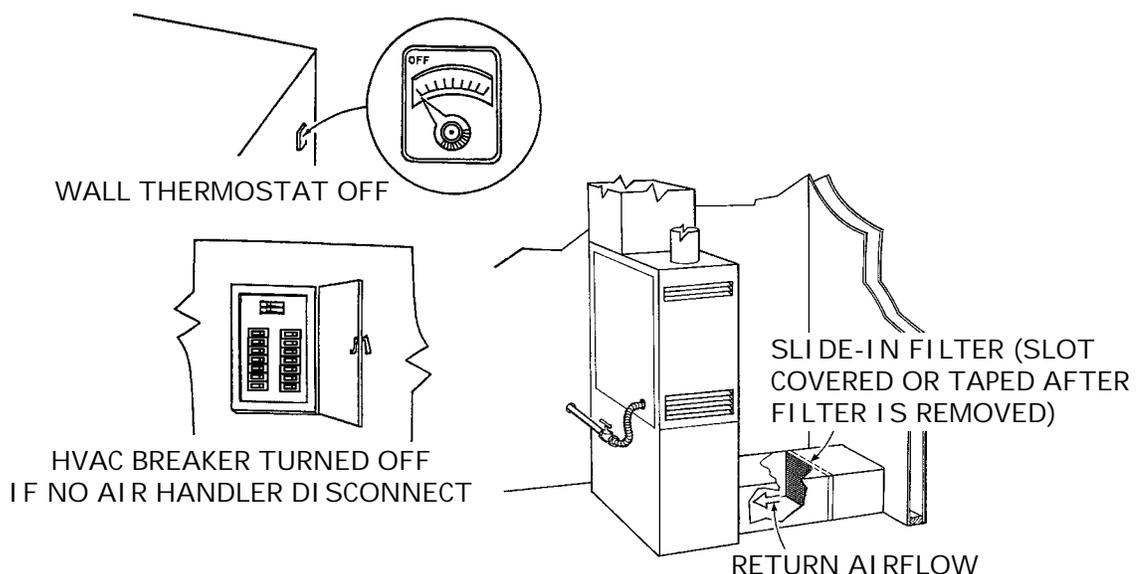
- Intakes connected to the duct system (e.g., makeup air, economizer venting damper, etc.) shall be temporarily sealed.

- All fan-equipped appliances shall be turned off, such as:

- HVAC equipment: FAU and room air conditioners.
- Exhaust devices: fans and clothes dryer vented outdoors.

- Duct system terminals shall be blocked as applicable.

- One return register or air handler access shall remain unblocked for installation of duct tester.
- All other supply registers and return grilles shall be blocked/sealed per Item 4.



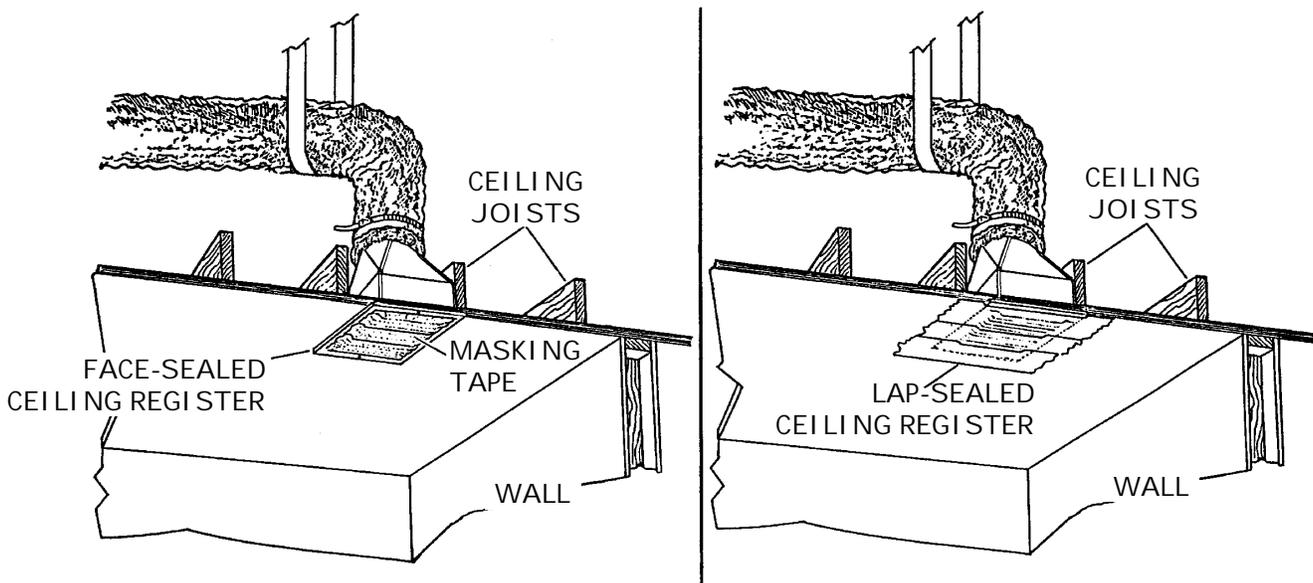
4. **BLOCKING SUPPLY AND RETURN DUCT TERMINATIONS**

- **All Blocking Methods**

- Terminations must be temporarily blocked/sealed to achieve a complete seal during duct pressurization testing.
- Leaky plenum slots for slide-in filters and air intakes connected to the duct system (e.g., makeup air) shall also be sealed.
- Blocking/sealing methods and materials must not damage home finishes.
- The same blocking/sealing method shall be used for all tests.

- **External Blocking Method**

- **Face Seal Register/Grille**
 - The face of the supply register or return grille is covered with a temporary barrier material (register-sealing film, wide masking tape, etc.).
 - Barrier material is restricted to the face of the register/grille and must cover and seal all openings.
- **Lap Seal Register/Grille**
 - The register/grille is covered with temporary barrier material that laps onto the surrounding surface.
 - This method may not be used where acoustical texturing is present and where barrier material is likely to peel off paint or otherwise damage the surface.
- Register/grille must be completely sealed.



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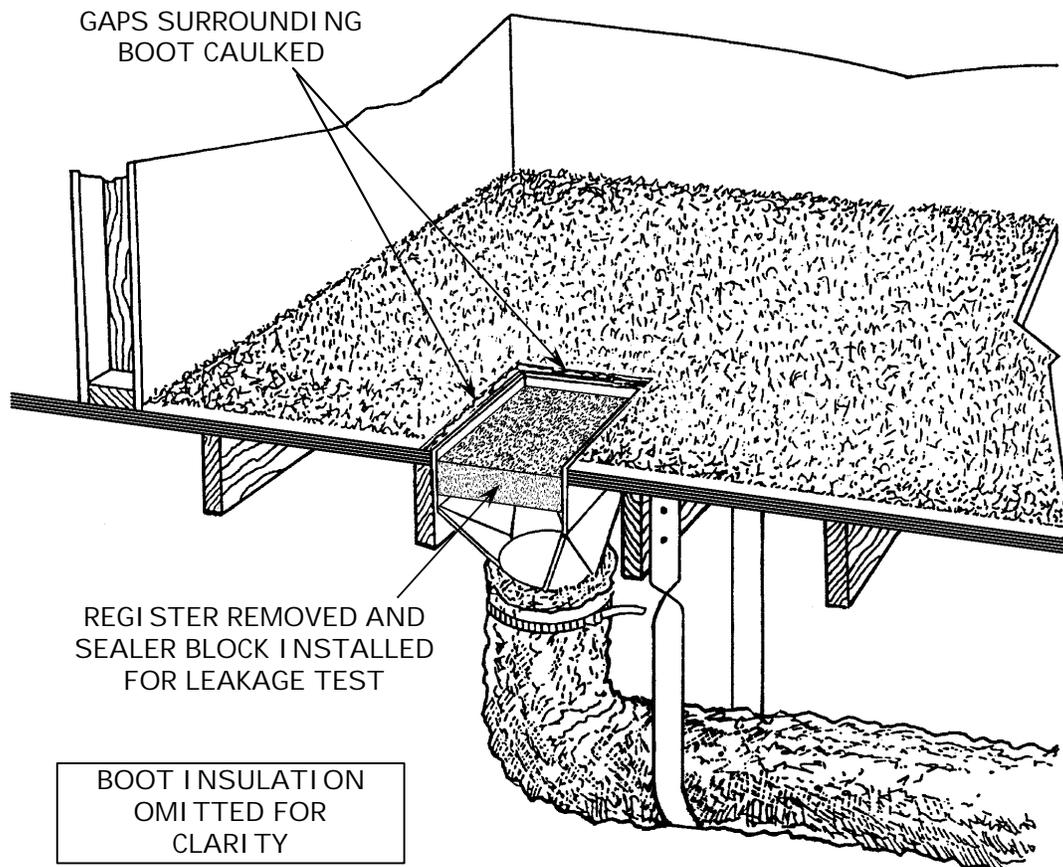
4. BLOCKING SUPPLY AND RETURN DUCT TERMINATIONS (continued)

- Cover Pan Method

- The supply/return opening is covered with a sealed pan-shaped device held firmly in place.
- The edge/flange of the cover pan must be gasketed to achieve a complete seal.
- This method shall not be used where acoustical texturing is present.

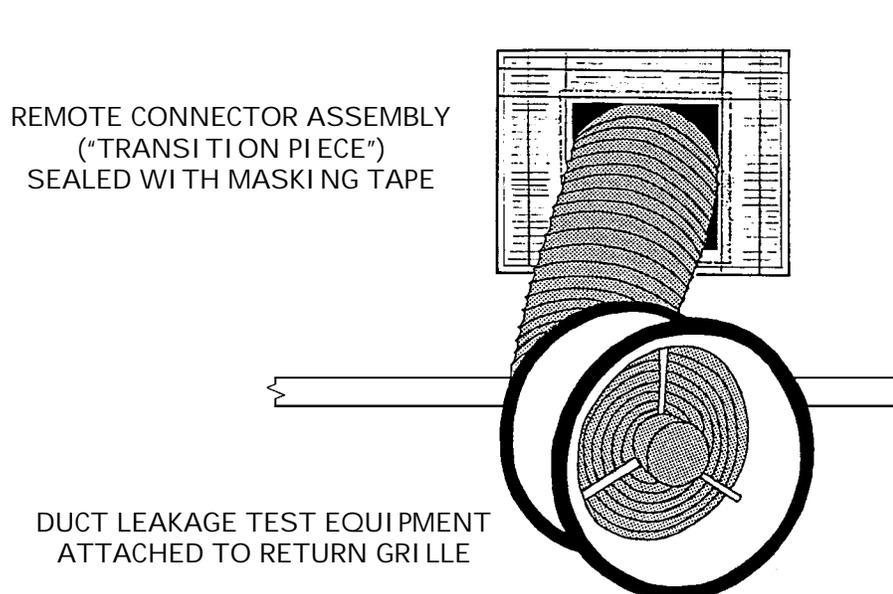
- Internal Blocking Method:

- The boot is internally blocked with a temporary plug or dam (e.g., a tight-fitting block of dense foam or duct board).
- Plug must seal the boot completely.
- Gaps between the boot and the structure shall be sealed/caulked if the internal blocking method is used.



5. DUCT TESTER INSTALLATION

- **Test equipment shall be set up, calibrated, and operated in accordance with manufacturer's instructions.**
- **General Guidelines for Duct Tester Fan Installation**
 - The duct tester fan housing or remote connector assembly (e.g., transition piece) is attached to the HVAC system.
 - The remote connector is attached to the return grille that is largest and closest to the air handler (minimum 1'x1' grille required).
 - On multi-return systems (e.g., more than one central return, or a return in every room), and in other situations when connection to a return grill is not feasible, the fan or remote connector is attached to the air handler blower access opening.
 - The fan/connector is secured and sealed completely with temporary tape/film.
 - The duct-pressure sampling hose/probe is installed from the digital pressure gauge to inside the taped register nearest the supply plenum.
 - The Fan Pressure hose is installed from the digital pressure gauge to the duct tester fan pressure tap.

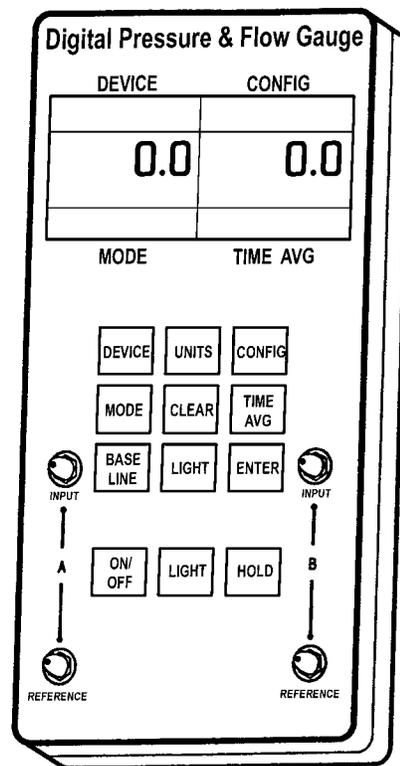


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6. TOTAL DUCT LEAKAGE TEST

- Tests shall be performed in accordance with test equipment manufacturer's instructions.
- Test Conditions and Preparation
 - Test conditions shall be established per Item 3.
 - Supply and return duct terminations shall be blocked per Item 4.
 - Duct tester shall be set per Item 5.
- Total Duct Leakage Test
 - To prevent depressurization of the conditioned space by the duct tester fan, an entry door or large window shall be opened.
 - To prevent pressurization of an unconditioned space containing ducts, the space must communicate with outdoors (e.g., by opening vents, access cover/door, etc., as needed).
 - People and objects must be kept away from the front of, and at least one foot to the side of, the duct tester fan inlet during tests.
 - Digital pressure gauge Mode shall be set for one-second averaging, or as recommended by manufacturer.
 - Digital pressure gauge shall be set on high Range, or as recommended by manufacturer.

DIGITAL GAUGE FOR MEASURING PRESSURE AND AIRFLOW



6. TOTAL DUCT LEAKAGE TEST (continued)

- **Pressurization test shall be performed per manufacturer's instructions, using flow control device (e.g., "Flow Ring") as needed.**
 - Duct Tester fan shall be adjusted to pressurize ducts to 25 Pa.
 - Flow control device shall be changed as needed to keep Fan Pressure within an acceptable range, as indicated in Table 10-1 for the Minneapolis Duct Blaster™.
- **Total Duct Leakage**
 - Total Duct Leakage CFM₂₅ shall be determined.
 - For digital pressure gauges that do not automatically convert fan pressure to fan flow, manufacturer's conversion tables and procedures shall be utilized to calculate Total Duct Leakage in cfm.
 - Total Duct Leakage in cfm shall be divided by Forced Air System Airflow in cfm and converted to a percentage:

$$[\text{Total Leakage} \div \text{System Airflow}] \times 100 = \% \text{ of System Airflow}$$
 - Target Total Duct Leakage is <15% of System Airflow, or as specified in the program P&P (see Item 7).
- **Very Leaky Systems**
 - When a Duct Pressure of 25 Pa cannot be achieved, and the digital gauge does not automatically estimate cfm at 25 Pa, manufacturer's instructions shall be followed.

TABLE 10-1: FAN FLOW CONTROL

Fan Configuration	Flow Range in CFM
Open Fan (no Flow Ring)	600 to 1,500
Ring 1	225 to 800
Ring 2 (smaller opening)	90 to 300
Ring 3 (smallest opening)	20 to 125

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7. DUCT SEALING PROTOCOL

- **Start Criteria**
 - Duct repair and sealing work may begin only if the *Initial* Total Duct Leakage satisfies the Start Criteria in the Program Policy & Procedures.
- **Stop Criteria**
 - When the LIEE Duct Sealing maximum leakage criteria must be met, one of the following LIEE P&P requirements shall be satisfied:
 - Target Leakage (stop) criteria, or
 - Economic Stop criteria.
 - When Title 24 criteria maximum leakage must be met:
 - Target Leakage must be met as shown in Table 10-2.
 - Measurement method (C) shall be used only when Target Leakage cannot be met using method (A) or (B).
- **Required data shall be recorded on the data form, including:**
 - Total Duct Leakage (or Leakage to Outside) CFM₂₅ from the *Initial* test, performed before starting duct repair and sealing work.
 - Total Duct Leakage (or Leakage to Outside) CFM₂₅ from the *Final* test performed after completing duct repair and sealing work.

TABLE 10-2: TITLE 24 DUCT SEALING TARGET LEAKAGE

MEASUREMENT METHOD	TARGET LEAKAGE	T-24 PROCEDURE ¹
(A) Total Duct Leakage	<15% of System Fan Flow	RC.4.3.1
(B) Duct Leakage Reduction	>60% Leakage Reduction ²	RC.4.3.4, RC.4.3.6, and RC.4.3.7
(C) Prescriptive Default	Target Not Met but All Accessible Ducts are Sealed ³	RC.4.3.5, RC.4.3.6, and RC.4.3.7

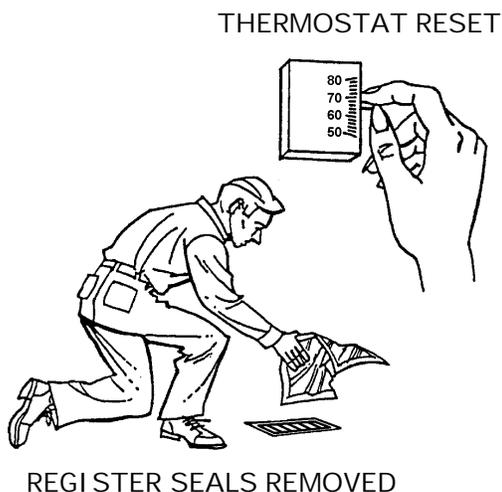
¹Title 24 ACM Residential Manual Appendix RC-2005

²Final duct leakage compared to Initial duct leakage, with a smoke test to confirm that all accessible leaks have been sealed.

³When leakage target cannot be met, all accessible leaks must be sealed, as confirmed by a smoke test.

8. WRAP-UP PROCEDURE

- **Following completion of duct testing, the HVAC system, appliances and the home shall be returned to original condition.**
- **Temporary sealing removed:**
 - All temporary sealing and blocking materials (register-sealing film, temporary tape, foam plugs, etc.) shall be removed.
 - Ventilation air intakes (see Item 3) shall be restored to normal.
- **Air filter(s) reinstalled:**
 - Filters removed for testing shall be reinstalled.
 - Dirty filters shall be cleaned before reinstallation.
- **Appliances and furnishings restored:**
 - Wall thermostat, water heater control, HVAC/air handler power, windows, doors, fans, room air conditioners, etc. returned to pre-test settings.
 - Home furnishings returned to original locations.
 - All test equipment, tools, supplies, and trash removed from the home.



Section 10

NONFEASIBILITY CRITERIA FOR DUCT TESTING

1. Ductwork contains excessive damage or deterioration that would preclude proper testing.
2. If the replacement of 40 or more feet of duct in unconditioned space would be necessary.
3. Ductwork contains or is made of asbestos.
4. Ductwork is insulated or sealed with asbestos.
5. Ductwork is inaccessible or an unsafe condition exists, causing duct testing to be unfeasible.
6. A hazardous condition exists requiring repair or replacement per NGAT policy, and repair/replacement is not feasible.
7. Forced air heating unit is inoperative and cannot be repaired.
8. Customer refuses.

DUCT SEALING STANDARDS

APPROVED MATERIALS

1. ALL MATERIALS

- **Surface burning characteristics, per UL 723, ASTM E84, NFPA 255, or UL 2043:**
 - Flame spread rating not to exceed 25.
 - Smoke developed rating not to exceed 50.
- **Only exterior-rated products shall be used on the exterior (outdoors).**
- **UL 181A and 181B listed sealants shall be labeled per Table 20-1.**

2. DUCT MASTIC

- **All Ducts**
 - Non-toxic and water resistant.
 - UL listed and labeled per UL 181A or 181B standards.
- **Flexible Metallic and Nonmetallic Ducts**
 - UL labeled to include the marking “181B-M”.
 - Compatible with the duct to which it is applied.
- **Rigid Metal Ducts and Components**
 - Mastic shall be UL labeled “181A-M” or “181B-M”.
- **Rigid Fiberglass Ducts**
 - Mastic shall be labeled “181A-M”.

TABLE 20-1: REQUIRED UL 181 IDENTIFICATION

DUCT TYPE	SEALING MATERIAL	UL IDENTIFICATION
<u>RIGID</u> METAL DUCTS AND COMPONENTS	PRESSURE SENSITIVE TAPE	MARKED “181A-P” <u>OR</u> “181A-P/181B-FX”
	HEAT ACTIVATED TAPE	MARKED “181A-H”
	MASTIC	LABELED “181A-M” <u>OR</u> “181A-M/181B-M”
<u>FLEXIBLE</u> DUCTS	PRESSURE SENSITIVE TAPE	MARKED “181B-FX” <u>OR</u> “181A-P/181B-FX”
	MASTIC	LABELED “181B-M” <u>OR</u> “181A-M/181B-M”

Section 20

3. MESH TAPE

- All Ducts

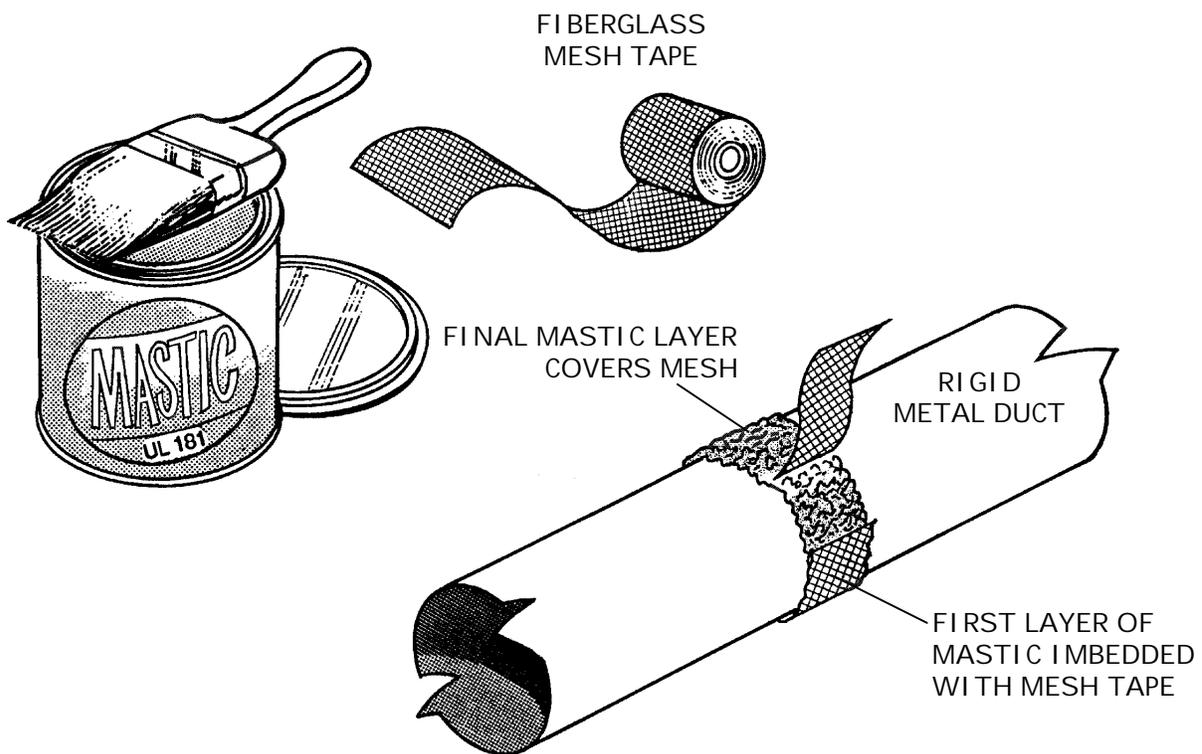
- Mesh fabric used to reinforce duct mastic shall:
 - Comply with mastic manufacturer's instructions, or
 - Meet the following specifications:
 - Fiberglass mesh tape.
 - Weave per inch: 9 x 9 minimum.
 - Thickness: 0.006" minimum.

- Flexible Ducts and Rigid Metal Ducts

- Mesh tape width: 2" minimum.

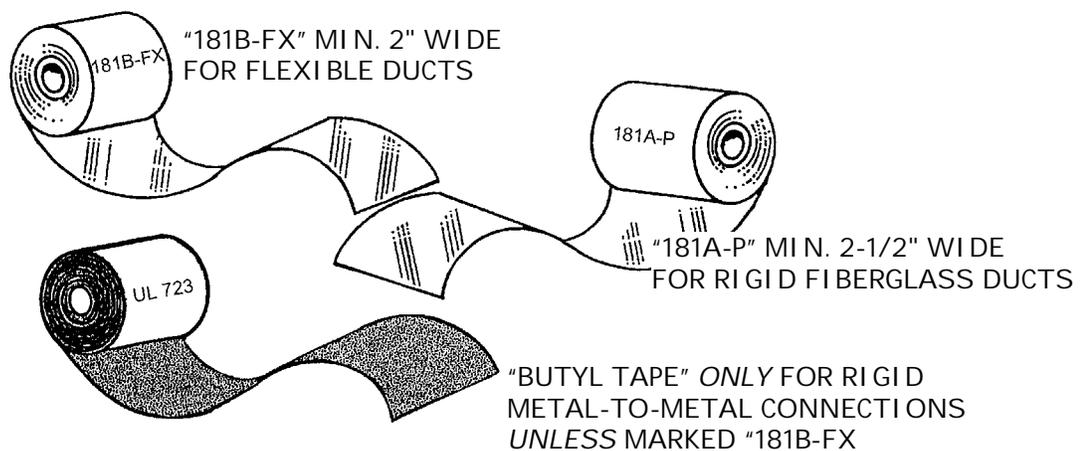
- Rigid Fiberglass Ducts

- Mesh tape width: 3" minimum.



4. PRESSURE SENSITIVE TAPE

- **Approved Tapes**
 - Listed per UL 181A or 181B and marked “181A-P” or “181B-FX”.
 - Metallic pressure sensitive tape: Aluminum foil backing.
 - Plastic pressure sensitive tape: Polypropylene or similar backing.
 - “Butyl Tape” (also known as “Foil Mastic”):
 - Aluminum foil tape with minimum 15 mil butyl adhesive.
 - Marked “181B-FX” or “UL 723” (or ASTM E84 or NFPA 255).
 - Butyl tape without “181B-FX” marking shall not be used to seal flexible ducts.
- **Tapes Not Allowed: Cloth-back tapes, even if marked “181B-FX”.**
- **Tapes for Sealing Flexible Nonmetallic and Flexible Metallic Ducts**
 - Tapes with markings that include “181B-FX”, minimum 2" wide.
- **Tapes for Sealing Rigid Metal Ducts and components**
 - Metallic tapes marked “181A-P” and/or “181B-FX”, min. 2" wide.
 - Exception: “Butyl tape” without “181A-P” or “181B-FX” markings may be used to seal rigid metal-to-metal connections.
- **Tapes for Sealing Rigid Fiberglass Ducts**
 - Metallic tapes marked “181A-P”, minimum 2-1/2" wide.
- **Access Panels**
 - Metallic tapes with non-butyl (e.g., acrylic) adhesive.
- **High Temperature Applications**
 - Metallic tapes with non-butyl (e.g., acrylic) adhesive and service temperature rating of at least 265°F.



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5. DRAWBANDS AND CLAMPS

- Materials

- Drawbands and clamps used to secure flexible nonmetallic ducts shall comply with duct manufacturer's installation instructions.
- Drawbands shall meet the following minimum standards:
 - Weather- and UV-resistant (e.g., black) nylon duct straps/ties rated for outdoor use.
 - Loop tensile strength: 150 pounds minimum.
 - Service temperature rating 165°F minimum.
- Clamps shall be stainless steel worm-drive clamps.

- Drawband Installation:

- Drawbands shall be tightened with an adjustable tensioning tool in accordance with duct manufacturer's instructions.

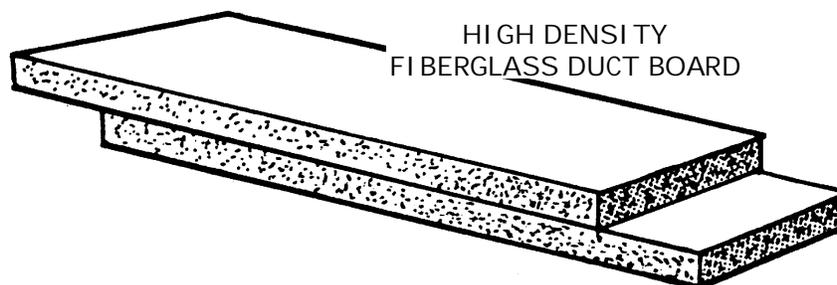
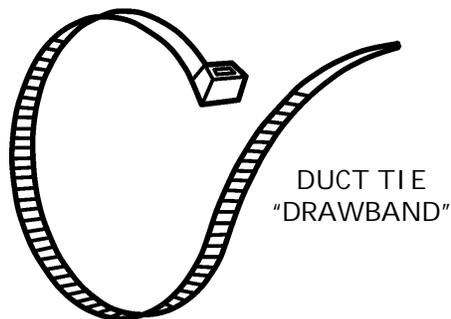
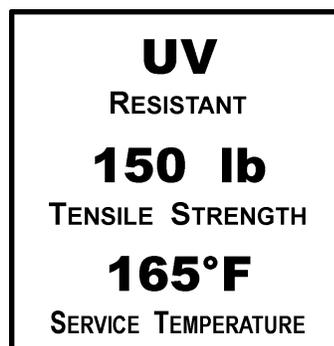
6. DUCT BOARD

- High Density Fiberglass Duct Board

- Conformance to ASTM C726, or NFPA 90B, or UL Class 1.

- Foam Board and Foam Sealant

- Not allowed as a barrier material or sealant in the repair of building cavities used as ducts, platforms, or other duct system components.

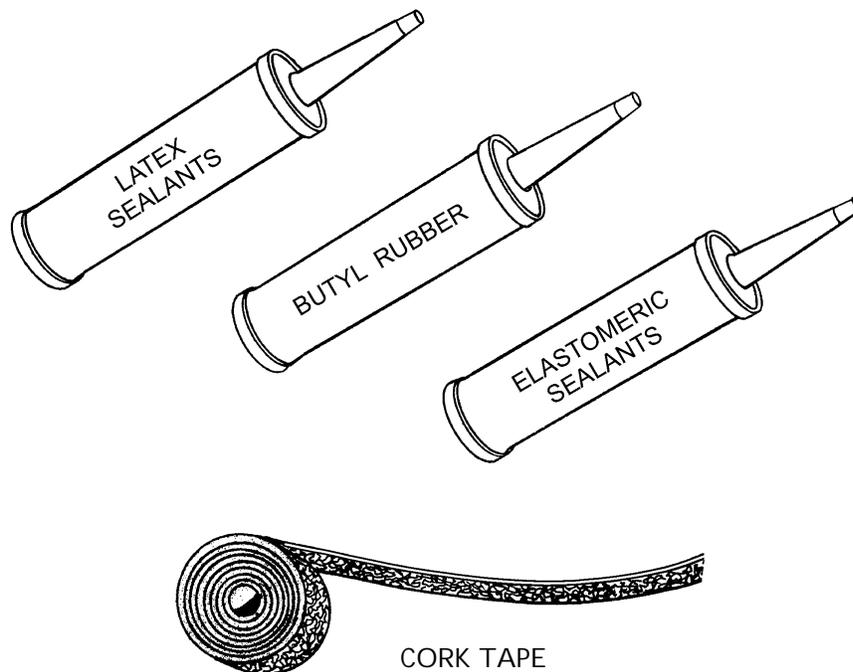


7. CAULKING MATERIALS

- **All Materials**
 - Shall be non-toxic.
 - Shall be selected and applied in accordance with Section 1.
- **Latex Sealing Compounds**
 - Conformance with ASTM C834.
- **Butyl Rubber Sealants**
 - Conformance with F.S. A-A-272A
- **Elastomeric Joint Sealants (Silicone, Polyurethane, Polysulfide)**
 - Conformance with ASTM C920 or F.S. A-A-1556A.

8. CORK TAPE

- **Shall be non-toxic.**
- **Shall be non-corrosive to copper.**
- **Elongation: 200% minimum.**
- **Hardening: 37% maximum.**



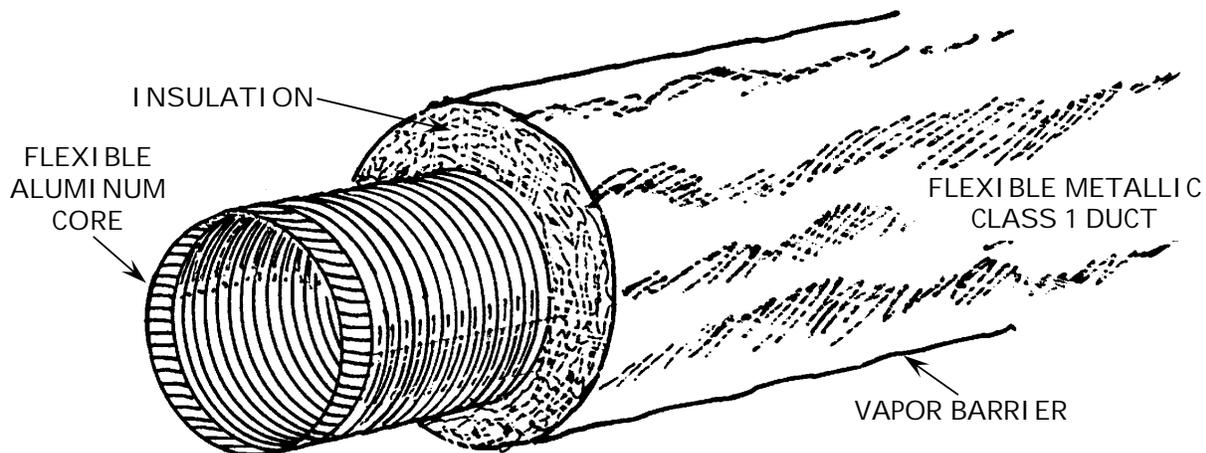
Section 20

9. ALL FLEXIBLE DUCTS

- Ducts shall conform to NFPA 90B and UL 181 Class 1.
- Nonmetallic insulated ducts with air-permeable core not allowed.
- Insulation minimum thermal resistance shall be as indicated below or greater if required by local code.
 - Natural Gas Heat
 - R-4.2 in CEC climate zones (CZ) 6 – 8.
 - R-6 in CZ 1 – 5 and 9 – 13.
 - R-8 in CZ 14 – 16.
 - Electric Heat
 - R-8 in all CZ.
- Vapor barrier (Jacket):
 - Thickness: 2.5 mils minimum.
 - Permeance: 1.0 perm maximum.
 - Degradation Protection: UV-resistant material (e.g., silver metalized polyester jacket).

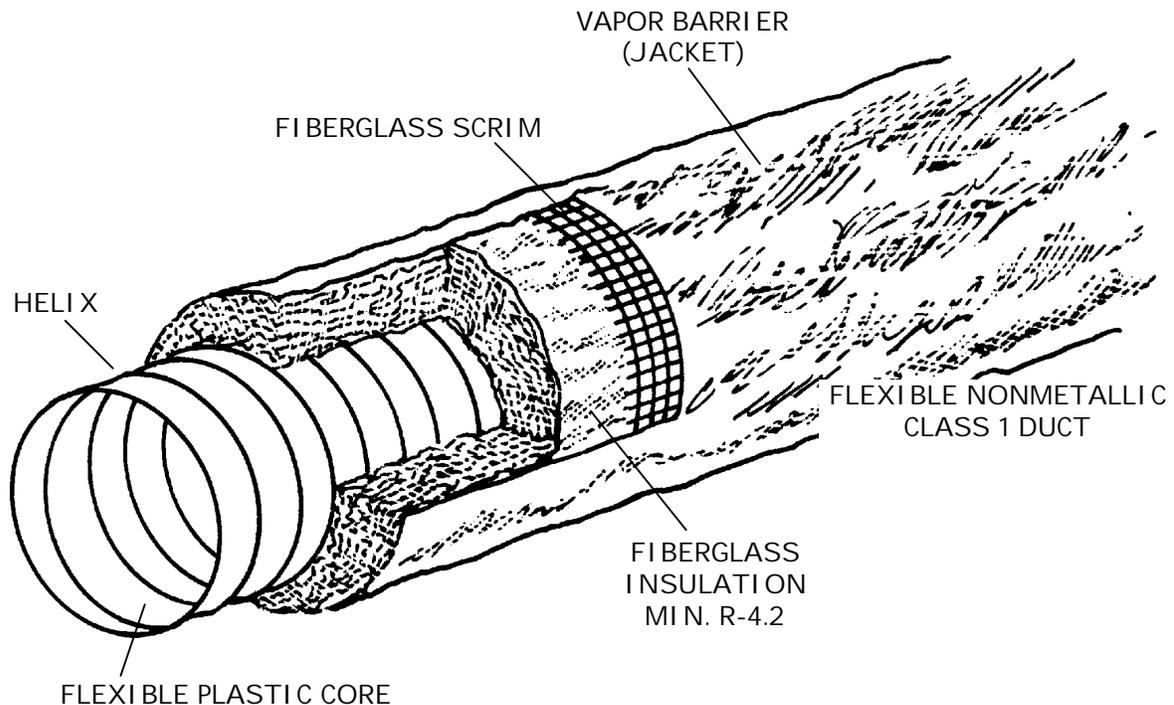
10. FLEXIBLE METALLIC DUCTS

- Ducts shall be rated to withstand the designated pressures and velocity of the system, but not less than:
 - 2 inches of water column (IWC) (500 Pa) positive pressure,
 - 0.75 IWC (188 Pa) negative pressure, and
 - 2500 fpm velocity.
- Core shall be fabricated from minimum 0.0065" thick aluminum material or equivalent.



11. FLEXIBLE NONMETALLIC DUCTS

- **Ducts shall be rated to withstand the designated pressures and velocity of the system, but not less than:**
 - 2 IWC (500 Pa) positive pressure,
 - 0.75 IWC (188 Pa) negative pressure, and
 - 2000 fpm velocity.
- **Duct Core (“Inner Liner”)**
 - Core shall be fabricated with a spring steel helix bonded within a nonporous material (e.g., molded composite or 2-ply lamination of polyester).
 - Air-permeable core not allowed.



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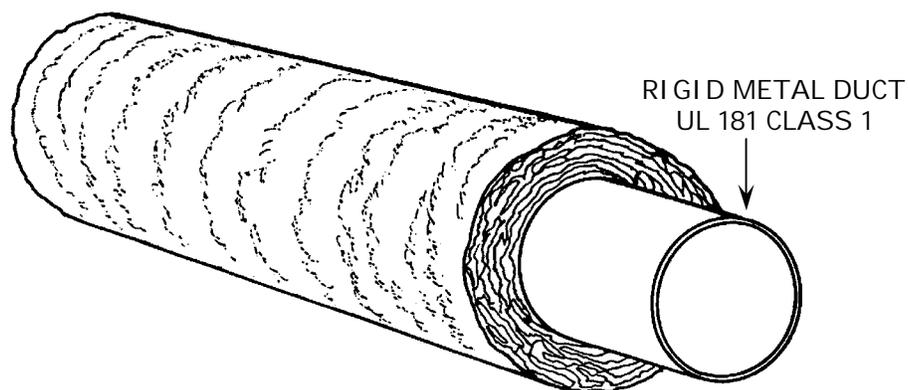
12. RIGID METAL DUCTS

- All Ducts

- Shall conform to NFPA 90B and UL 181 Class 1 or Class 0.
- Shall be constructed of noncorrosive material.
- Rectangular metal ducts shall conform to CMC requirements.
- Round metal ducts shall conform to minimum thickness requirements of the CMC, some of which are shown in Table 20-2.

TABLE 20-2: MINIMUM GAGE OF ROUND METAL DUCTS

ROUND METAL DUCTS AT POSITIVE STATIC PRESSURE UP TO 2 IWG (500 PA)		
DIAMETER OF DUCT	MIN. SHEET GAGE (GALVANIZED STEEL)	MIN. B. & S. GAGE (ALUMINUM)
Up to 14"	26	24
15" to 23"	24	22
24" to 37"	22	20
38" to 51"	20	18



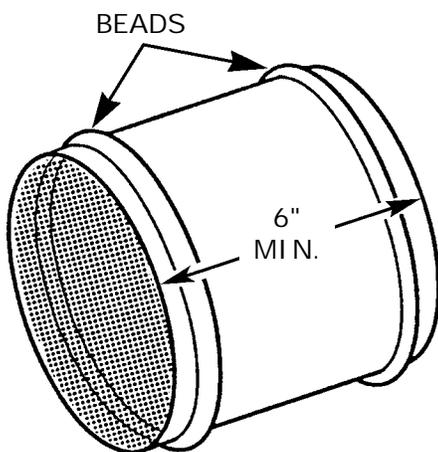
13. SHEET METAL

- All Rigid Components

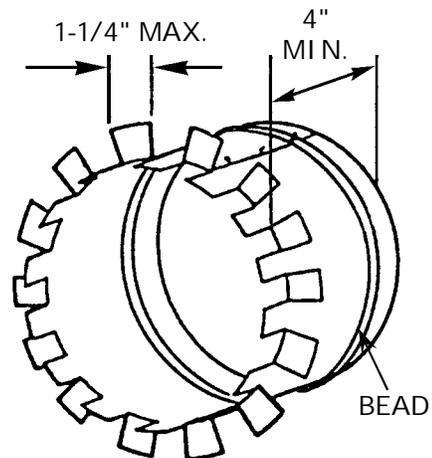
- Components shall be constructed of noncorrosive materials.
- Fittings (starting collars, splicing sleeves/couplings, adjustable elbows, wyes, etc.) shall have wall thickness (gage) no thinner than specified for attached ducts (per Item 12 and Table 20-2).

- New Fittings Used with Flexible Nonmetallic Ducts

- Starting Collars
 - 4" installed length (6" recommended).
 - 26 gage galvanized steel up to 14" diameter.
- Splicing Sleeves
 - 6" length (8" recommended).
 - 26 gage galvanized steel up to 14" diameter.
- All Fittings
 - Fittings shall be beaded at each core connection (e.g., both ends of a sleeve) when flexible nonmetallic ducts are attached.
 - Exception: When a preexisting fitting is not beaded, the core's wire coil shall be secured to the fitting as prescribed in Item 24.



BEADED SLEEVE MINIMUM 6" LONG FOR FLEXIBLE NONMETALLIC DUCTS



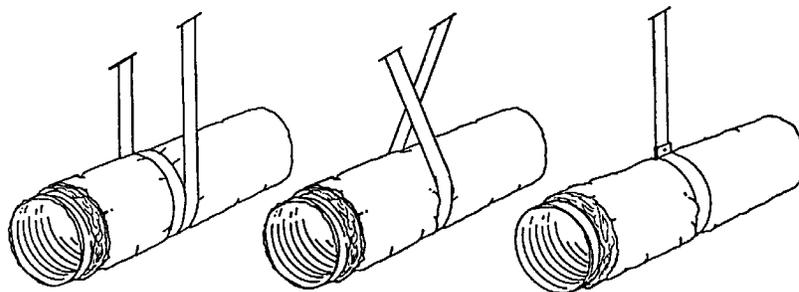
SHEET METAL COLLAR (DOVETAIL) MIN. 4" LONG AND BEADED FOR FLEXIBLE NONMETALLIC DUCTS

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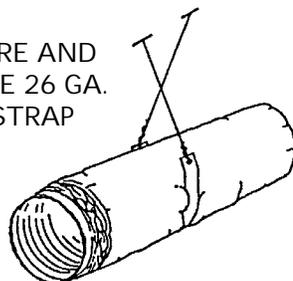
14. DUCT SUPPORTS

- **All Ducts**
 - Support materials shall be corrosion resistant and shall:
 - Conform to duct manufacturer's installation instructions.
 - Be installed in compliance with Item 18.
- **Flexible Ducts (Horizontal and Vertical)**
 - Nonmetallic Support Straps
 - May be used only if allowed by the local jurisdiction.
 - Polypropylene monofilament, woven polyester, polyester scrim reinforced vinyl laminate, or equivalent.
 - Minimum width: 1-3/4".
 - Minimum tensile strength: 70 lbs./inch of width.
 - Sheet Metal Support Straps and Saddles
 - Width: 1-1/2" minimum.
 - Thickness: 26 gage minimum.
 - Support Saddles
 - Shall fit neatly around and cover lower half (180°) of duct.
 - Shall not constrict inner diameter of duct nor cut the jacket.

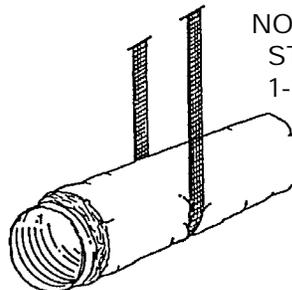
26 GA. SHEET METAL STRAP, MIN. 1-1/2" WIDE



18 GA. WIRE AND
1-1/2" WIDE 26 GA.
METAL STRAP



NONMETALLIC
STRAP, MIN.
1-3/4" WIDE



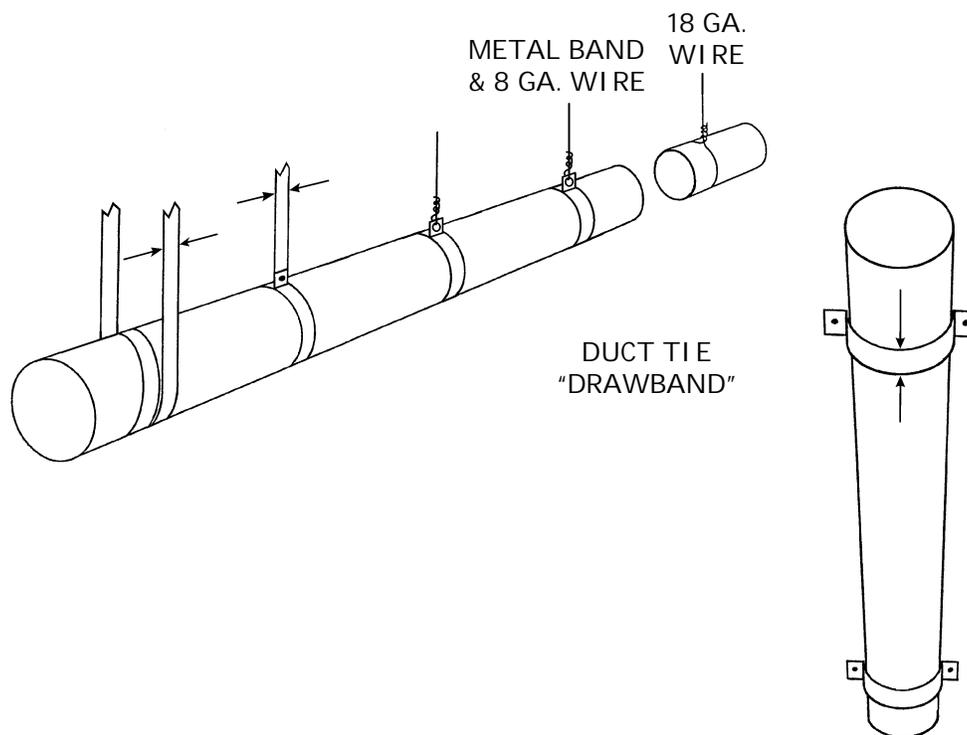
14. DUCT SUPPORTS (continued)

- **Horizontal Rigid Round Metal Ducts**

- Up to 10" Diameter
 - Galvanized steel straps, same gage as duct, 1" minimum width, or
 - 18 gage galvanized steel wire.
- 11" to 40" Diameter
 - Galvanized steel straps, same gage as duct, 1" minimum width, or
 - 8 gage galvanized steel wire tied to a galvanized steel band, 1" minimum width, surrounding the duct.

- **Vertical Rigid Round Metal Ducts**

- Up to 10" Diameter
 - 18 gage galvanized steel straps, 2" minimum width.
- 11" to 20" Diameter
 - 16 gage galvanized steel straps, 2" minimum width.

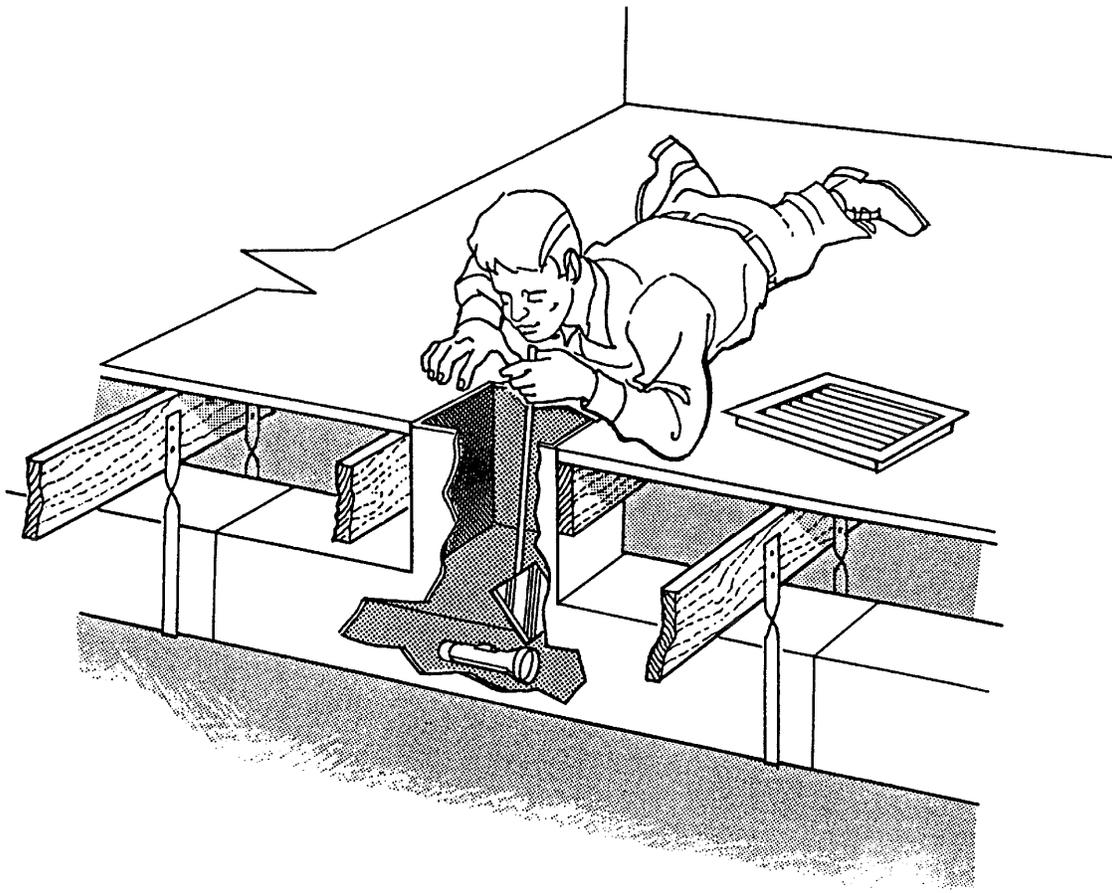


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DUCT SYSTEM DIAGNOSTICS

15. DUCT SYSTEM INSPECTION AND ANALYSIS

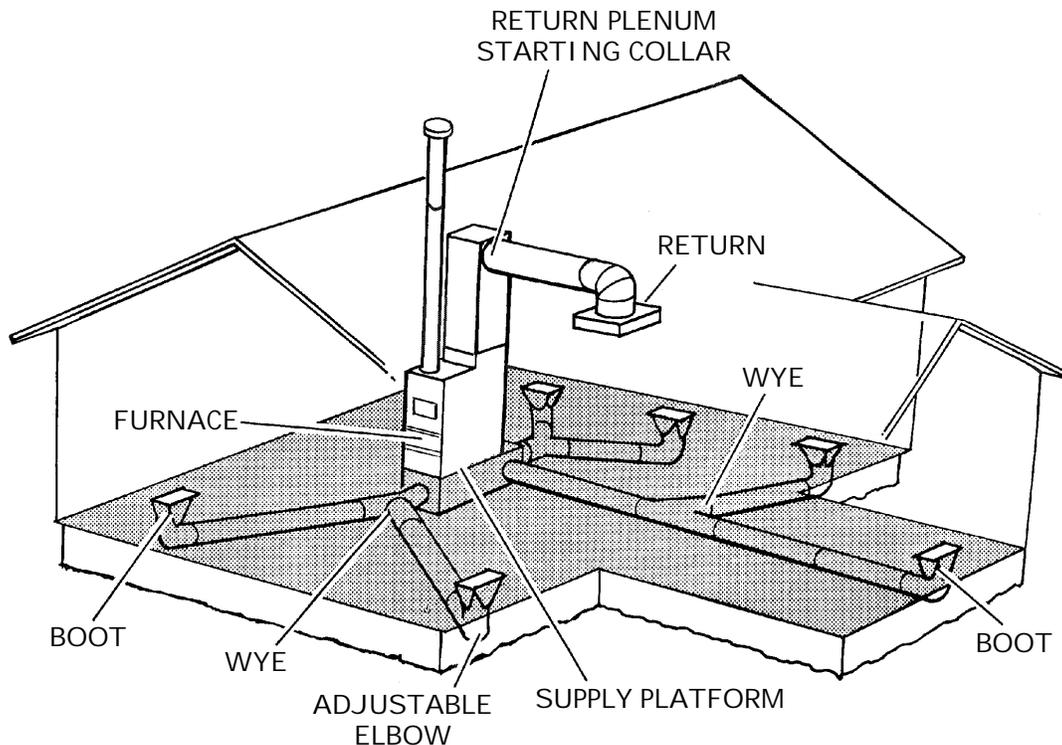
- **Asbestos Caution**
 - When any part of a duct system is known or suspected to be made of or insulated with asbestos, no action shall be taken which will cause such material to be unencapsulated or discharged into the air.
- **Internal Inspection of Ductwork**
 - Supply registers and return grilles shall be removed to facilitate inspection and performance of repair/sealing work.
 - A mirror and light shall be used as needed to perform the internal inspection of boot joints, connections and duct runs.



15. DUCT SYSTEM INSPECTION AND ANALYSIS (continued)

- External Inspection of Duct System

- The duct system shall be inspected for disconnections and other leaks and evidence of damage and deterioration.
- All accessible portions of the duct system shall be accessed (i.e., where crawl clearance is adequate per program Policies & Procedures).
- Diagnostics may include:
 - Pressurizing the duct system with a duct tester fan (e.g., Duct Blaster[®]) or blower door to locate leaks.
 - Checking plenums and starting collars and plenum/furnace connections (areas with largest pressures and leaks).
 - Shaking rigid ducts and looking for discolored fiberglass insulation.
 - Checking flex duct connections for loose or brittle cloth tape.
 - Checking metal flex ducts for evidence of crushed sections.
 - Checking for broken duct supports and ducts lying in the dirt.

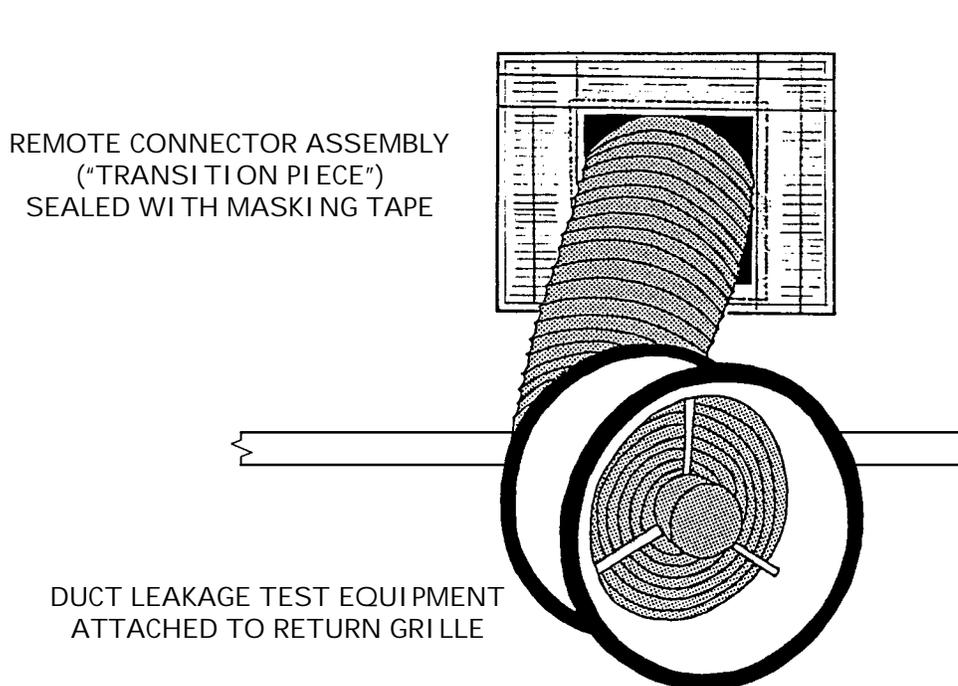


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15. DUCT SYSTEM INSPECTION AND ANALYSIS (continued)

- Pressure Diagnostics

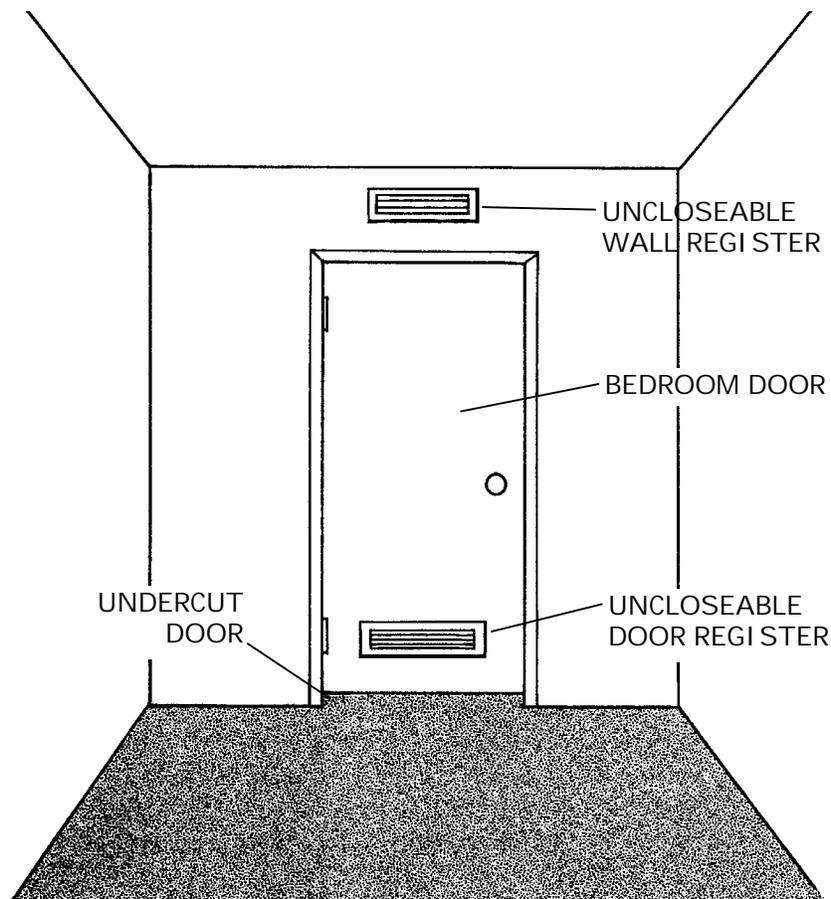
- When using a duct pressurization system (Duct Blaster[®]):
 - Registers/grilles shall be sealed (e.g., with masking tape).
 - Duct tester shall be attached to the return grille nearest the FAU, or as instructed by the manufacturer.
 - Ducts shall be pressurized to 25 Pa (0.1 iwc).
 - Test shall be performed in accordance with manufacturer's instructions, with the result being the measured duct leakage.
- Duct testing performed to determine whether duct sealing is feasible (initial leakage meets start criteria) and when to stop sealing (final leakage meets stop criteria) shall be performed as prescribed in Section 10, Duct Testing Standards.



15. DUCT SYSTEM INSPECTION AND ANALYSIS (continued)

- Duct System Balance

- Duct systems shall be balanced to provide adequate air movement throughout the living space with interior doors closed.
- Rooms closed off by doors from the FAU return intake shall be provided with an adequate return air path.
- The required return air path for each room shall be provided by a permanent means, such as one of the following:
 - A transfer or jump duct from the room to the hallway.
 - Uncloseable grilled or louvered venting in the door or wall.
 - An undercut door leading to the hallway.



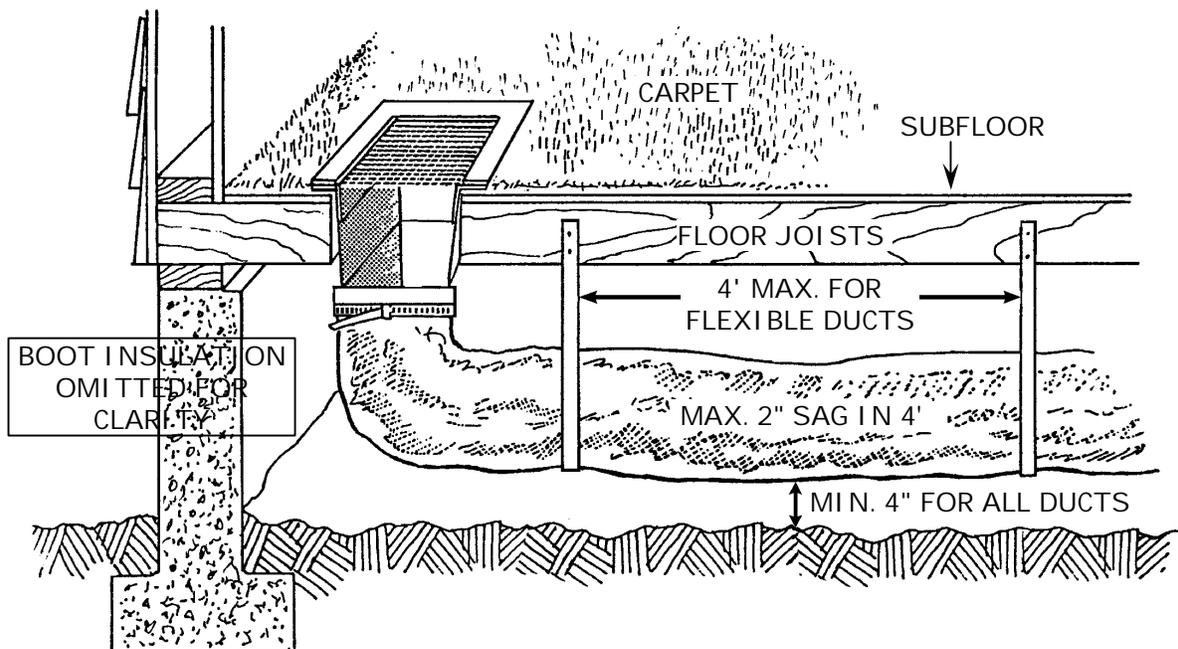
Section 20

DUCT INSTALLATION

16. GENERAL INSTALLATION CRITERIA

- All Duct Installations

- Installation shall comply with these standards, manufacturer's instructions and local codes, with the more stringent requirements taking precedence.
- Ducts shall be:
 - Installed with at least 4" of separation from earth.
 - Protected from physical damage.
 - Installed in locations not exposed to the weather, unless designed for exterior use.
 - Supported as prescribed in Item 18.
- Ducts installed within a closet or room shall be enclosed within a cavity constructed of materials equivalent to those used in construction of the closet/room.
- A building cavity shall not be used as a duct without a sealed duct board or metal liner.
- Existing platform returns shall be sealed per Item 30.

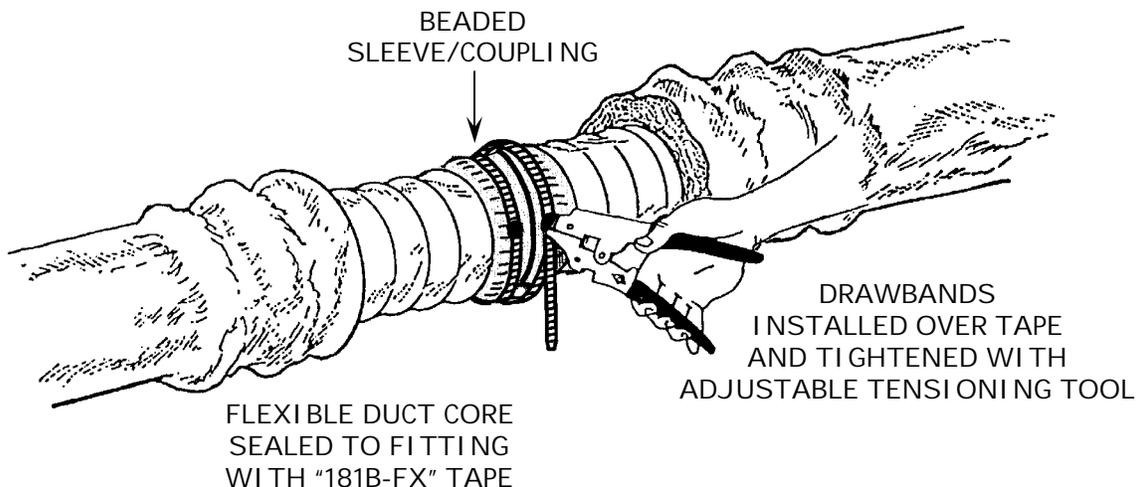


16. GENERAL INSTALLATION CRITERIA (continued)

- **Surface Preparation**
 - Preparation shall be in conformance with duct and sealant manufacturers' instructions.
 - Surfaces shall be:
 - Cleaned prior to application of tapes and sealants.
 - Free of dust, dirt, oil, grease, moisture and similar substances.
- **Air Handler Operation**
 - Air handler shall:
 - Be off during the application of all tapes and sealants.
 - Remain off for the drying time specified by sealant manufacturer.

17. DRAWBAND INSTALLATION

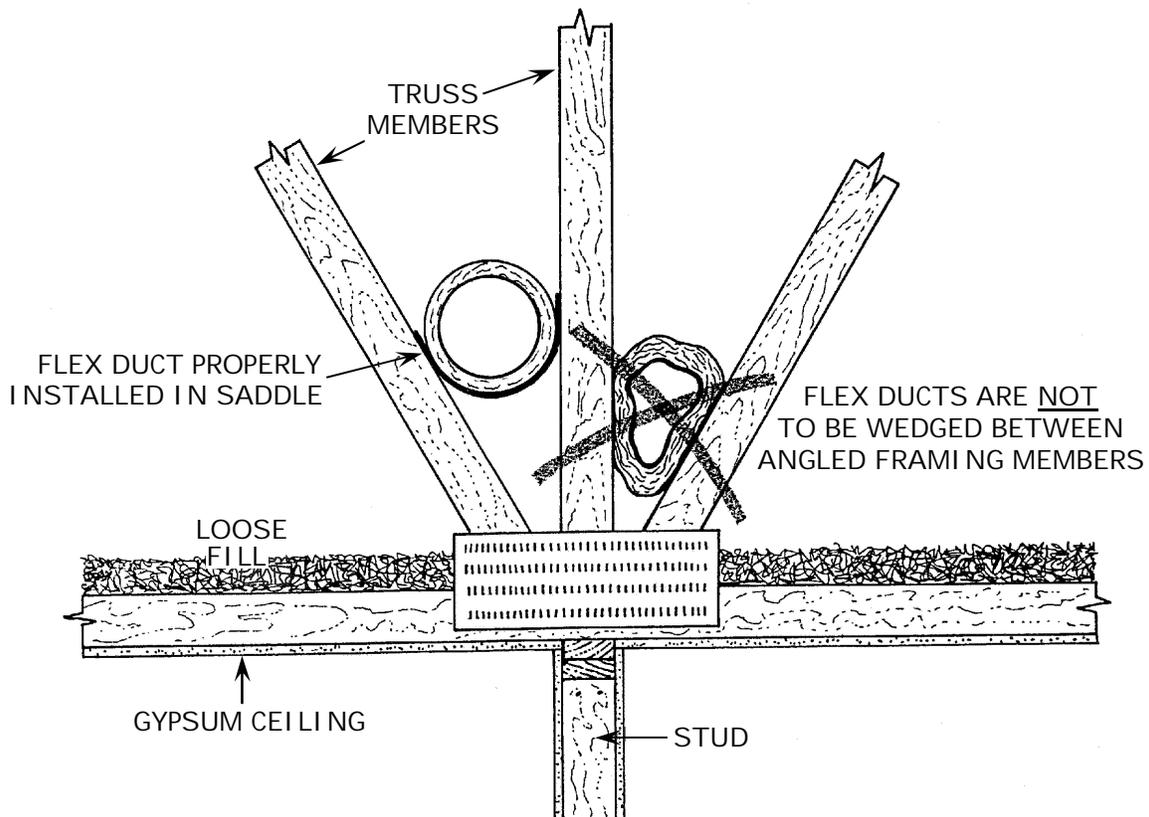
- **Drawbands used to secure flexible nonmetallic ducts shall be installed:**
 - In accordance with manufacturer's instructions.
 - Behind the bead when the fitting is beaded.
 - Tightened appropriately with an adjustable tensioning tool.
 - With the excess (tail) removed.
- **Stainless steel worm-drive clamps may also be used.**



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18. DUCT SUPPORT INSTALLATION

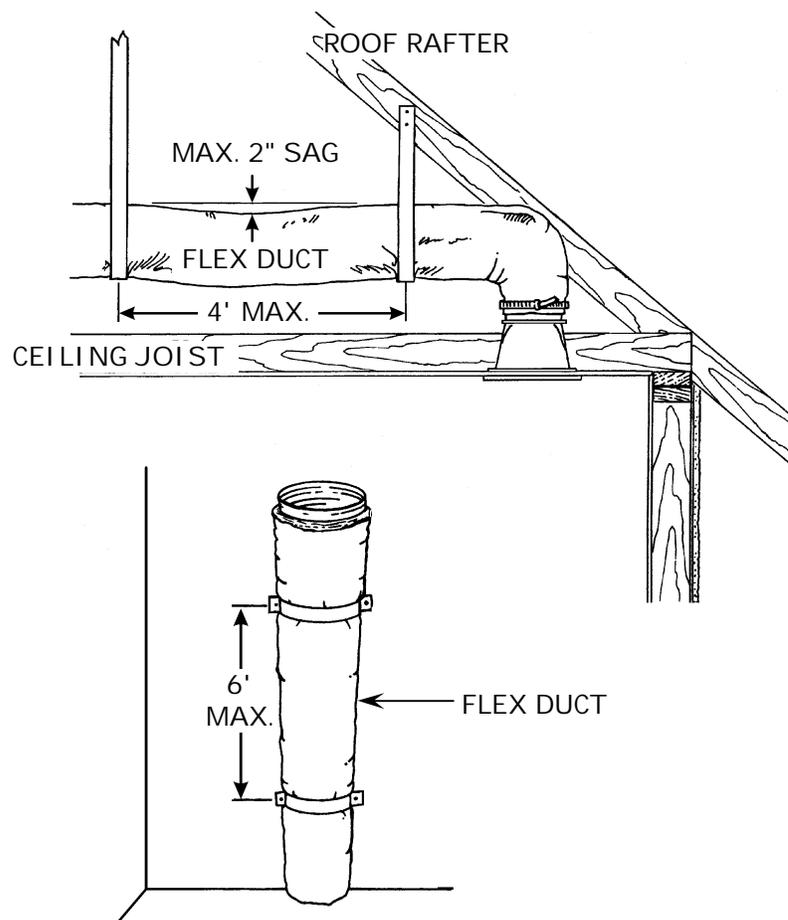
- **All Duct Supports shall:**
 - Comply with duct manufacturer's instructions and local code.
 - Be installed in accordance with support manufacturer's instructions.
- **Flexible Ducts**
 - All Installations
 - Straps and other means of support shall not constrict the duct below its rated internal diameter.
 - Duct may rest on ceiling joists or truss members, if:
 - Support spacing and sag limitations are met.
 - Duct is not wedged between truss members.
 - Termination devices (e.g., register boots) shall be properly secured and shall not rely upon duct for support.



18. DUCT SUPPORT INSTALLATION (continued)

- Flexible Ducts (continued)

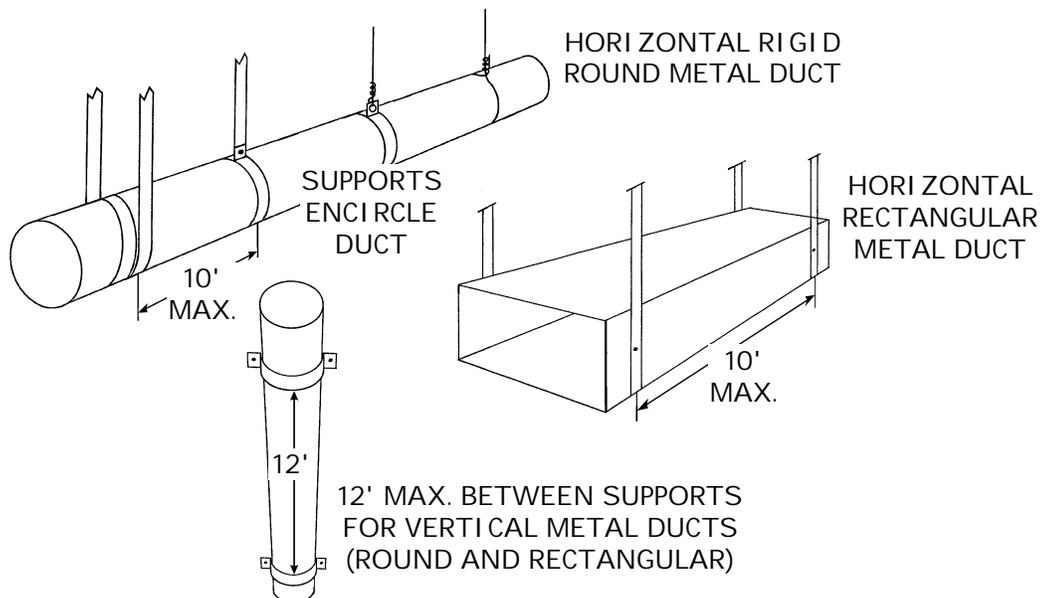
- Nonmetallic Support Straps
 - Acceptable when allowed by the local jurisdiction.
 - At each end, at least 2" shall be folded over and secured by two or more anchors that penetrate both layers of strap material.
- Horizontal Flexible Ducts
 - Spacing between supports shall be 4' maximum.
 - Sag shall be no more than:
 - 1/2" per foot of distance between supports.
 - 2" between supports.
- Vertical Flexible Ducts
 - Spacing between supports shall be 6' maximum.



Section 20

18. DUCT SUPPORT INSTALLATION (continued)

- **Rigid Round Metal Ducts**
 - Horizontal Installations
 - Spacing between supports shall be 10' maximum.
 - Support shall tightly encircle the duct.
 - Vertical Installations
 - Spacing between supports shall be 12' maximum.
- **Rigid Rectangular Metal Ducts**
 - Horizontal Installations
 - Spacing between supports shall be 10' maximum.
 - Support straps shall be secured to sides of duct with sheet metal screws, rivets or bolts.
 - Vertical Installations
 - Spacing between supports shall be 12' maximum.
- **Rigid Fiberglass Ducts**
 - Ducts shall be supported and reinforced in conformance with the CMC and local code.
- **Horizontal Plenums (Metal and Fiberglass Duct Board)**
 - Shall not rely on furnace for support.
 - Shall be independently supported at each end, and intermediately if over 10' in length.



DUCT REPAIR AND SEALING

19. DUCT CLOSURE SYSTEMS

- **All Closure Systems**
 - Sealants shall be applied per manufacturer’s instructions.
 - A complete, durable seal shall be achieved.
 - Pressure sensitive tapes shall be marked, and mastic containers shall be labeled, in conformance with:
 - UL 181B for flexible metallic and nonmetallic ducts.
 - UL 181A or 181B for rigid metal ducts and components.
 - Exception: Butyl tape without UL 181 markings may be used to seal rigid metal-to-metal connections, per Item 4.
- **Gap Size and Sealing Materials**
 - Sealing materials shall be selected in conformance with Table 20-3.
 - Flexible duct connections with gaps wider than 1/4" shall be replaced with properly-sized duct and/or fitting.
 - For rigid metal ducts, gaps 1" or wider shall be repaired with a sheet metal patch (Item 28) or sleeve.

TABLE 20-3: GAP SIZE AND APPROVED SEALING MATERIALS

GAP SIZE	FLEXIBLE METALLIC & NONMETALLIC DUCTS		RIGID METAL & FIBERGLASS DUCT	
	Sealing with MASTIC	Sealing with TAPE	Sealing with MASTIC	Sealing with TAPE
≤ 1/4"	Mastic	Tape	Mastic	Tape
> 1/4" - < 1"	Repair Required*	Repair Required*	Mastic & Mesh	Mastic over Tape
1" or more	Repair Required*	Repair Required*	Metal Patch or Sleeve & Mastic	Metal Patch or Sleeve & Tape

***Duct and/or fitting must be replaced with proper size.**

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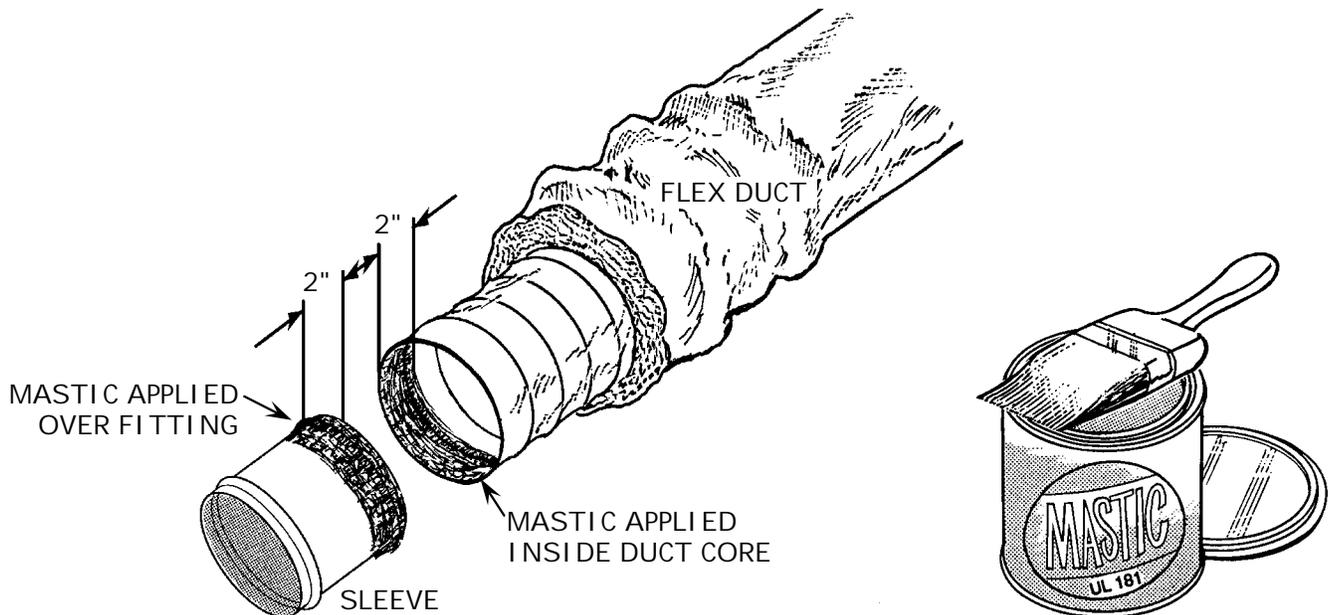
19. DUCT CLOSURE SYSTEMS (continued)

- Externally-Applied Closure Systems

- Sealing materials shall:
 - Be centered over the joint or gap, and
 - Extend at least 1" onto each of the two joined/sealed surfaces.

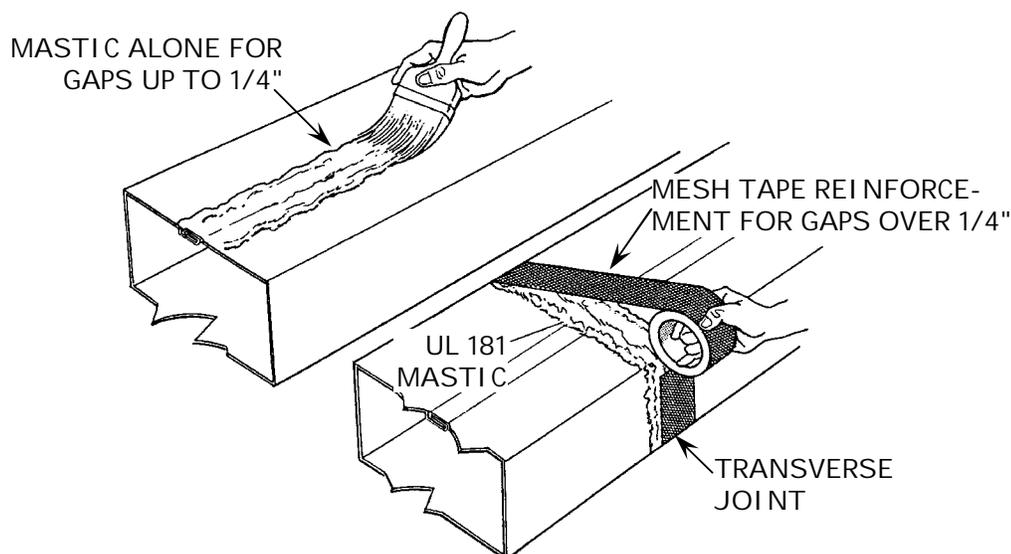
- Internally-Placed Mastic Sealant (Core-to-Fitting Joints)

- Mastic may be applied either:
 - Inside the duct core, or
 - Onto the rigid component over which the core is attached.
- Mastic coating shall be at least 1/8" thick and 2" wide.



20. SEALING WITH MASTIC

- **Mastic shall be applied as prescribed by manufacturer, including:**
 - Surface preparation/cleaning.
 - Temperature and moisture limitations.
 - Thickness and set-up time.
- **Rigid Metal and Fiberglass Ducts and Components**
 - Mastic by itself may be used to seal gaps up to 1/4".
 - Mastic shall be reinforced with fiberglass mesh tape when used to seal gaps larger than 1/4".
 - Gaps 1" or wider shall be repaired and sealed:
 - Metal ducts per Item 28.
 - Fiberglass ducts repaired with fiberglass duct board or sheet metal and screws, and sealed with mastic or metallic tape.
- **Flexible Metallic and Nonmetallic Ducts**
 - Mastic used to seal core-to-fitting connections may be:
 - Externally applied over the duct core and rigid fitting, or
 - Internally placed between the core and the fitting.
 - Externally-Applied Mastic
 - Mastic shall be reinforced with fiberglass mesh tape when mastic is used to seal the jacket (vapor barrier).
 - When a gap greater than 1/4" exists between the duct core and the fitting (starting collar, coupling, elbow, wye, etc.), duct and/or fitting must be replaced with the proper size (see Item 19).

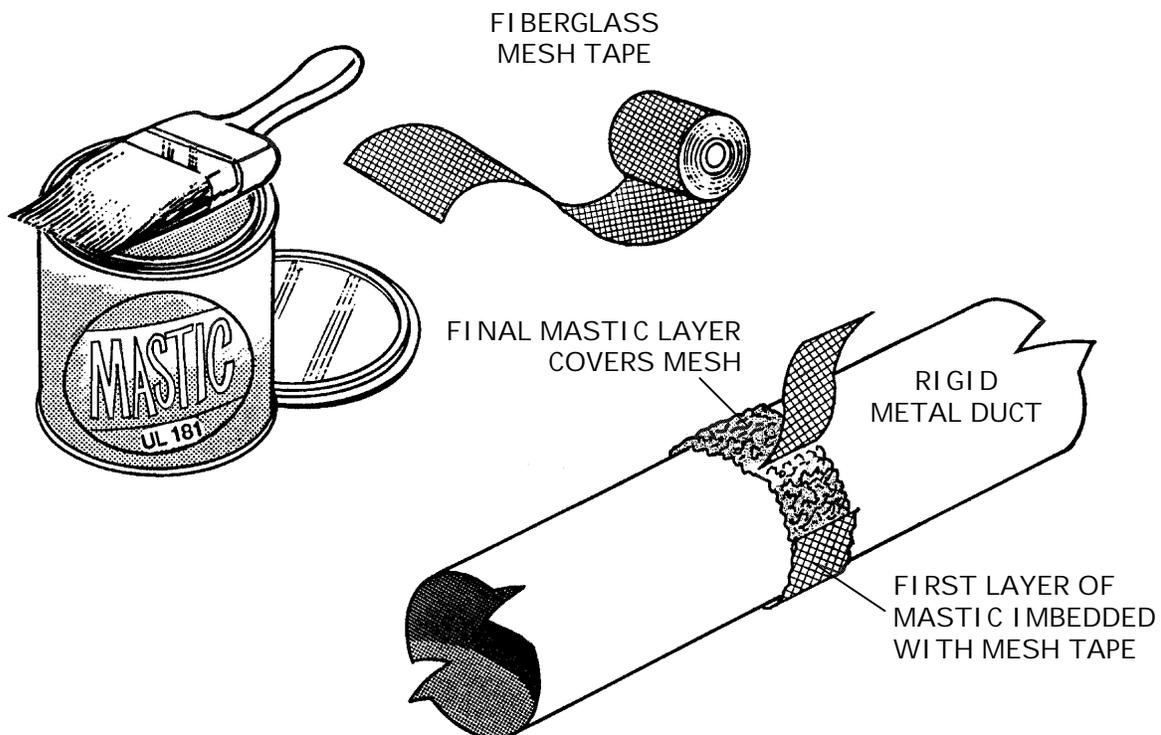


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20. SEALING WITH MASTIC (continued)

- Reinforcement of Mastic with Fiberglass Mesh Tape

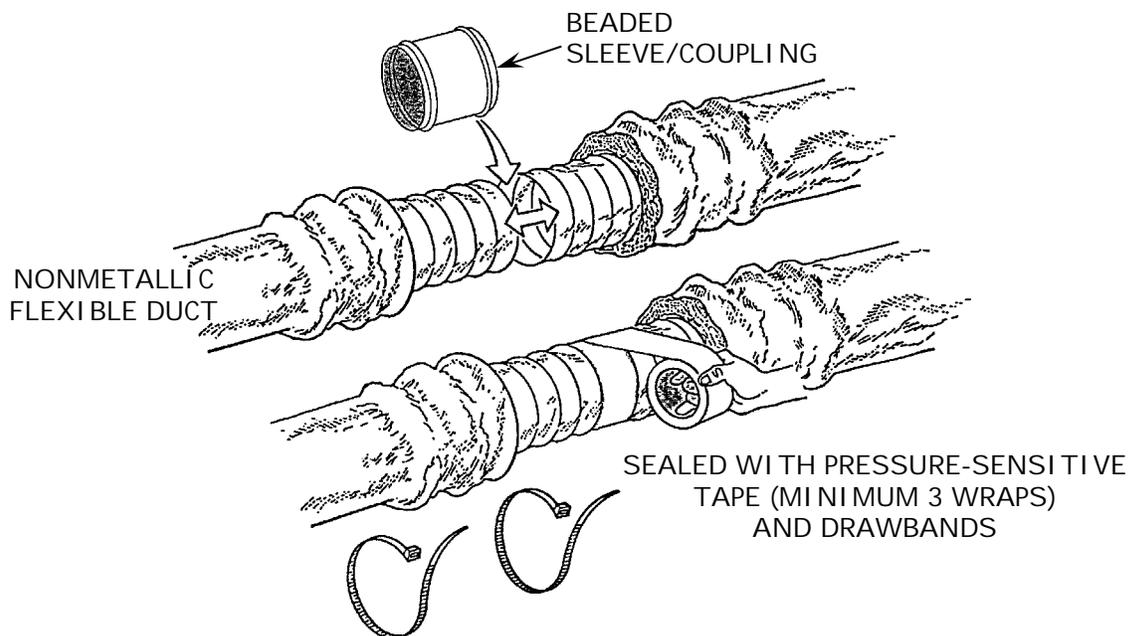
- Mesh fabric shall be imbedded between two layers of duct mastic to form a mastic closure system.
 - The first layer of mastic shall:
 - Be centered over the joint or gap to be sealed.
 - Extend at least 1" onto each of the joined surfaces.
 - Extend beyond the width of the mesh.
 - The mesh fabric shall be:
 - Embedded in the mastic.
 - Applied at least one layer thick over the entire joint or gap.
 - Wrapped around the entire circumference on transverse joints (e.g., where two sections of duct are joined together).
 - A second layer of mastic shall be installed over the mesh, filling the scrim pattern completely and covering the mesh.



21. SEALING WITH PRESSURE SENSITIVE TAPE

- All Pressure Sensitive Tapes

- Tapes shall be installed as prescribed by manufacturer, including:
 - Surface preparation/cleaning.
 - Application of pressure/rubbing.
 - Temperature and moisture limitations.
- Successive wraps of tape shall be staggered and should overlap by 50 to 75% of the tape width.
- At least 3 wraps of tape shall be applied when sealing:
 - Transverse joints at splices and connections in round or rectangular metal ducts.
 - Flexible duct core-to-fitting attachments (with a drawband also installed to secure the core).
 - Jacket (vapor barrier) splices on flexible ducts.
- When gaps over 1/4" up to <1" wide are sealed with tape:
 - Tape shall be applied as prescribed above and then covered with duct mastic.
 - The mastic shall be applied at least 1/8" thick over the installed tape to provide additional strength and durability.
 - Mastic shall extend beyond the width of the tape.



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21. SEALING WITH PRESSURE SENSITIVE TAPE (continued)

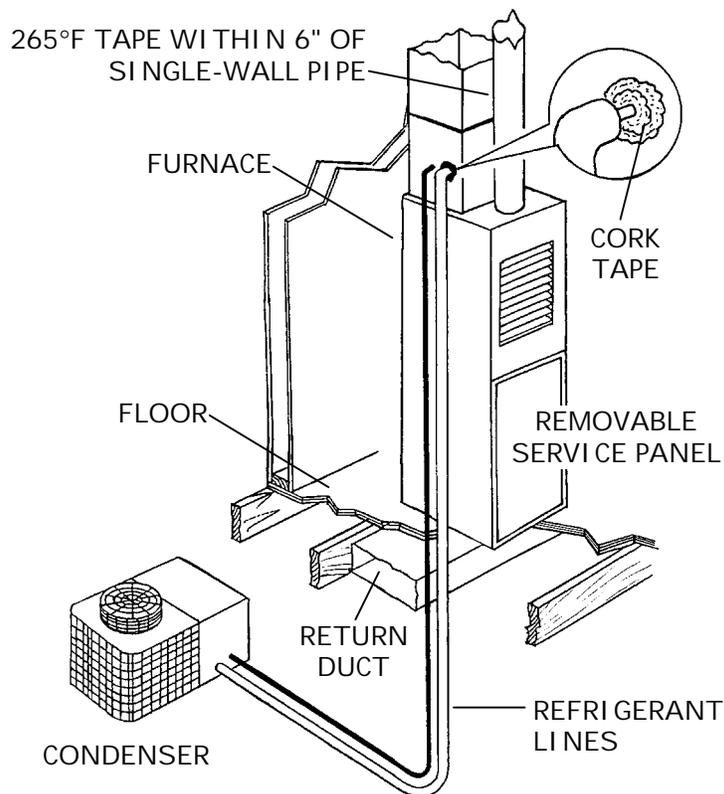
- **Tapes for Rigid Metal Connections**
 - Metallic pressure sensitive tapes shall be used.
- **Tapes for High Temperature Applications**
 - Metallic pressure sensitive tape with a service temperature rating of at least 265°F shall be used when sealing:
 - Within 1" of a double-wall gas flue/vent pipe.
 - Within 6" of a single-wall gas flue/vent pipe.

22. SEALING REFRIGERANT LINES

- **Sealant**
 - Cork tape shall be used for sealing gaps where refrigerant lines penetrate the coil box/plenum.

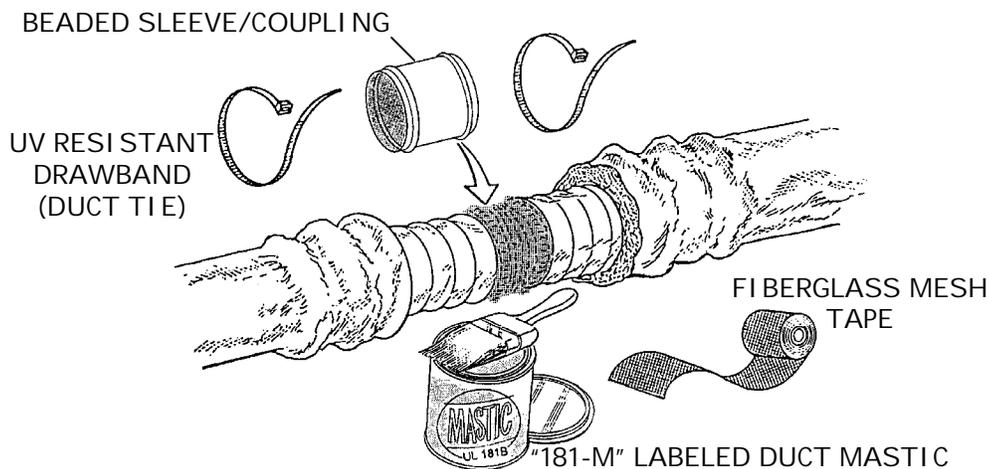
23. SEALING REMOVABLE SERVICE PANELS

- **Sealant**
 - UL 181A or 181B metallic pressure sensitive tape with non-butyl (e.g., acrylic) adhesive shall be used to seal service panels, filter access covers, etc.



24. REPAIRING AND SEALING FLEXIBLE NONMETALLIC DUCTS

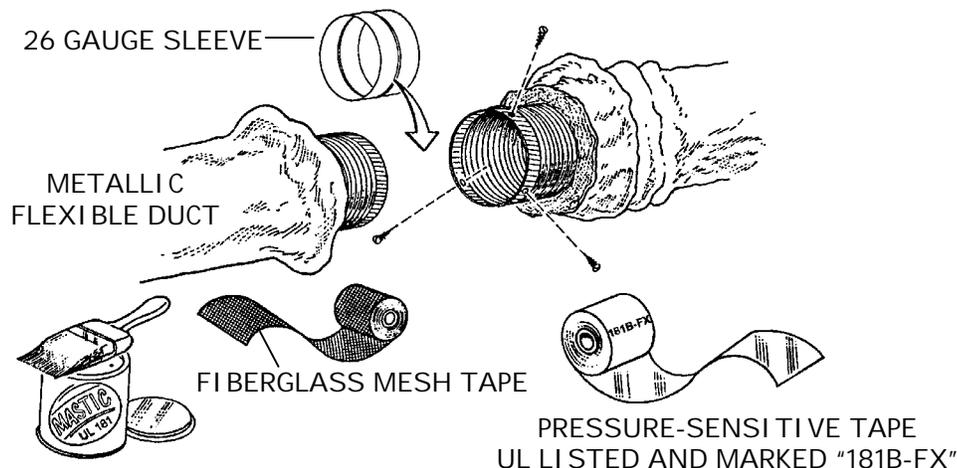
- **Beaded Fittings—Mastic Sealants**
 - A uniform coat of mastic is applied to the outside of the fitting.
 - At least 2" of duct core is pulled onto the fitting, with at least 1" extending past the bead.
 - A drawband (or metal clamp) is installed behind the bead.
 - Mastic is applied externally as needed to ensure a complete seal.
- **Beaded Fittings—Pressure Sensitive Tapes**
 - At least 2" of duct core is pulled onto the fitting, with at least 1" extending past the bead. (Fitting must provide additional 1" surface beyond duct core for application of tape.)
 - A drawband (or metal clamp) is installed behind the bead.
 - Connection is sealed with at least 3 staggered wraps of tape applied uniformly over both the core and the fitting.
- **Non-Beaded Pre-existing Fittings—All Sealants**
 - The duct core is secured to the fitting with internally-placed mastic and a drawband, or
 - The duct core's wire coil is secured to the fitting with evenly-spaced #8 sheet metal screws that capture the wire.
 - Screws must penetrate "181B-FX" pressure sensitive tape applied over the duct core to protect it from tearing.
 - 3 screws for diameters up to 12"; 5 screws for diameters over 12".
 - The connection is sealed with duct mastic or 3 staggered wraps of pressure sensitive tape.
- **Core Repairs**
 - Holes/damage in the duct core shall be repaired by removal of the damaged section and insertion of a sleeve/coupling.



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25. REPAIRING AND SEALING FLEXIBLE METALLIC DUCTS

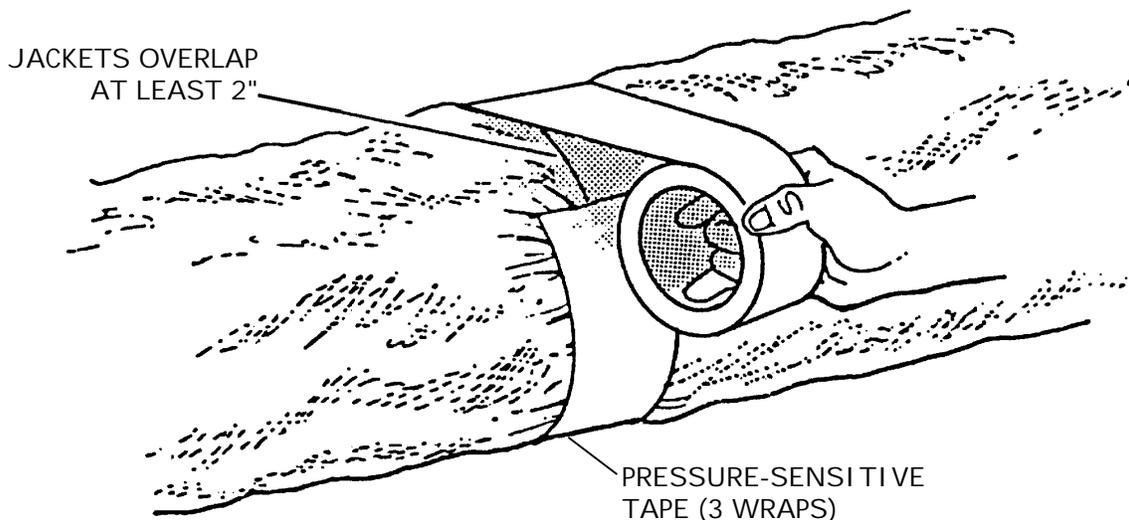
- **Factory-installed Sleeve Present**
 - Connection shall be secured and sealed, like rigid metal ducts, per Item 27.
- **Factory-installed Sleeve Not Present**
 - The end of the core shall be trimmed squarely, then secured and sealed as described below.
 - Sealing with Mastic
 - A uniform coat of mastic is applied to outside of the fitting.
 - At least 1" of the duct core is pulled over the fitting and secured with screws (see below).
 - Mastic is applied externally as needed to ensure a complete seal.
 - Sealing with Pressure Sensitive Tape
 - At least 1" of duct core is pulled over the fitting and secured with screws (see below).
 - Fitting must provide additional 1" surface beyond duct core.
 - Connection is sealed with at least 3 staggered wraps of tape applied uniformly over both the core and the fitting.
 - Installation of Screws
 - The core is secured to the fitting with #8 sheet metal screws positioned at least 1/2" from the end of the core.
 - Screws are equally spaced.
 - 3 screws for duct diameters under 12".
 - 5 screws for diameters 12" and over.
- **Core Repairs**
 - Holes/damage in the duct core shall be repaired by removal of the damaged section and insertion of a sleeve/coupling.



20-28

26. FLEXIBLE DUCT INSULATION AND JACKET

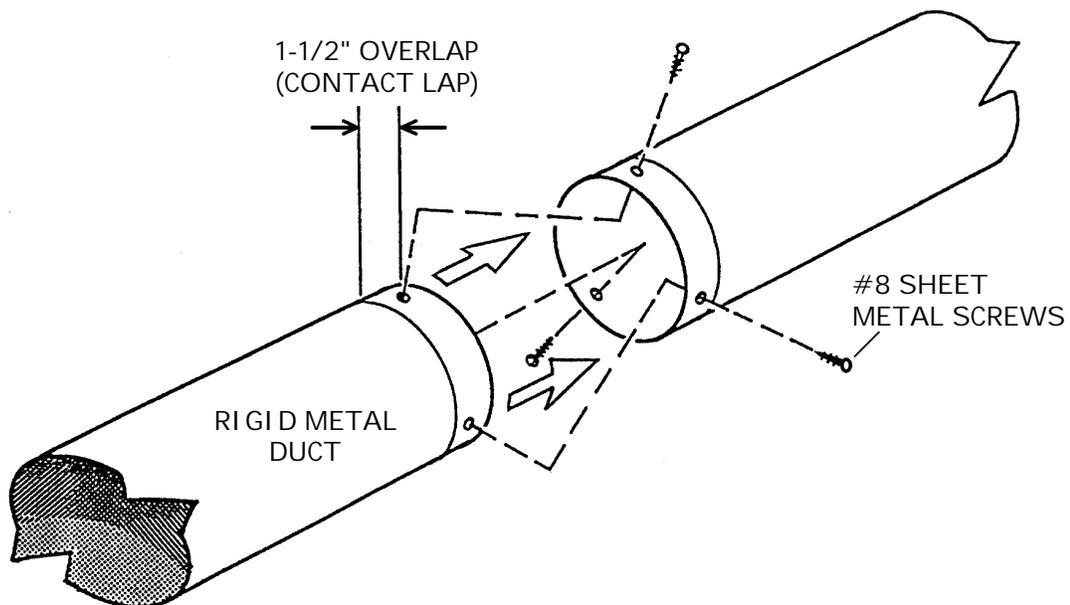
- Insulation shall completely cover the duct core and fitting.
- Jacket (Vapor Barrier)
 - The jacket shall be pulled back over the insulation.
 - The jackets shall overlap at least 2" at splices.
 - Jackets shall be secured/sealed with a drawband and/or 3 staggered wraps of pressure sensitive tape.
- Jacket Repairs
 - Rips and holes in the vapor barrier shall be repaired with pressure sensitive tape or with mastic and mesh tape.
 - Ducts with *Air-Permeable Core*:
 - The jackets shall be overlapped at least 2" at splices.
 - Jacket ends at splices and connections shall be secured and sealed with:
 - 3 staggered wraps of minimum 2" pressure sensitive tape, or
 - Mastic applied between the jackets and secured with a drawband.
 - Breaches in the outer vapor barrier shall be sealed with pressure sensitive tape, or mastic and mesh tape.



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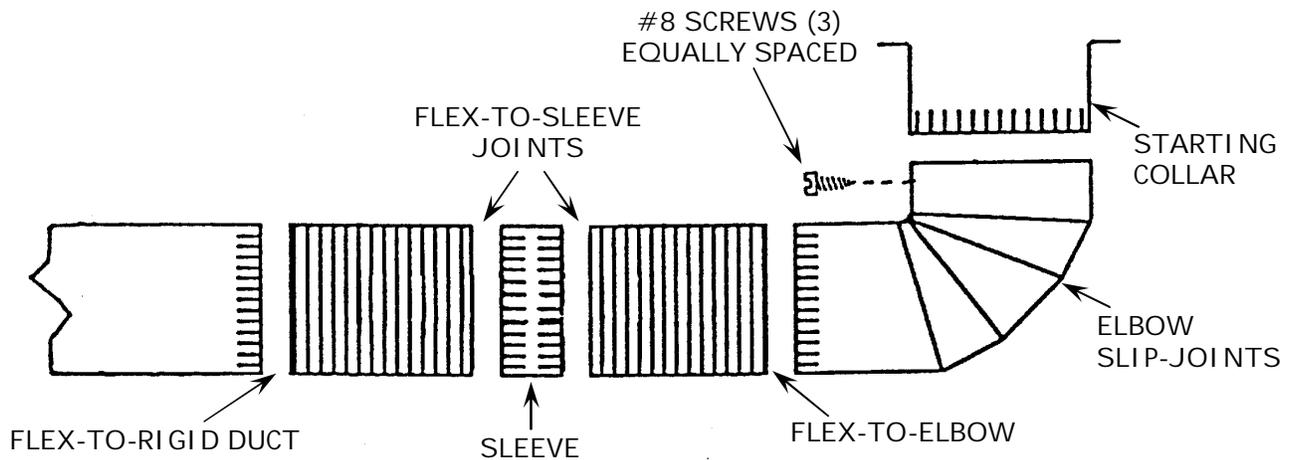
27. REPAIRING AND SEALING RIGID METAL DUCTS

- **Rigid Metal Connection Contact Lap**
 - Crimp joints shall overlap at least 1-1/2" (e.g., connection of duct to fitting, or two sections of duct).
- **Mechanical Fasteners**
 - Rigid metal duct connections shall be secured with equally-spaced #8 sheet metal screws.
 - Round Ducts
 - 3 screws on diameters up to 14".
 - 4 screws on diameters 15" to 19".
 - 5 screws on diameters 20" to 24".
 - Rectangular Ducts
 - At least 1 screw per side.
 - Lapped Seams (Field Fabricated Metal Plenums, etc.)
 - Overlapped surfaces shall be:
 - In substantial contact with each other along the entire seam.
 - Securely fastened together (e.g., with #8 sheet metal screws at intervals of 12" or less).



27. REPAIRING AND SEALING RIGID METAL DUCTS (continued)

- **Gaps 1/4" or smaller may be sealed with:**
 - Duct mastic, or
 - Metallic pressure sensitive tape.
- **Gaps over 1/4" up to less than 1" wide shall be sealed with:**
 - Duct mastic with embedded fiberglass mesh, or
 - Metallic pressure sensitive tape covered with mastic.
- **Gaps 1" or wider shall be:**
 - Repaired with a sleeve or a sheet metal patch (per Item 28), and
 - Sealed with mastic or tape.
- **All Connections**
 - Mastic and fiberglass mesh shall be installed per Item 20.
 - Metallic pressure sensitive tapes shall be installed per Item 21.

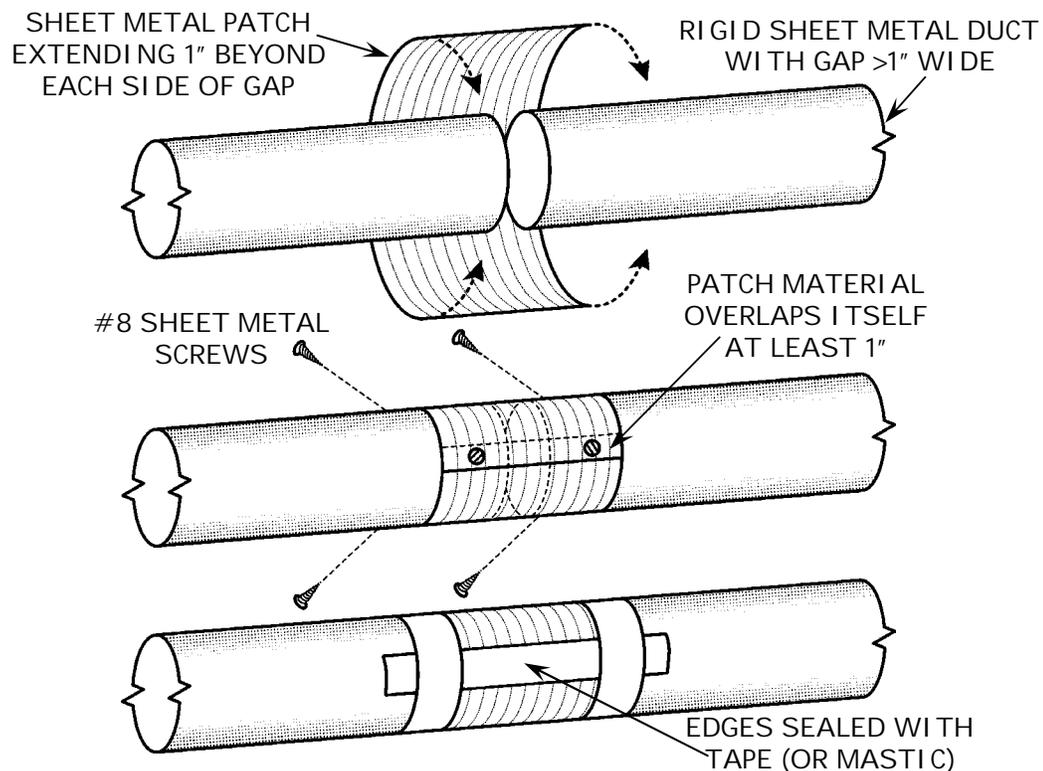


- TAPE OR MASTIC ON GAPS UP TO 1/4"
- MASTIC & MESH, OR METALLIC TAPE COVERED BY MASTIC, ON GAPS OVER 1/4"

Section 20

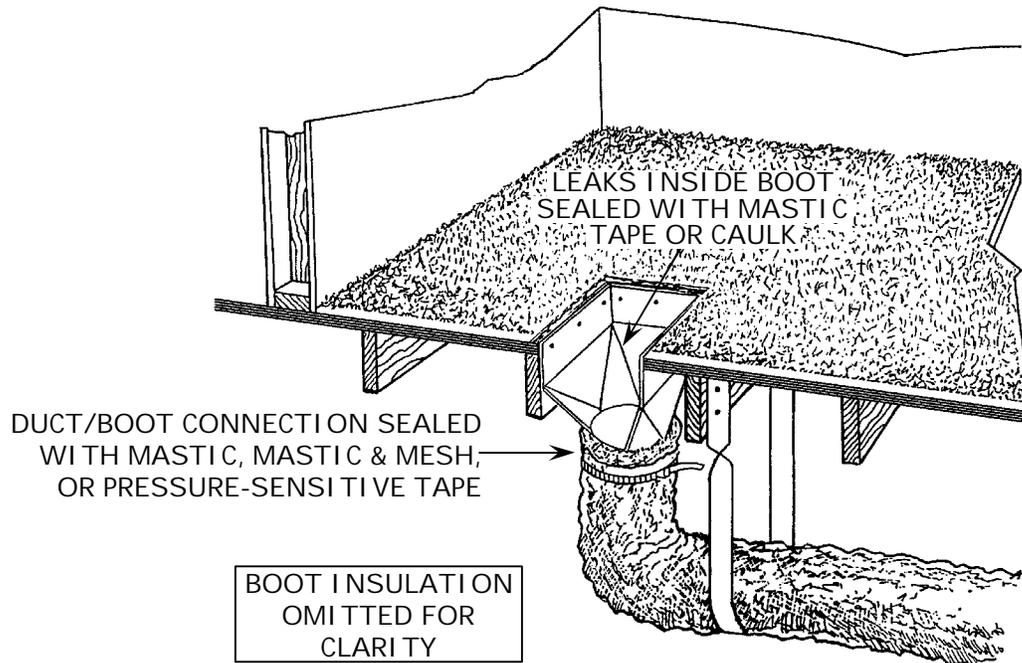
28. SHEET METAL PATCHES FOR RIGID METAL DUCTS

- **Material**
 - Patch material shall match the existing duct material (i.e., galvanized patch for galvanized duct, or aluminum patch for aluminum duct).
 - Gauge of the patch shall equal or exceed gauge of the existing duct.
- **Installation**
 - Patch material shall:
 - Extend at least 1" beyond each edge of the gap, and
 - Overlap itself by at least 1".
 - The patch shall be wrapped tightly around the duct and secured with #8 sheet metal screws.
 - Where the patch overlaps itself, at least 1 screw shall be installed on each side of the gap.
 - At least 2 more screws shall be evenly-spaced around the duct on each side of the gap.
- **Sealing**
 - All patch edges/gaps shall be sealed per Item 27.



29. SEALING REGISTER BOOTS

- **Boot-to-Duct Connection**
 - Flexible nonmetallic ducts shall be connected and sealed per Items 24 and 26.
 - Flexible metallic ducts shall be connected and sealed per Items 25 and 26.
 - Rigid metal ducts shall be connected and sealed per Item 27.
- **Leaks in the Boot**
 - Gaps 1/4" or smaller may be sealed with:
 - Duct mastic, or
 - Metallic pressure sensitive tape.
 - Gaps over 1/4" up to <1" shall be sealed with:
 - Duct mastic with embedded fiberglass mesh, or
 - Metallic pressure sensitive tape covered by mastic.
 - Gaps up to 3/8" may be sealed with elastomeric caulk.
 - Gaps 1" or wider:
 - Gap shall be repaired with sheet metal and #8 screws, and
 - Sealed as prescribed above for "Leaks in the Boot".
- **Boot Sealing Material**
 - Shall not interfere with removal or reinstallation of register.



Section 20

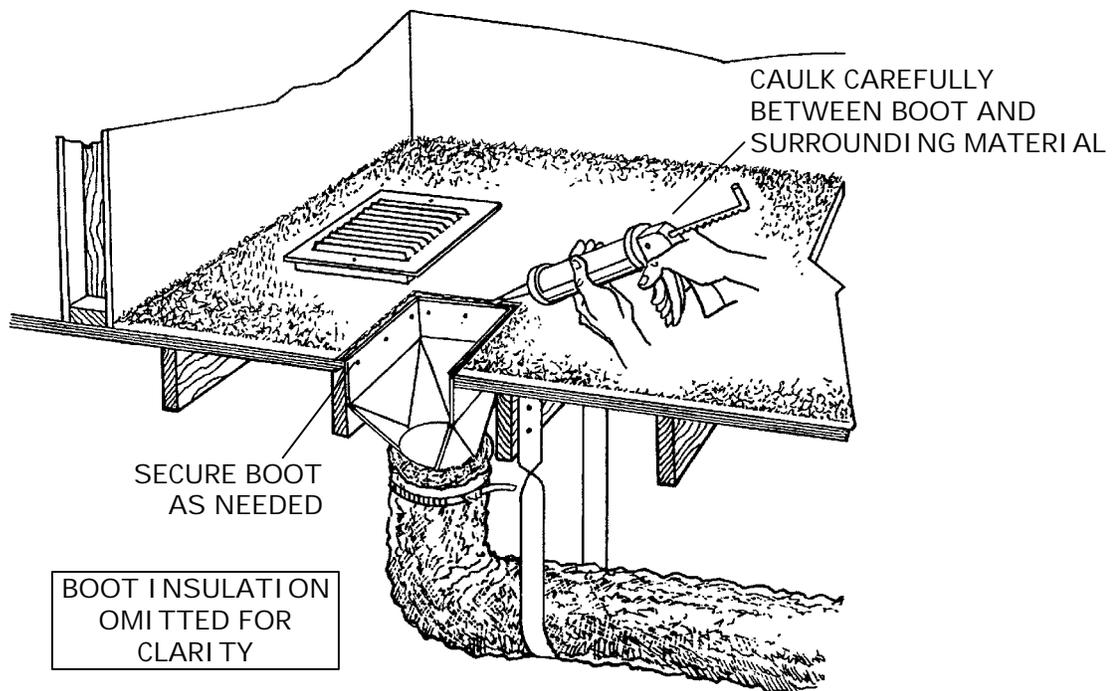
29. SEALING REGISTER BOOTS (continued)

- Boot-to-Floor/Wall/Ceiling Connection

- Boot shall be mechanically secured to the structure and shall not rely on the duct for support or stability.
- Gaps between boot and surrounding material shall be sealed with one of the following:
 - Elastomeric caulk (gaps up to 3/8").
 - Elastomeric caulk supported by backer rod (gaps 7/16" to 5/8").
 - Duct mastic or metallic pressure sensitive tape (gaps up to 1/4").
 - Duct mastic reinforced with fiberglass mesh, or metallic tape covered with mastic (gaps over 1/4" up to <1").

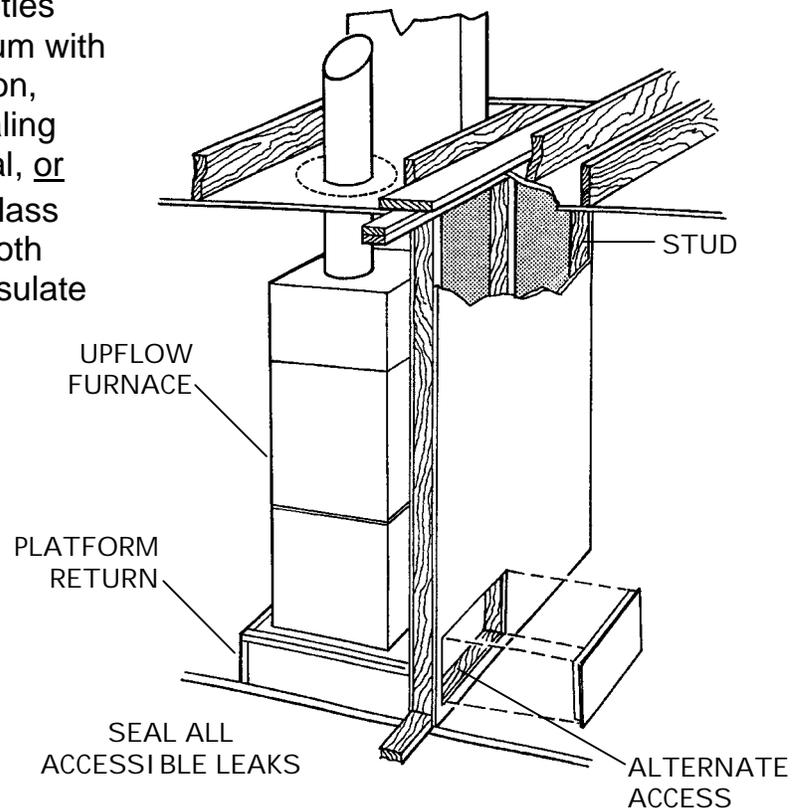
- Unhindered Register Removal/Replacement

- Sealants applied to the boot shall not interfere with the removal and replacement of the register.
- Exposed sealant may be covered with metallic pressure sensitive tape to prevent adhesion to the register.



30. SEALING BUILDING CAVITIES

- **Accessible leaks shall be sealed.**
 - Building cavities being used as ducts (e.g., platform return, panned joists, building cavity/chase, cabinet toe-kick supply terminal, etc.) shall be sealed where accessible.
 - Repair/liner materials may include sheet metal and fiberglass duct board.
- **Sealants may include:**
 - Duct mastic alone (gaps up to 1/4").
 - Duct mastic plus fiberglass mesh or metallic tape covered with mastic (gaps larger than 1/4" up to <1").
 - Approved caulk (e.g., elastomeric sealants).
 - Metallic pressure sensitive tape (for metal and foil surfaces).
- **Foam board, foam sealants, and gypsum wallboard shall not be used.**
- **Platform Plenum Insulation**
 - When uninsulated platforms are sealed, they shall also be insulated.
 - Insulation requirement may be met by:
 - Filling stud cavities inside the plenum with flexible insulation, when lining/sealing with sheet metal, or
 - Installing fiberglass duct board to both line/seal and insulate the plenum.

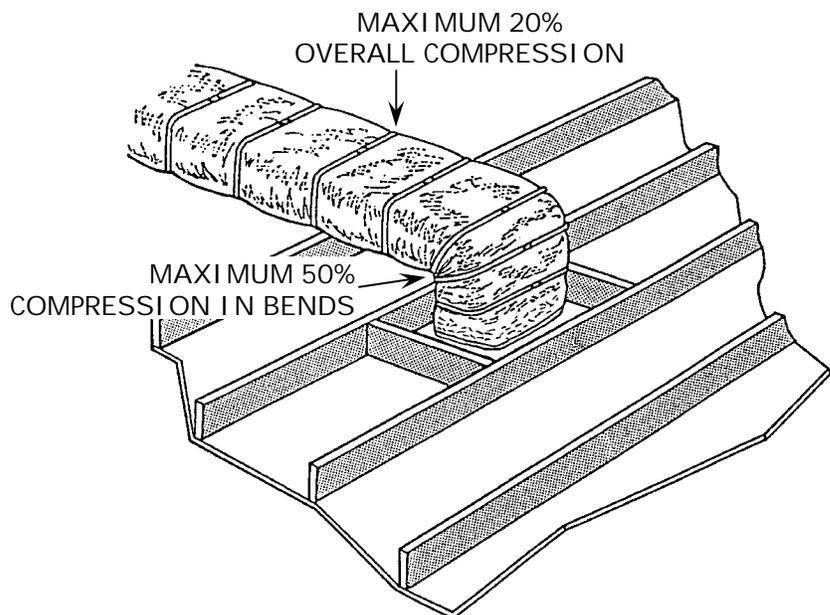


Section 20

DUCT INSULATION

31. DUCT INSULATION

- **Material**
 - Flexible or rigid fiberglass.
 - Vapor retarder (maximum 0.5 perm facing) required for air conditioning ducts.
- **Minimum R-Values**
 - Natural Gas Heat
 - R-4.2 in CEC climate zones (CZ) 6 – 8.
 - R-6 in CZ 1 – 5 and 9 – 13.
 - R-8 in CZ 14 – 16.
 - Electric Heat: R-8 in all CZ.
- **Coverage**
 - All air ducts, air connectors, plenums, distribution boxes and system components shall be insulated.
 - Insulation is to be installed on portions of the duct system located outside of conditioned space.
 - Rigid metal ducts located entirely within conditioned space may be insulated to prevent condensation.
 - 100% coverage required without gaps or openings.
- **Compression**
 - Maximum 20% overall compression by attachments.
 - Maximum 50% compression in corners/bends.



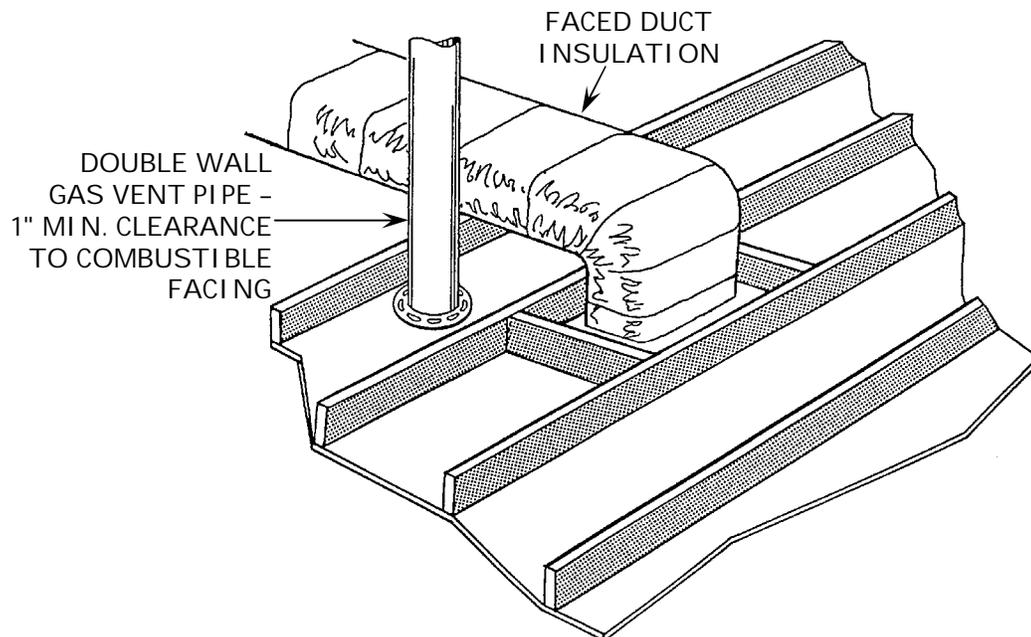
31. DUCT INSULATION (continued)

- Clearances

- Combustion air vents shall not be obstructed by duct insulation.
- Combustible Facings and Attachments
 - 6" clearance from single wall gas flue/vent pipes.
 - 1" clearance or clearance specified by the listing, whichever is greater, for listed Type B double-wall gas vent pipes.
 - 3" clearance from all other heat producing devices.

- Attachment of Rigid Fiberglass Insulation

- Insulation shall be securely attached (e.g., with stickpins).
- Seams shall be sealed with:
 - Metallic pressure sensitive tape marked "181A-P", or
 - Duct mastic labeled "181A-M" reinforced with mesh tape.

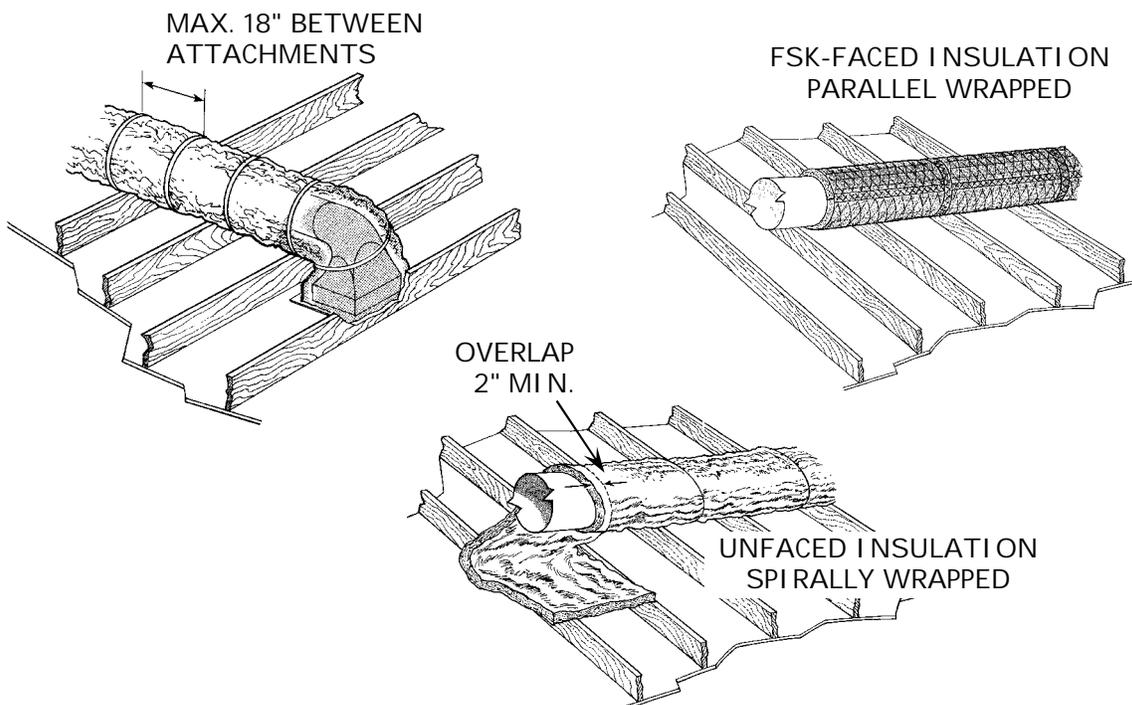


Section 20

31. DUCT INSULATION (continued)

- Installation of Flexible Insulation

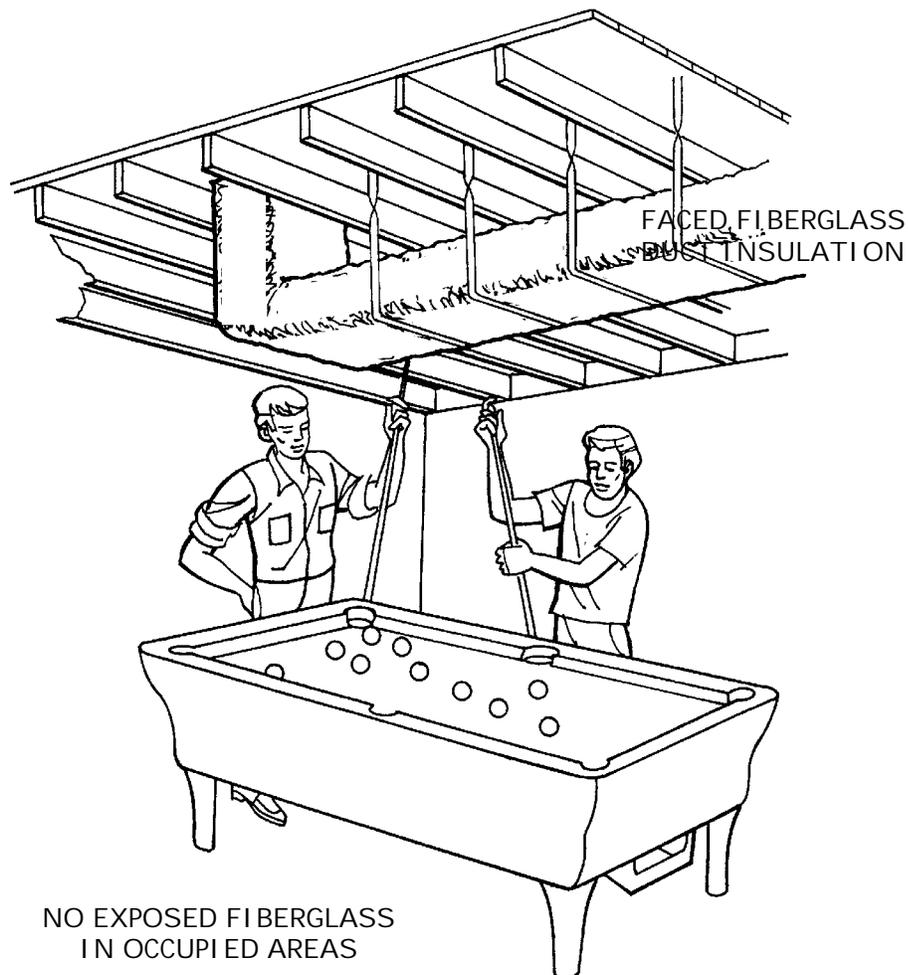
- Insulation shall be permanently secured with one of the following:
 - Drawbands (duct ties).
 - Noncorrosive wire, 20 gage minimum.
 - Rust-resistant nails or staples.
 - Pressure sensitive tape (e.g., metallic or FSK) wrapped a minimum of 3 times around the circumference.
- Spirally Wrapped
 - Wraps of unfaced insulation shall overlap each other at least 2".
 - Insulation shall be mechanically secured (e.g., with drawbands, wire, nails, or staples) as needed to prevent gaps or openings.
- Parallel Wrapped
 - Faced wraps shall be secured and sealed with pressure sensitive tape or as prescribed by manufacturer.
 - Unfaced wraps shall be mechanically secured with fasteners (drawbands, wire, nails, or staples) installed no more than 18" apart along the lengthwise seam (overlap) of the insulation.



31. DUCT INSULATION (continued)

- Exposed Ducts

- Ducts Located Outdoors or Not Protected from the Elements
 - Ducts shall be insulated with materials which are:
 - Intended for exterior applications.
 - Selected and installed in conformance with manufacturer's instructions and local codes.
- Ducts Located in Area Subject to Human Contact
 - When fiberglass insulation is installed, it shall be faced.
 - Fiberglass edges shall not be left exposed in the living space.



Section 20

32. LEAD-SAFE WEATHERIZATION

- Lead-safe practices shall be employed when working with pre-1979 painted materials per state codes T8 Section 1532.1 and T17 Section 36000, et seq.

33. POST-INSTALLATION REQUIREMENTS

- Paint dust and chips, scraps, and other debris resulting from weatherization activities shall be cleaned up and removed from the premises—utilizing lead-safe practices when applicable.
- Furniture and other household items moved for weatherization work shall be returned to their original positions.

CALIFORNIA DEPARTMENT OF HEALTH SERVICES	
	Childhood Lead Poison Prevention Program Lead-Related Construction Information Hot-Line 1-800-597-LEAD (1-800-597-5323) www.childlead.com
NATIONAL LEAD INFORMATION CENTER 1-800-424-LEAD	
 US EPA Region IX 75 Hawthorne St. San Francisco, CA 94105 Region IX Contact: Don Lanier (415) 744-1123	U.S. Department of Housing and Urban Development Office of Lead Hazard Control 451 7th Street, S.W., Room B-133 Washington, DC 20410 PH: 202-755-1785 FAX: 202-755-1000
www.epa.gov/lead/index.html	www.hud.gov/lea/leahome.html

**NONFEASIBILITY CRITERIA FOR
DUCT SEALING**

- 1. Duct leakage is below the threshold leakage per the Duct Testing and Sealing Form.**
- 2. If the replacement of 40 or more feet of duct in unconditioned space would be necessary.**
- 3. A natural gas appliance hazard exists, and repair is not feasible.**
- 4. Duct system has been abandoned.**
- 5. Duct system is damaged and deteriorated beyond repair.**
- 6. A health or safety hazard is present, such as insect infestation, hazardous electrical wiring, or structural hazard, which prevents safe access to the duct system.**
- 7. Ducts and/or components are made of or insulated with asbestos.**
- 8. Access to the duct system does not meet minimum accessibility criteria specified in the Program Policy & Procedures Manual.**
- 9. For ducts in the crawl space: sewage waste is on the ground, or excessive ground moisture (standing water or mud) is present.**
- 10. Customer refuses.**

CENTRAL HIGH EFFICIENCY AIR CONDITIONER REPLACEMENT STANDARDS

1. APPROVED MATERIALS

- All Units

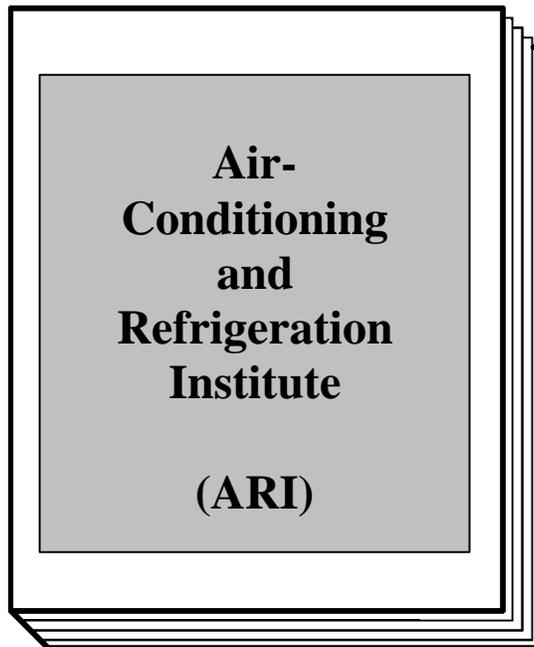
- All materials shall be in conformance with the CBC and CMC.
- Replacement air conditioning systems shall be rated by the Air-Conditioning and Refrigeration Institute (ARI).
- Programmable thermostat shall be selected and installed as prescribed in Section 23.

- Package Units (Dual Packs)

- Minimum SEER of 13 and EER of 11.5.

- Split Systems

- Minimum SEER of 13 and EER of 11.5 with a Thermostatic Expansion Valve (TXV).
- The EER shall be determined by the coil match as listed in the current ARI Directory.



Section 21

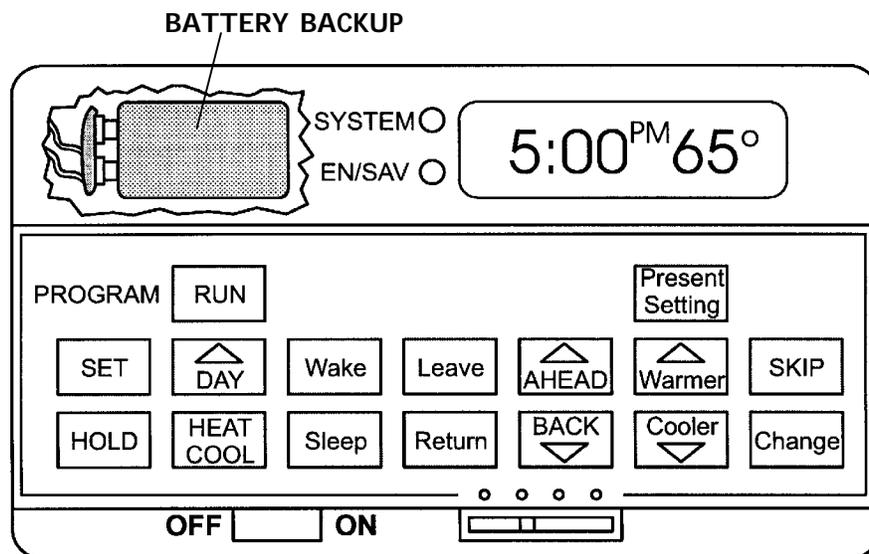
1. APPROVED MATERIALS (continued)

- Programmable Wall Thermostat

- ENERGY STAR[®] qualified.
- System powered, not battery powered, on 24 volt systems.
- Digital with anti-short-cycle feature.
- Minimum setback capability of 10°F.
- At least two setback periods per 24 hour day, with change cycle increments being no greater than 30 minutes.
- Manual override and standard alkaline battery backup or other program saving backup system.
- Positive on/off switch that is easily accessible.
- Compatible with the HVAC equipment.

- Standard Wall Thermostat

- Alternative when customer refuses programmable thermostat.
- Digital with built in anti-short-cycle feature.
- Conforms with manufacturer's instructions.
- Compatible with the HVAC equipment.
- Includes a positive on/off switch.



DIGITAL PROGRAMMABLE THERMOSTAT
WITH ON/OFF SWITCH

2. WARRANTY

- All Installations

- Parts and labor shall be covered by a minimum one (1) year written warranty.
- Compressor warranty shall extend to five (5) years.
- All written warranty information and manufacturer's operating and maintenance instructions shall be supplied to the customer.

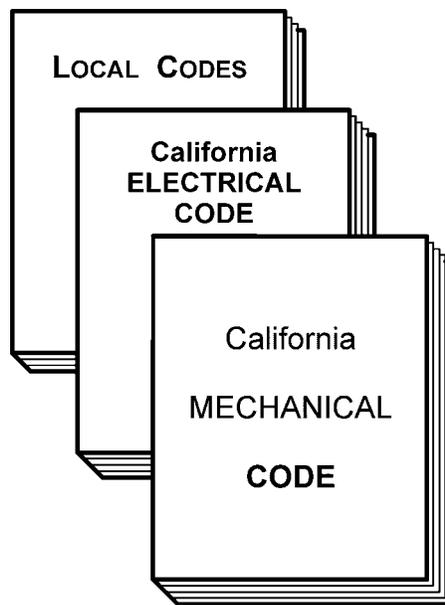
3. GENERAL REQUIREMENTS

- All Installations

- A permit for the installation shall be obtained from and finalized by the local jurisdiction.
- Installation shall be in compliance with:
 - Manufacturer's instructions and specifications.
 - Currently adopted California Electrical Code (CEC).
 - Currently adopted California Mechanical Code (CMC).
 - Local building code and regulations regarding seismic precautions, zoning, noise abatement, access, etc.

- Air Filters

- All air filters shall be installed and clean.
- Unframed washable filters shall be properly supported to prevent being drawn into the air handler, as prescribed in Section 18.



Section 21

4. SIZING CRITERIA

- System Size

- Unit shall be sized in accordance with Title 24 or local code, whichever is more stringent.
- The tonnage of the new system should be equal to or smaller than the existing system.

- Refrigerant Lines

- Shall be properly sized per manufacturer's specifications.
- Shall provide the rated EER for the combination condenser and evaporator coil match.

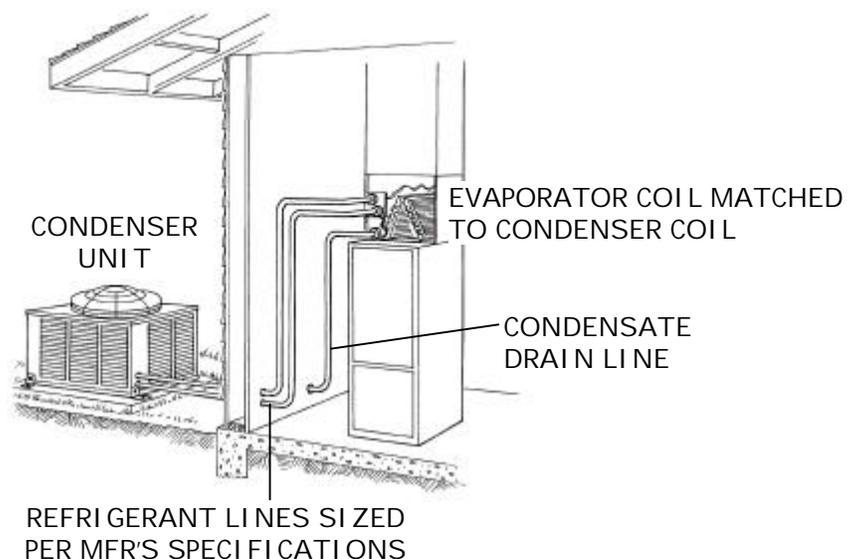
5. EVAPORATOR (INDOOR) COIL AND CONDENSER (OUTDOOR) COIL

- Split Systems

- An evaporator coil shall be installed which is verified to be a rated match with the condenser unit, as listed in current ARI Directory.
- The coil label shall be visible.
- Condenser coil and evaporator coil shall be verified to function properly.
- An access panel shall be provided for cleaning.

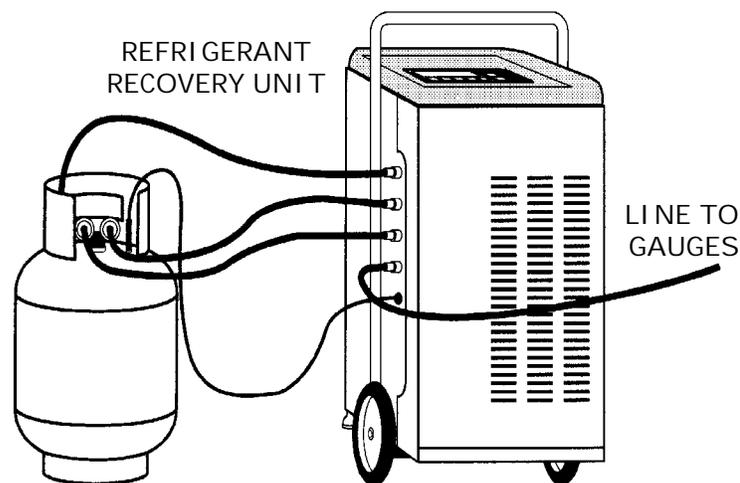
- Evaporator Coil Replacement

- Prior to charging, vacuum shall be drawn on the refrigerant lines to test for leaks and remove water vapor.
- Depth of vacuum and length of time shall be as specified by the manufacturer.



6. OPERATIONAL REQUIREMENTS

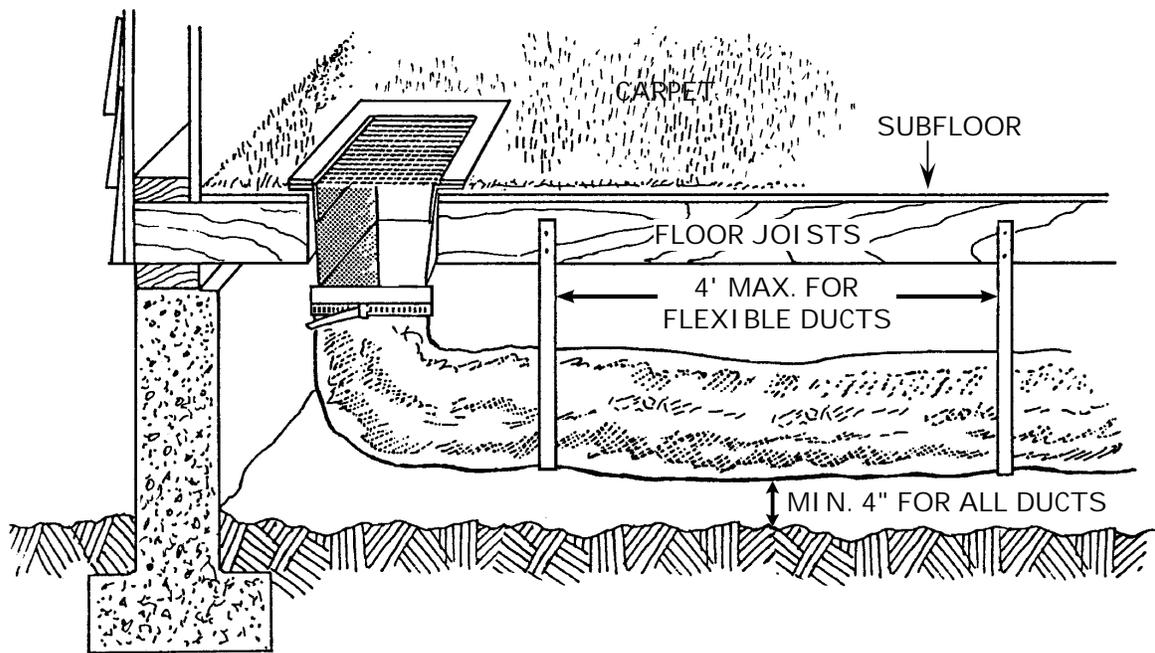
- **Air Flow**
 - Air flow through the indoor coil shall be adequate to meet manufacturer's specifications.
- **Programmable Thermostat Control**
 - A new programmable thermostat shall be installed in accordance with Section 18.
 - Thermostat shall be tested and verified to operate properly per manufacturer's instructions.
- **Refrigerant System Charging**
 - Refrigerant system shall be properly charged using methods specified by the manufacturer.
 - Refrigerant recovery shall be performed in accordance with Federal law.
 - A recovery device shall be used.
 - Ventilation to the atmosphere is not allowed.
 - Technicians performing evacuation and charging must have EPA-approved certification as a Type II or Universal technician.



Section 21

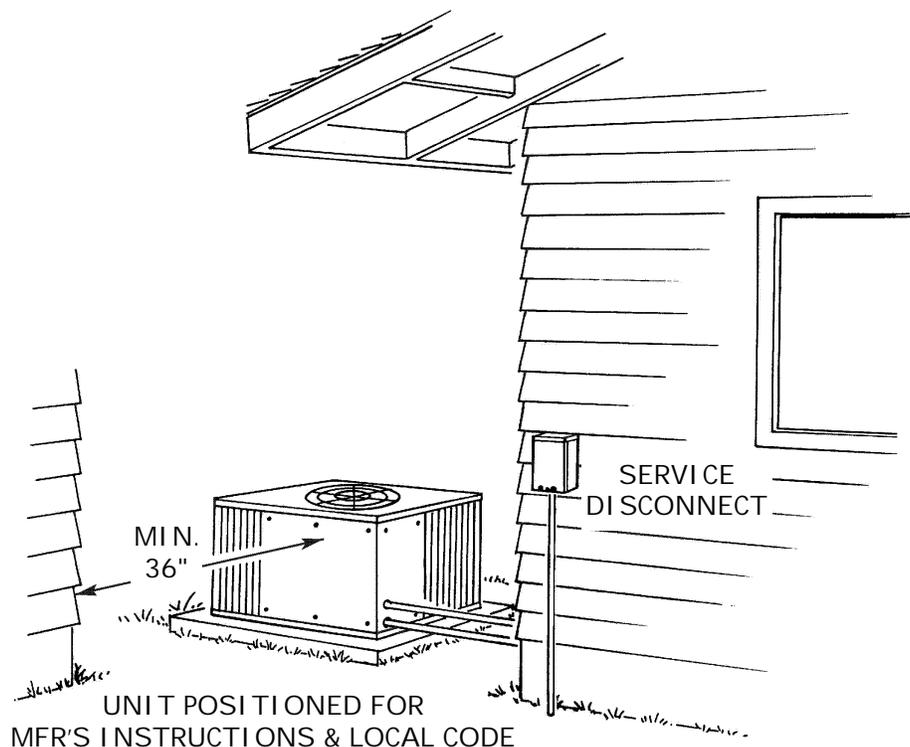
7. AIR DISTRIBUTION SYSTEM

- **All Units**
 - Distribution system shall be in conformance with HVAC manufacturer's specifications.
- **Retrofit Units Utilizing Existing Duct System**
 - Duct system shall be examined for leaks and disconnections and brought into conformance with Title 24 requirements, in accordance with the program Policy and Procedures.
 - Testing shall be performed in accordance with WIS Section 10, Duct Testing Standards, and repairs and sealing shall be made in accordance with WIS Section 20, Duct Sealing Standards.
 - The supply and return plenums shall be securely attached to the air handler.
 - The supply and return ductwork shall be securely attached to the respective plenums.
- **New Ductwork**
 - The new duct system shall be installed in conformance with manufacturer's instructions.



8. ELECTRICAL ACCESSIBILITY AND GROUNDING

- **All Equipment Installations**
 - Access and working space shall be provided in conformance with CEC Section 110-16 and local code.
- **Open Space for Panels and Equipment**
 - An open space shall be provided around electrical panels and equipment requiring servicing, which shall be minimum 30" wide by 36" deep or as specified by local jurisdiction.
- **Accessibility for Equipment**
 - The air-conditioning equipment shall be accessible for inspection, service, repair and replacement without removing permanent construction (per CMC Section 1106.3).
 - Minimum clearance between air-conditioning equipment and the adjacent structure/wall/obstruction shall be:
 - 36" on side(s) containing service access panels, and
 - 12" on all other sides, or
 - As specified by manufacturer and local jurisdiction.
 - Exception: Other clearances allowed when variance is granted by building department.



Section 21

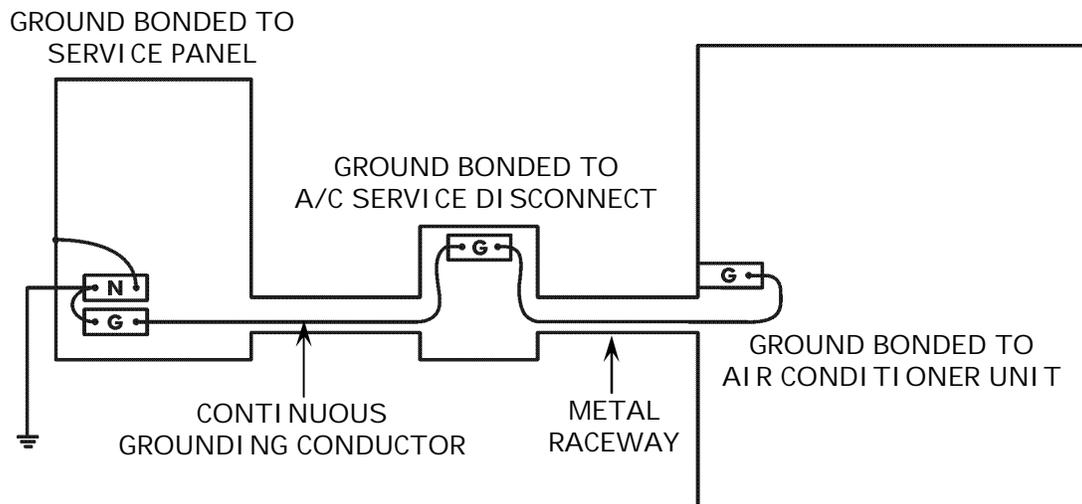
8. ELECTRICAL ACCESSIBILITY AND GROUNDING (continued)

- Service Receptacle

- A 120-volt service receptacle shall:
 - Be located within 25' of the equipment.
 - Be on the same level as the equipment.
 - Not be connected on the load side of the disconnect.

- Grounding

- Exposed noncurrent-carrying metal parts shall be grounded in compliance with CEC Article 250, Part J., Grounding Conductors (Sections 250-91 through 250-99), and Part K., Grounding Conductor Connections (Sections 250-112 through 250-119).
- Parts of the equipment capable of carrying electrical current shall be grounded to the service ground by a continuous:
 - metal raceway,
 - wire, or
 - appropriate conductor in a cable assembly.
- Connections and splices in the grounding conductor shall:
 - Be made in compliance with the CEC.
 - Provide a continuous path to the service ground with all disconnects and controllers in the open position.



CONTINUOUS GROUNDING PATH FROM SERVICE PANEL TO A/C UNIT PROVIDED BY CONDUCTOR OR RACEWAY

9. BRANCH-CIRCUIT PROTECTION

- **General Requirements**
 - Air-conditioning equipment shall be provided with:
 - Overcurrent protection per CEC Article 240.
 - Disconnecting means per CEC Article 440, Part B.
 - Branch-circuit short-circuit and ground-fault protection per CEC Article 440, Part C.
- **Protection Device Type**
 - The overcurrent protection device shall be the type specified on the air-conditioning equipment nameplate (see Table 21-1).
 - When nameplate specifies an HACR circuit breaker, the installed circuit breaker shall be listed and labeled HACR type (suitable for use with heating, air-conditioning and refrigeration equipment).
- **Protection Device Rating**
 - The branch-circuit protection device shall not exceed the maximum amperage rating specified on the nameplate of the air-conditioning unit.

TABLE 21-1: OVERCURRENT PROTECTION SELECTION GUIDE

HEAT PUMP UNIT NAMEPLATE MARKED:	OVERCURRENT PROTECTION DEVICE* MUST BE:
“Maximum Fuse Size <u> X </u> Amps”	An <u> X </u> Amp Fuse
“Maximum Fuse or HACR Circuit Breaker <u> X </u> Amps”	An <u> X </u> Amp Fuse or HACR-Type Circuit Breaker
“Maximum Fuse, HACR Circuit Breaker, or Circuit Breaker <u> X </u> Amps”	An <u> X </u> Amp Fuse, HACR-Type Circuit Breaker, or Standard Circuit Breaker
“Maximum Overcurrent Protection Device <u> X </u> Amps”	An <u> X </u> Amp Fuse, HACR-Type Circuit Breaker, or Standard Circuit Breaker

***Amperage rating of the device must not exceed that specified on the nameplate.**

Section 21

10. BRANCH CIRCUIT CONDUCTORS

- **Ampacity and Rating of Conductors**
 - Minimum wire size shall, as applicable, be:
 - Selected from CEC Tables 310-16 through 310-19, or
 - Calculated in accordance with CEC Section 310-15.
- **Voltage Drop and Wire Length**
 - Circuits shall be installed in conformance with CEC Section 210, Branch Circuits, and Section 215, Feeders.
 - The voltage drop over the branch-circuit conductor should not exceed 3%. (See CEC Section 210-19(a) (Fine Print Note No. 4).)
 - In 240v circuits, the maximum conductor length should not exceed the values given in Table 21-2.

TABLE 21-2: MAXIMUM LENGTH OF CIRCUIT (IN FEET)

WIRE SIZE	AMPACITY OF CIRCUIT			
	15	20	30	40
AWG				
12	160'	120'	–	–
10	250'	190'	130'	–
8	300'	225'	150'	115'

Notes:

- The table is based on a 4.6v drop ($230v \times 2\% = 4.6v$).
- The table applies to non-plated (uncoated) solid wire copper conductors at 75°C (167°F) ambient temperature.
- For alternate conditions or conductors, use applicable CEC Tables (e.g., see Article 210, "Branch Circuits"; Article 215, "Feeders"; and Chapter 9, Table 8, "Conductor Properties").

11. UNIT DISCONNECTING MEANS (SERVICE DISCONNECT)

- All Installations

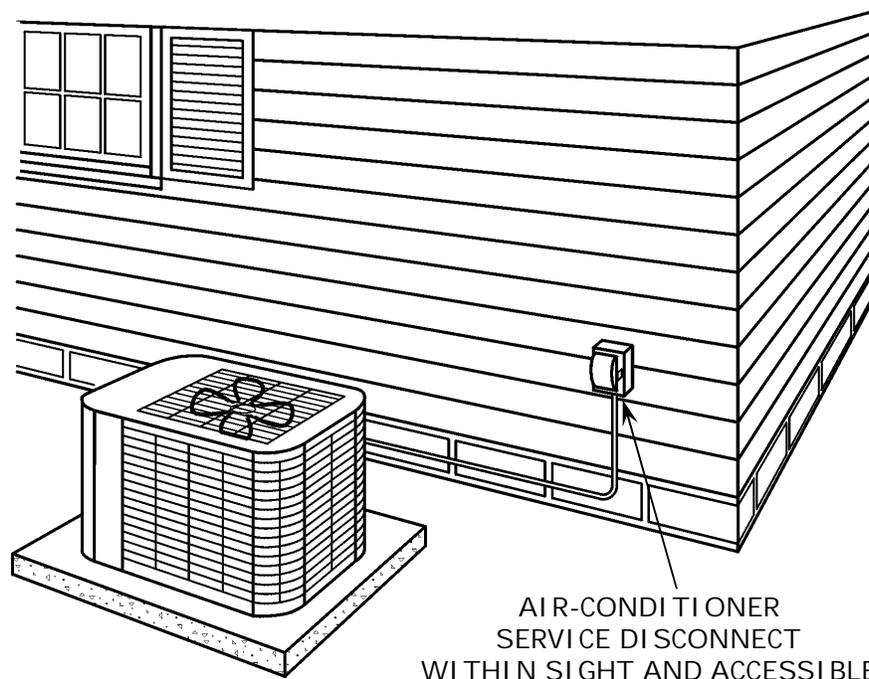
- A disconnecting means, which is capable of disconnecting the air-conditioning equipment from the circuit feeder shall be installed in conformance with CEC Article 440, Part B, Disconnecting Means.

- Location

- The service disconnect:
 - Shall be located within sight from, and readily accessible from the air-conditioning equipment, or as required by the local jurisdiction.
 - May be installed on or within the air-conditioning equipment.

- Rating

- The rating of the disconnecting means shall not exceed the over-current rating of the installed equipment.
- The rating of the installed fuses or circuit breakers shall not exceed:
 - The overcurrent rating of the installed air conditioning equipment.
 - The rating of the box in which they are located.

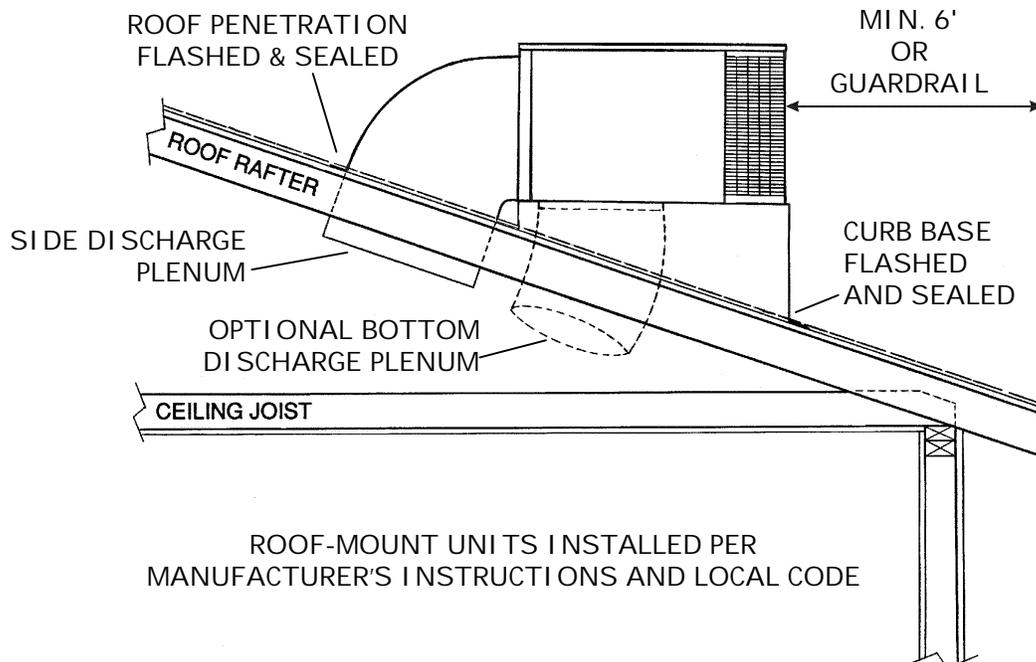


Section 21

12. MOUNTING OF EQUIPMENT

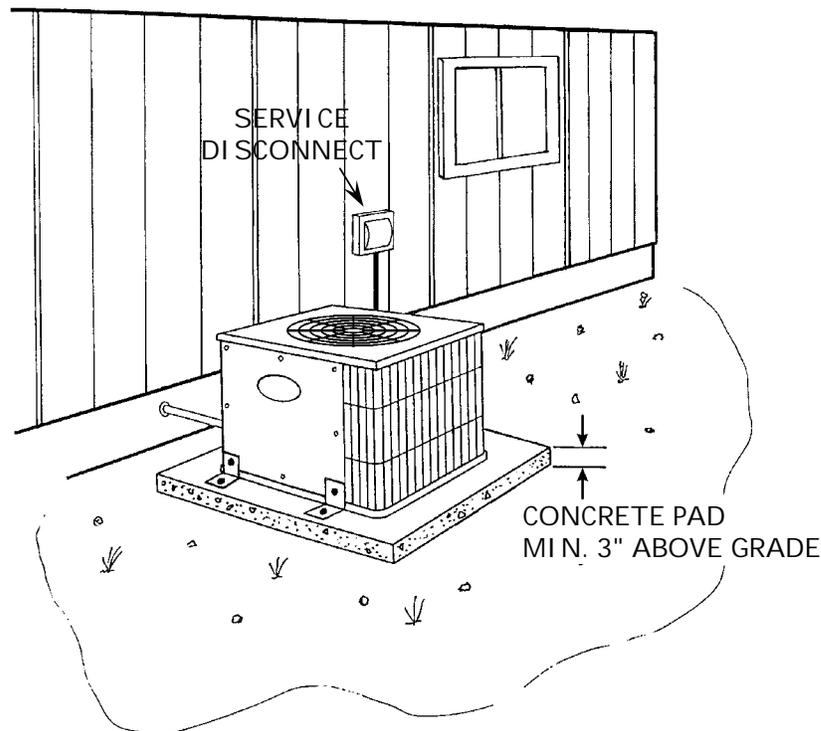
- Roof Mount

- The roof shall be structurally adequate to properly support the installed equipment in conformance with CBC and local code.
- Design and installation of support frame or curb and installation of air-conditioning equipment and applicable safety apparatus shall be in conformance with manufacturer's instructions and local code.
- Curb base and exposed roof penetrations shall be properly installed, flashed and sealed watertight.
- The condensate drain line shall be:
 - Equipped with a trap.
 - Painted to resist UV degradation if PVC is used.
- Roofing materials shall be in good condition and not in need of repair or replacement.



12. MOUNTING OF EQUIPMENT (continued)

- **Ground Mount**
 - Air-conditioning equipment shall be installed in conformance with CMC Section 1106.0.
 - The unit shall rest on concrete or other approved base extending at least 3" above the adjoining ground level.
- **Protection**
 - Units subject to mechanical damage shall be protected in conformance with CMC Section 308.
 - Unit shall be attached to base with seismic straps, when required by local code.
- **Overhead Clearance**
 - Overhead clearance shall be provided in conformance with manufacturer's specifications and local code.



Section 21

13. FUEL-GAS PIPING

- All Installations

- Gas lines, fittings and valves shall be free of leaks.
- New lines shall be pressure-tested.

14. FLUE AND VENT SYSTEMS

- All Installations

- New flue/vent system shall be selected, installed and secured in conformance with listing specifications, manufacturer's instructions and local code.

- Appliances Sharing a Common Vent

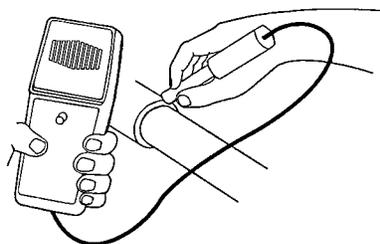
- When an existing furnace that shares a common vent with another appliance is replaced with a new unit utilizing either a common or separate vent system, contractor shall ensure that both appliances vent properly.

15. COMBUSTION AIR

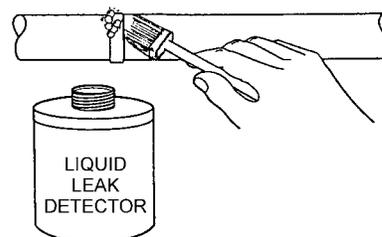
- Fuel-Burning Appliances

- Combustion air for installed units shall be supplied in conformance with manufacturer's instructions and local code.
- Combustion air supply for all other appliances sharing the same space/enclosure shall comply with local code.
- Combustion air vents shall be free of obstructions (e.g., overblown ceiling insulation, duct insulation, etc.) which interfere with proper venting.

ELECTRONIC LEAK DETECTOR



BUBBLE LEAK DETECTION



ALL GAS LINES, FITTINGS, AND
VALVES CHECKED FOR LEAKS

16. THERMOSTAT INSTALLATION

- Location and Mounting

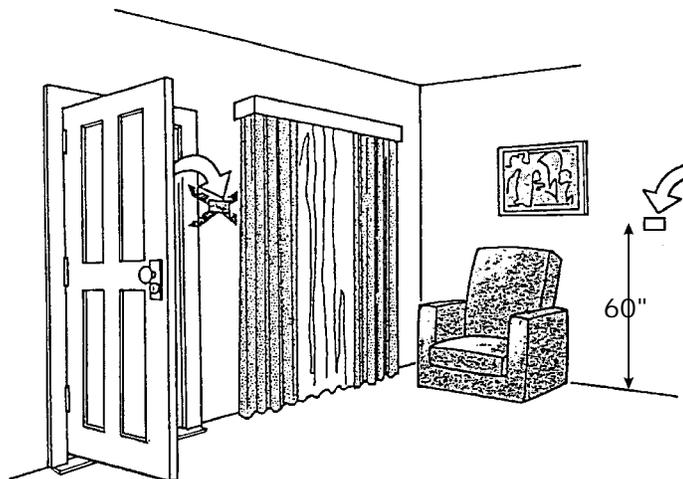
- New thermostat shall be installed at existing location unless affected by drafts, heat from direct sun, or adjacent appliances.
- Thermostat installed in a new location:
 - Shall be mounted with the top of thermostat 60" above the floor when occupants are not handicapped.
 - May be installed as low as 48" above the floor when an occupant uses a wheelchair.
- Thermostat shall be located away from direct sunlight, doors, windows, return/supply air, appliances, and sources of electrical interference.
- Mounting bracket shall be securely attached to wall with screws for wood, or appropriate anchors for drywall and plaster.
- Any holes or damage to wall from installation or removal of thermostat shall be repaired in a workmanlike manner.

- Wiring

- All wiring shall be a minimum of 18 gauge and conform to manufacturer's specifications and local codes.
- All wiring shall be installed inside wall cavities when possible.
- When not inside a wall, exposed wiring shall be enclosed in a raceway.

- Programming and Operation

- Thermostat shall be cycled to insure proper operation of all functions.
- Setbacks shall be programmed in accordance with customer's wishes.



Section 21

16. THERMOSTAT INSTALLATION (continued)

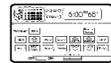
- Instructions and Warranty

- Customer shall be provided with:
 - A demonstration with verbal instructions for operating the thermostat and installing batteries.
 - The manufacturer's written instructions and warranty.

17. POST-INSTALLATION REQUIREMENTS

- Appliance Operation

- The installed unit shall be tested for proper operation.
- Proper operation shall be explained and demonstrated to the customer, including:
 - Operation of all user-accessible controls.
 - Filter replacement.
 - Routine maintenance recommended by manufacturer.
- Manufacturer's written instructions and warranty documents shall be supplied to the customer.



INSTRUCTIONS AND WARRANTY
PROVIDED TO CUSTOMER

17. POST-INSTALLATION REQUIREMENTS (continued)

- Cleanup and Disposal

- Paint dust and chips, scraps, and other debris resulting from weatherization activities shall be cleaned up and removed from the premises—utilizing lead-safe practices when applicable.
- Furniture and other household items moved for weatherization work shall be returned to their original positions.
- All packing materials and installation debris shall be cleaned up and removed from the premises.
- All replaced equipment and parts shall be removed from the premises and properly disposed of unless specified otherwise in the home improvement contract.
- Refrigerant shall be recovered and all hazardous waste materials shall be disposed of in conformance with federal, state and local codes.



INFORMATION ABOUT HANDLING REFRIGERANT AND
OTHER HAZARDOUS MATERIALS IS AVAILABLE FROM EPA'S
STRATOSPHERIC OZONE INFORMATION HOT LINE

Section 21

18. LEAD-SAFE WEATHERIZATION

- Lead-safe practices shall be employed when working with pre-1979 painted materials per state codes T8 Section 1532.1 and T17 Section 36000, et seq.

CALIFORNIA DEPARTMENT OF HEALTH SERVICES	
	Childhood Lead Poison Prevention Program Lead-Related Construction Information Hot-Line 1-800-597-LEAD (1-800-597-5323) www.childlead.com
NATIONAL LEAD INFORMATION CENTER 1-800-424-LEAD	
 EPA <small>United States Environmental Protection Agency</small> US EPA Region IX 75 Hawthorne St. San Francisco, CA 94105 Region IX Contact: Don Lanier (415) 744-1123	U.S. Department of Housing and Urban Development Office of Lead Hazard Control 451 7th Street, S.W., Room B-133 Washington, DC 20410 PH: 202-755-1785 FAX: 202-755-1000
<u>www.epa.gov/lead/index.html</u>	<u>www.hud.gov/lea/leahome.html</u>

NONFEASIBILITY CRITERIA FOR AIR CONDITIONER REPLACEMENT

1. The existing air conditioner is not operational.
2. The central AC has a SEER greater than 9.0.
3. The property is renter-occupied,
4. Existing system is a combined HVAC unit and the unit has not passed the pre-weatherization NGAT,
5. For a roof-mounted unit, the roof is not structurally adequate to support the installation,
6. Electrical service requirements cannot be met,
7. Ducts cannot be brought into compliance with the Duct Sealing Section of the WIS Manual.
8. Existing HVAC unit is a combined fuel unit and the gas is not provided by one of the IOUs,
9. Duct system is inadequate,
10. Split system refrigerant line set is inadequate,
11. Customer refuses.

NONFEASIBILITY CRITERIA FOR INSTALLATION REQUIRING ATTIC OR CRAWL SPACE ACCESS

1. Crawl clearance is inadequate:
 - Attic clearance is less than 24" between top of ceiling joists and bottom of ridge board.
 - Under-floor clearance is less than 18" from the ground to bottom of floor joist system.
2. Any of the following conditions are present in the crawl space area where access is required:
 - Hazardous insect or pest infestation.
 - Excessive ground moisture (standing water or mud).
 - Sewage waste on ground or other unsanitary conditions posing a health and safety hazard.

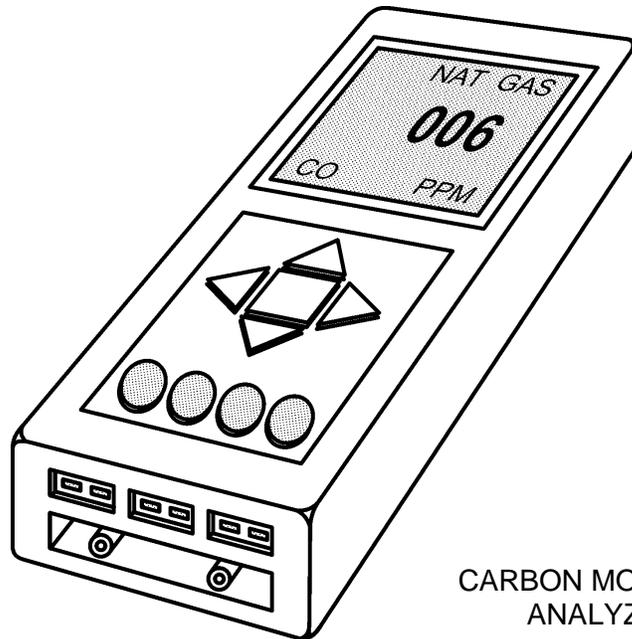
SECTION 29

NATURAL GAS APPLIANCE TESTING (NGAT) STANDARDS

PART 1: GENERAL CRITERIA

1. TEST EQUIPMENT AND ACCESSORIES

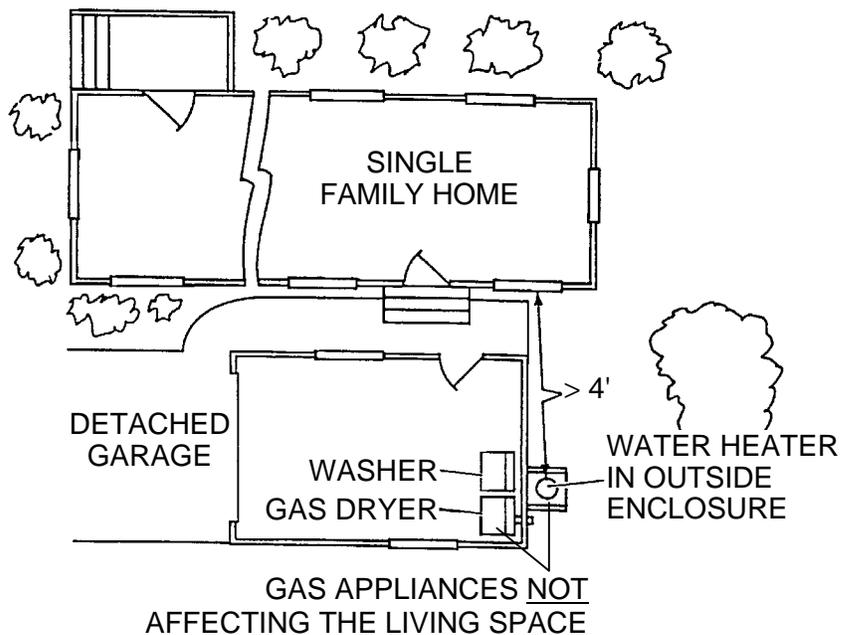
- Carbon Monoxide Analyzers
 - Shall be manufactured under an ISO 9001 quality management system or be ISO 9001 Certified.
 - Must, at a minimum, measure CO levels from zero ppm to 999 ppm.
- Test Equipment Calibration
 - Carbon monoxide analyzers shall be maintained and calibrated in accordance with manufacturer's specifications.



CARBON MONOXIDE
ANALYZER

2. NGAT APPLICABILITY

- In homes receiving infiltration reduction measures, NGAT shall be conducted when the home:
 - Is heated with natural gas, or
 - Has one or more other natural gas appliances affecting the living space.
- NGAT shall be conducted for all natural gas appliances affecting the living space except appliances that are: (a) abandoned*, or (b) inaccessible*.
- **Natural Gas Appliances Affecting the Living Space**
 - Appliances affecting the living space are (a) all space heating appliances, and (b) other appliances in the following locations:
 - Partially or entirely within the living space (including closets located within the envelope but accessed from outdoors).
 - Attached garage, attic, or basement.
 - An outdoor location within 4' of an operable door or window leading into the living space.
 - A location where combustion products from the appliance could infiltrate a forced air duct system (e.g., in a garage or room containing supply or return plenum/ductwork).
 - Appliances in all other locations are considered to be appliances not affecting the living space.
- **Natural Gas Appliances Not Affecting the Living Space**
 - Only checks for gas leaks are performed.

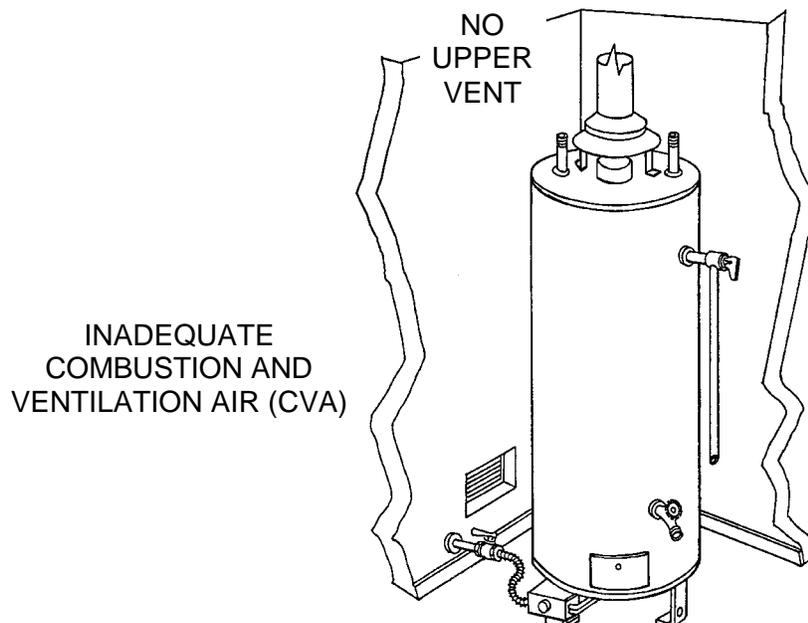


*See Definitions.

PART 2: PRE-WEATHERIZATION EVALUATIONS

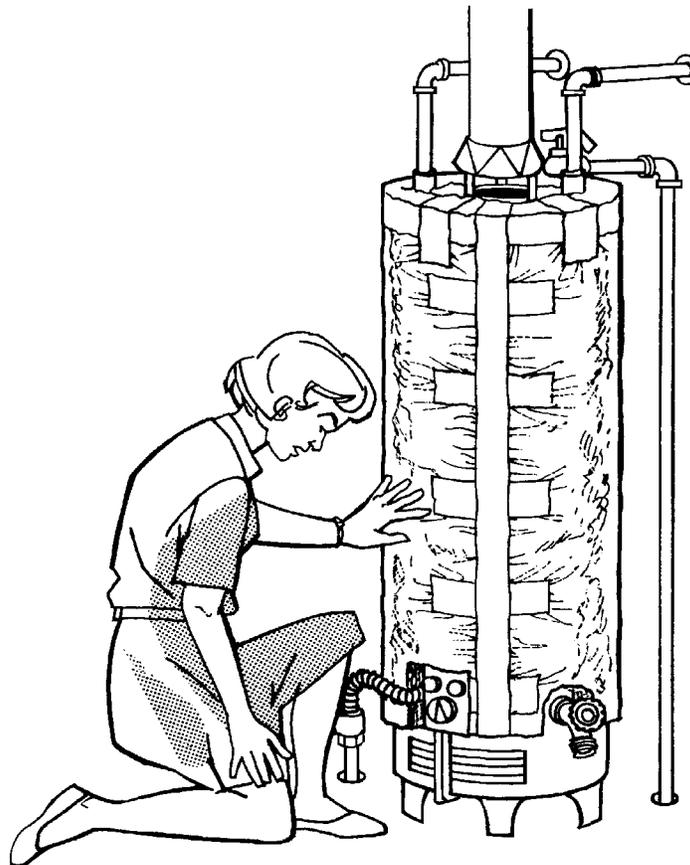
3. PRE-WEATHERIZATION ASSESSMENT

- The assessment process shall include a check of the following:
 - Gas leaks (Item 4)
 - Inadequate CVA (Item 5)
 - Inadequate clearance between water heater vent termination and evaporative cooler inlet (Item 6)
 - Other improper flue/vent terminations (Item 6)
 - Inoperable **or inaccessible** gas appliance (Item 7)
 - Gas clothes dryer in the living space not exhausted outdoors (Item 7)
 - Unvented combustion space heater in the living space (Item 7)
 - When a whole house fan is in ceiling, gas water heater or open combustion furnace with standing pilot in the attic (Item 7)
 - Range with Space Heater/Incinerator not vented outdoors (Item 7)
 - Open combustion water heater located in a sleeping area (Item 7)
- Before weatherization work commences, (a) gas leaks shall be repaired, (b) inoperable appliances shall be checked by a utility gas service technician (or designee), and (c) all vent termination clearances/defects and combustion air deficiencies shall be confirmed feasible to correct.



4. GAS LEAKS

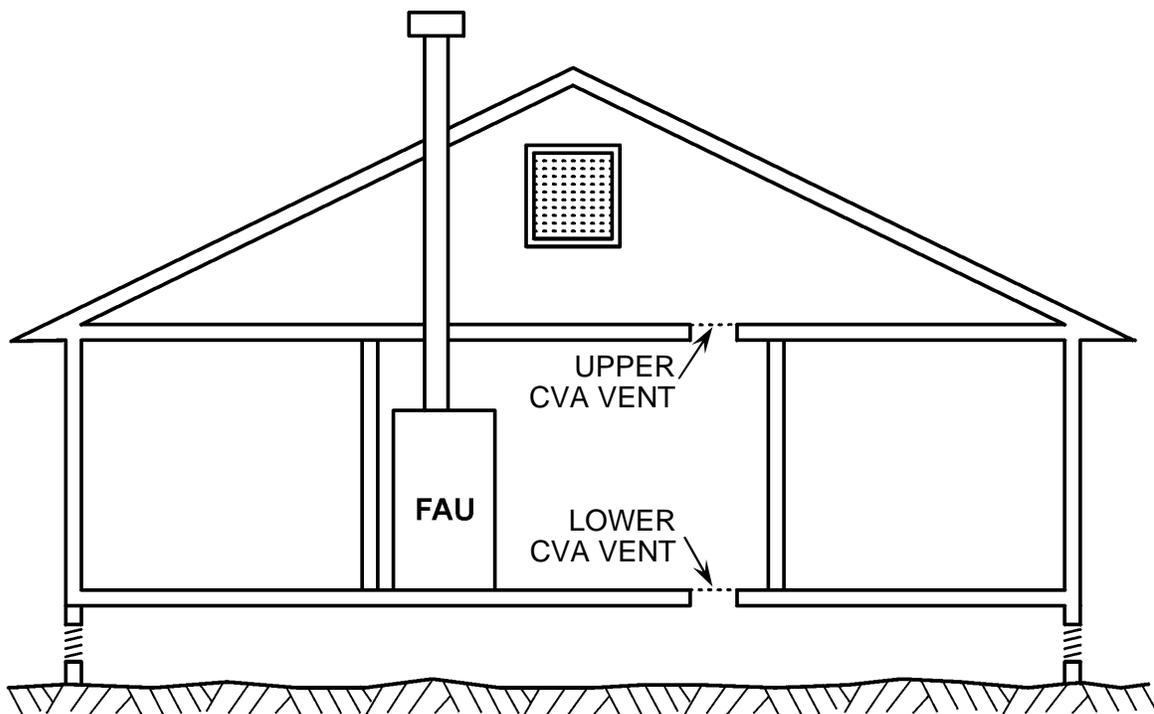
- Natural gas appliances shall be checked for gas leaks.
- Acceptable methods include the following:
 - Olfactory (Sniff) Test performed above, but within 2' of, all valves and fittings.
 - Application of leak detection liquid to line valves and to fittings on valves, flexible gas connectors, and pipes.
 - Air sampling with electronic leak detection equipment near valves, fittings, flexible gas connectors, and pipes.
- Gas leaks shall be repaired by a utility gas service technician (or designee).



CHECKING FOR NATURAL GAS ODOR

5. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION

- CVA shall be evaluated for open combustion natural gas heating systems and water heaters (cooking appliances and clothes dryers are *excluded*).
- CVA shall comply with these guidelines and Appendix A.
- Appliances Drawing *Outdoor* Air through Combustion-Air Openings or Ducts
 - An *upper* opening or duct shall be located above the draft hood, and a *lower* opening or duct shall be located within 12" of the floor.
 - Combustion air openings and vertical ducts shall each provide 1 sq. in. net free venting area (NFVA) per 4,000 Btu/hr of input.
 - Horizontal ducts shall each provide 1 sq. in. NFVA per 2,000 Btu/hr of input.
 - Combustion air may also be obtained through a single upper vent or duct to outdoors under the following conditions:
 - Vent NFVA is at least: (a) 1 sq. in. per 3,000 Btu/hr input, and (b) not less than the sum of the cross-sectional areas of all vent connectors in the space.
 - Equipment has clearances of at least 1" sides and back, and 6" in front.



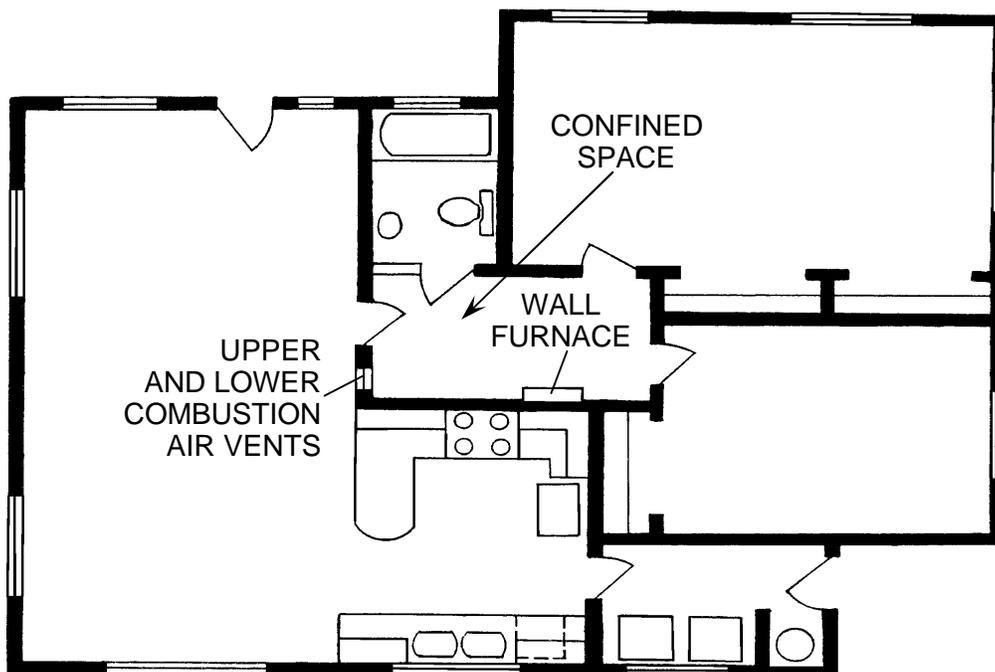
5. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

- **When Appliances Draw Combustion Air from Outdoors**
 - **Combustion air may be obtained from outdoors by means of:**
 - **Permanent openings (undampered vents) of the required size directly to outdoors through enclosure floor, roof or walls; or**
 - **Continuous vertical or horizontal ducts of the required cross-sectional area extending from the enclosure to outdoors.**
 - **Combustion air may be obtained from the attic, provided:**
 - **Attic vents are not subject to ice or snow blockage.**
 - **The attic vertical clear height is at least 30" at the peak (from top of ceiling joists to bottom of rafters/ridge board).**
 - **Attic ventilation is sufficient to provide the required volume of combustion air.**
 - **Combustion air may be obtained from under the floor, provided:**
 - **Under-floor spaces have free flow of air.**
 - **Unobstructed openings to outdoors exist that are at least twice the NFVA of the required combustion air vent openings.**
 - **Louvers, Grilles, and Screens**
 - **Blocking effects of louvers, grilles, and screens shall be considered when calculating NFVA of an opening (see Appendix A).**

SOURCES OF COMBUSTION AIR		
OUTDOORS	ATTIC	UNDER FLOOR
<ul style="list-style-type: none"> • Permanent openings with undampered vents <u>or</u> continuous ducts (vertical or horizontal). • Vent directly to outdoors. • 1/4" screen mesh on all combustion-air openings. 	<ul style="list-style-type: none"> • Minimum 30" attic height at the peak. • Adequate attic ventilation that is unobstructed. • Duct/sleeve extending 6" above top of ceiling joists and insulation. 	<ul style="list-style-type: none"> • Free flow of air. • Unobstructed openings to outdoors with at least twice the area of required combustion air vent NFVA.

5. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

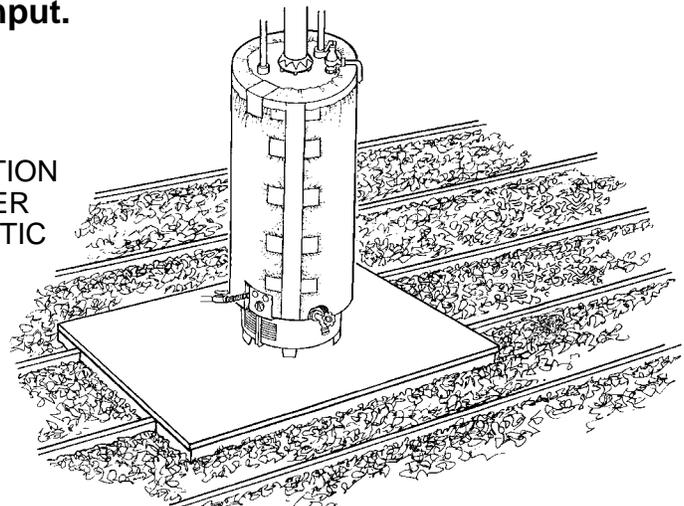
- When Appliances Draw Combustion Air from Indoors
 - Unconfined Space:
 - A room/space that has a volume of at least 50 cu. ft. per 1,000 Btu/hr total input rating of the open combustion furnace and/or water heater in that room/space.
 - Combustion air is considered adequate.
 - Confined Space:
 - A room/space that has a volume of less than 50 cu. ft. per 1,000 Btu/hr total input of the open combustion furnace and/or water heater in that room/space.
 - Combustion air is not adequate, and
 - Proper vent openings to adjacent space(s) must be present.
- Appliances Located in an Indoor Confined Space
 - Upper and lower vent openings shall be present which: (a) freely communicate with other indoor rooms/spaces, and (b) provide a combined volume of at least 50 cu. ft. per 1,000 Btu/hr total input.
 - The vent openings shall meet the following requirements:
 - Each vent opening shall provide 1 sq. in. of NFVA per 1,000 Btu/hr input, and shall be no smaller than 100 sq. in. NFVA.
 - Lower vents shall be located within 12" of the floor, and upper vents shall be located above the draft hood.



5. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

- Appliances Located in a Garage
 - When a garage (finished or unfinished) is an unconfined space, combustion air is considered adequate.
 - When a converted (finished) garage is a confined space used as conditioned living space:
 - Appliance(s) shall be isolated from the conditioned space by an enclosure vented to outdoors (as specified on page 29-5).
 - The garage shall not be vented into the main body of the house to obtain additional indoor combustion air.
 - When a garage is a confined space that is (a) unfinished or (b) finished and unconditioned (not living space), upper and/or lower permanent venting to outdoors shall provide at least 1 sq. in. NFVA per 4,000 Btu/hr total input.
- Appliances Located in a Crawlspace or Partial Basement
 - When the underfloor area (crawlspace or crawlspace plus partial basement) is an unconfined space, combustion air is adequate.
 - When the underfloor area is a confined space:
 - The under-floor space shall have free flow of air.
 - Unobstructed openings to outdoors shall provide at least twice the NFVA of the required combustion air vent openings.
- Appliances Located in an Attic
 - When attic is unconfined space, combustion air is adequate.
 - When attic is a confined space:
 - Upper and/or lower permanent attic venting shall be present on two sides/ends of the attic, and
 - Venting on each side/end shall provide at least 1 sq. in. NFVA per 4,000 Btu/hr total input.

OPEN COMBUSTION
WATER HEATER
LOCATED IN ATTIC



6. FLUE/VENT SYSTEM EXAMINATION

- All gas vents shall terminate outdoors.
- Gas vents located 4' or more from a vertical wall or similar obstruction shall **extend at least 1' above the roof in accordance with CMC Chapter 8.**
 - ~~Extend at least 1' above the roof.~~
 - ~~Comply with Table 29-1.~~
- Gas vents located less than 4' from a vertical wall or similar obstruction shall terminate at least:
 - 2' above the highest point where they pass through the roof, and
 - 2' higher than any portion of the building within 10'.
- Gas vents shall terminate no closer to a door, openable window, or gravity air inlet than the following minimum distances:
 - 4' below, or
 - 4' horizontally from, or
 - 1' above.

Exception 1: Vent terminals for Direct Vent **furnaces/appliances:**

 - At least 9" away for inputs up to 50,000 Btu/hr.
 - At least 12" away for inputs 50,100 to 65,000 Btu/hr.

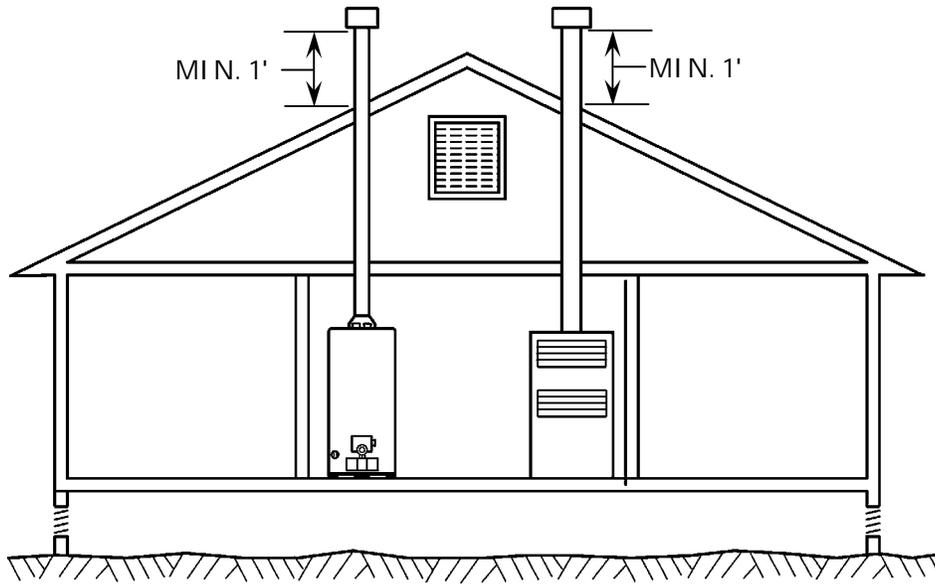
Exception 2: Vent terminals for Forced or Induced Draft systems (e.g., induced draft space/water heater or condensing furnace):

 - At least 12" away.

~~Table 29-1: Vent Termination Above a Roof~~

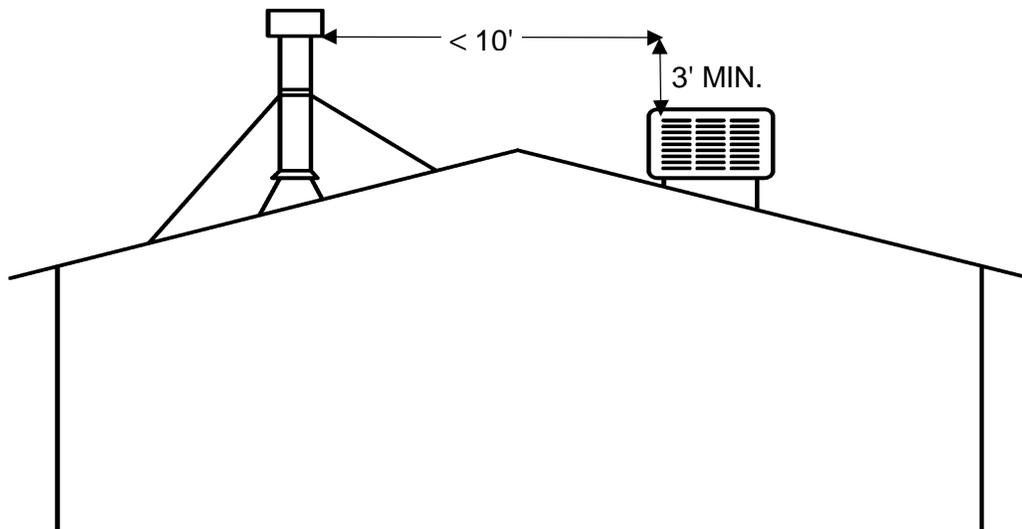
MINIMUM HEIGHT FROM ROOF TO LOWEST DISCHARGE OPENING	
ROOF SLOPE (INCHES)*	HEIGHT ABOVE ROOF
Flat to 6/12	1' – 0"
Over 6/12 to 7/12	1' – 3"
Over 7/12 to 8/12	1' – 6"
Over 8/12 to 9/12	2' – 0"
Over 9/12 to 10/12	2' – 6"
Over 10/12 to 11/12	4' – 0"
Over 11/12 to 12/12	5' – 0"

~~*For other slopes, see CMC Chapter 8.~~



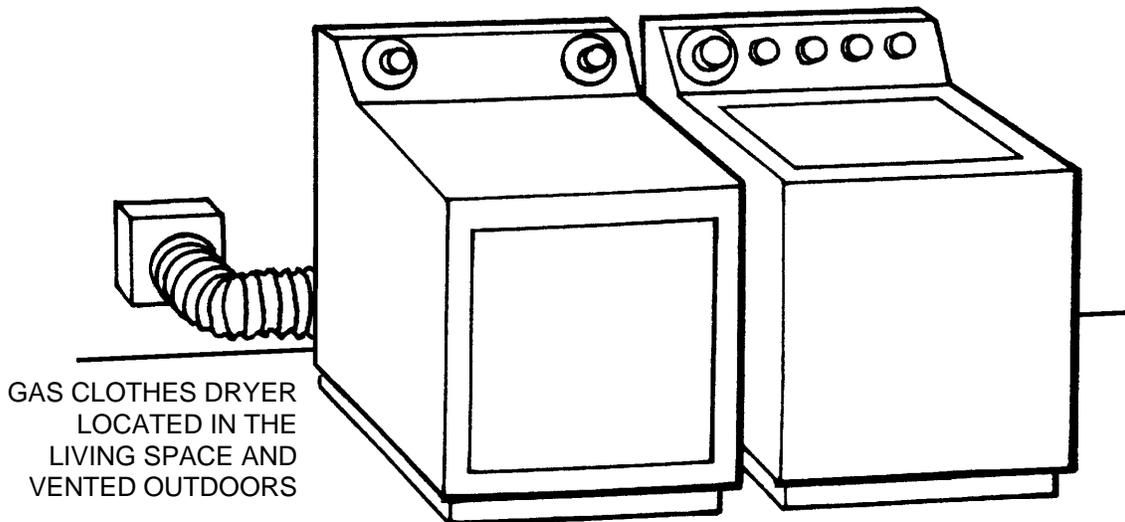
6. FLUE AND VENT SYSTEM EXAMINATION (continued)

- Outdoor Water Heater Vent Termination
 - When an outdoor water heater is located within 4' of a first-floor wall, the vent pipe must terminate at least 1' above the first-floor roof.
 - The pipe may be offset from the roof overhang.
 - Offsets shall not exceed 45°, except one 60° offset is allowed.
- Flue and Vent Systems Terminating Near an Evaporative Cooler
 - A water heater flue/vent pipe located within 10' of an evaporative cooler shall terminate at least 3' above the cooler intake.
 - Furnace flue/vent pipes within 10' of an evaporative cooler shall terminate at least 3' above the cooler intake unless:
 - All cooler discharge openings are equipped with a vent cover, *and*,
 - The client is informed of the non-conforming flue/vent and advised to keep cover(s) in place during the heating season.



7. ADDITIONAL EXAMINATIONS OF NATURAL GAS APPLIANCES

- Inoperable Gas Appliances
 - Inoperable natural gas appliances must be checked by a utility gas service technician (or designee), *unless* they are: (a) abandoned*, or (b) inaccessible*.
 - Infiltration reduction measures shall not be installed if any of the following conditions are present:
 - Gas clothes dryer located in the living space but not exhausted outdoors**.
 - Return leak present that can draw in combustion products from the FAU or other open combustion appliances (e.g., in a garage or room containing supply or return plenum/ductwork).
 - Whole house fan vented into an attic that contains a gas water heater or an open combustion furnace with standing pilot.
 - Unvented combustion space heater (e.g., gas or kerosene unit) present in the living space.
 - Open combustion water heater present in a sleeping area.
 - Gas range present which has a space heater or incinerator that is not properly vented outdoors.
- *Inoperable gas appliance.*



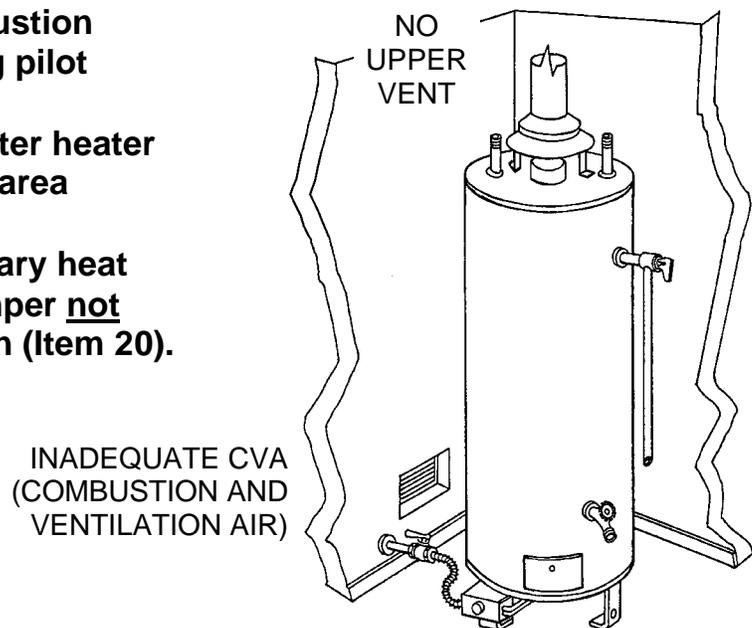
*See Definitions.

****Termination in a crawlspace or basement is acceptable when the space: (a) has adequate cross-ventilation, (b) does not have a return air intake in the floor, and (c) does not contain an open combustion furnace or a combustion air vent located in the floor. Any dryer termination in an open combustion appliance enclosure/closet is not acceptable.**

PART 3: WEATHERIZATION CREW VERIFICATIONS

8. PRELIMINARY VISUAL EVALUATIONS

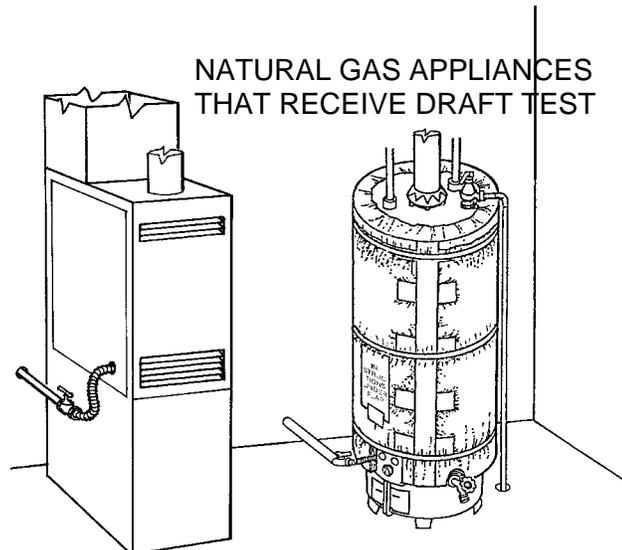
- A check shall be made for the following conditions, which preclude installation of infiltration reduction measures unless repair is feasible:
 - Gas leaks and soldered gas connectors (Item 10)
 - Inadequate CVA (Item 11)
 - Inadequate clearance between water heater vent termination and evaporative cooler inlet (Item 12)
 - Other improper flue/vent terminations (Item 12)
 - Draft hood improper—misaligned, missing, or doubled (Item 12)
 - Flue/vent hazard, such as disconnection, hole/leak indoors, not extended outdoors (Item 12)
 - Flue/vent connection to a solid-fuel chimney (Item 12)
 - Inoperable *or inaccessible* gas appliance (Item 13)
 - Appliance components missing or damaged (Item 13)
 - Gas clothes dryer located in the living space but not exhausted outdoors (Item 13)
 - Return leaks that can draw in combustion products from the FAU or other open combustion appliances (Item 13)
 - Unvented combustion space heater in the living space (Item 13)
 - Gas range with heater/incinerator not vented outdoors (Item 13)
 - Whole house fan vented into an attic that contains gas water heater or open combustion furnace with standing pilot (Item 13)
 - Open combustion water heater located in a sleeping area (Item 13)
 - When gas log is primary heat source, fireplace damper not blocked partially open (Item 20).



PART 4: POST-WEATHERIZATION NGAT PROCEDURES

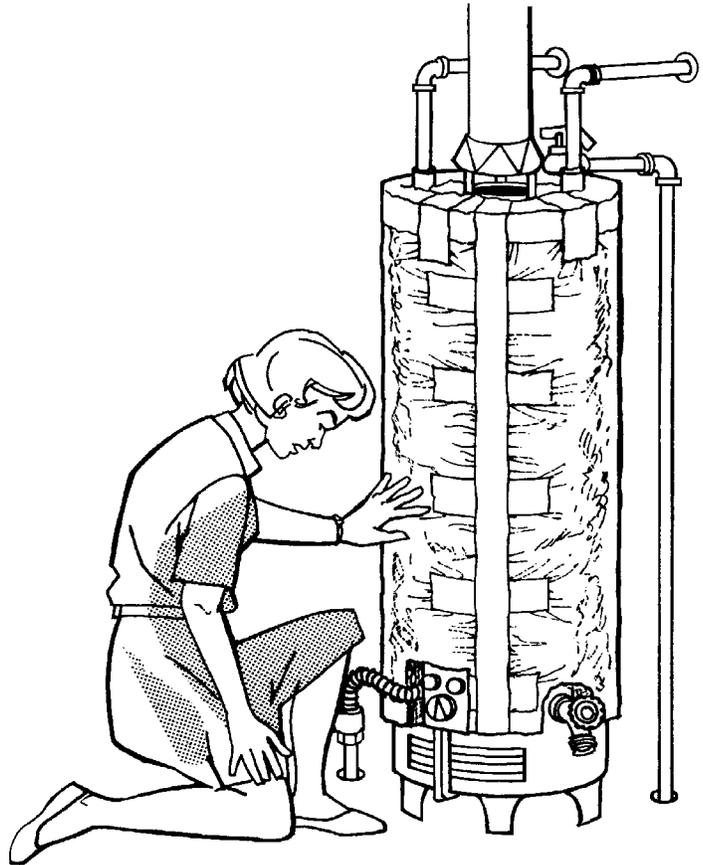
9. POST-WEATHERIZATION NGAT

- Post-Weatherization NGAT shall be performed, which shall include the following procedures:
 - CO Analyzer zeroed outdoors.
 - Room Ambient CO Test with gas appliances off.
 - Check for gas leaks.
 - CVA Evaluation.
 - Appliance-off visual inspection of appliances, components, and flue/vent systems.
 - Appliance Ambient CO Test with natural gas appliances operated individually.
 - Draft Test on natural draft space and water heating appliances.
 - Exhaust/flue CO Test and Draft Test on natural gas fireplace logs.
 - Appliance-on visual inspection of appliances.
- Appliances that Fail NGAT Protocol
 - If a Room Ambient or Appliance Ambient CO measurement equals or exceeds the action level of 10 ppm, unit(s) causing elevated CO reading shall be serviced/adjusted by a utility gas service technician (or designee) and, when applicable, repaired or replaced.
 - An appliance that has inadequate draft or is inoperable shall be serviced/adjusted by a utility gas service technician (or designee) and, when applicable, repaired or replaced.
 - All units repaired or replaced shall undergo post-repair/replacement testing per Item 24.



10. GAS LEAKS AND SOLDERED GAS CONNECTORS

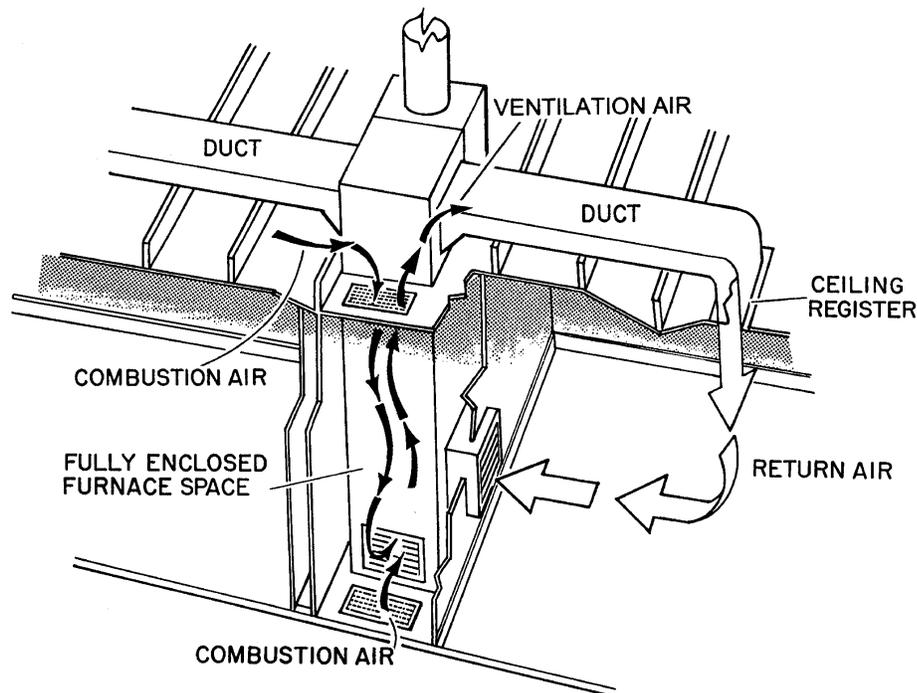
- Natural gas appliances shall be checked for gas leaks:
 - Prior to operating the appliance for testing.
 - With combustion appliances and exhaust fans/devices off.
- Appliances shall be checked for natural gas leaks using one or more of the following methods:
 - Olfactory (Sniff) Test performed above, but within 2' of, all valves and fittings.
 - Application of leak detection liquid to line valves and to fittings on valves, flexible gas connectors, and pipes.
 - Air sampling with electronic leak detection equipment near valves, fittings, flexible gas connectors, and pipes.
- When a gas leak is detected, inspection shall be conducted by a utility gas service technician (or designee).
- Leaks shall be repaired by a utility gas service technician (or designee) before appliances are operated for natural gas appliance tests.
- When faint gas odors are present prior, testing may occur; however, appliance shall be checked by a utility gas service technician (or designee).
- Soldered Gas Connectors
 - Old-style flexible gas connectors with soldered-on fittings shall be replaced with a new listed flexible gas connector.



CHECKING FOR NATURAL GAS ODOR

11. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION

- CVA shall be evaluated for open combustion natural gas heating systems and water heaters (cooking appliances and clothes dryers are *excluded*).
- CVA shall comply with these guidelines and Appendix A, unless superseded by manufacturer's instructions or local code.
- Appliances Drawing *Outdoor Air* through Combustion-Air Openings or Ducts
 - An *upper* opening or duct shall be located within 12" of the enclosure ceiling, and a *lower* opening or duct shall be located within 12" of the floor.
 - **Exception:** Pre-existing upper openings and ducts are acceptable at any height above the draft hood.
 - Combustion air openings and vertical ducts shall each provide 1 sq. in. net free venting area (NFVA) per 4,000 Btu/hr of input.
 - Horizontal ducts shall each provide 1 sq. in. NFVA per 2,000 Btu/hr of input.
 - Combustion air may also be obtained through a single upper vent or duct to outdoors under the following conditions:
 - Vent NFVA is at least: (a) 1 sq. in. per 3,000 Btu/hr input, and (b) not less than the sum of the cross-sectional areas of all vent connectors in the space.
 - Equipment has clearances of at least 1" sides and back, and 6" in front.



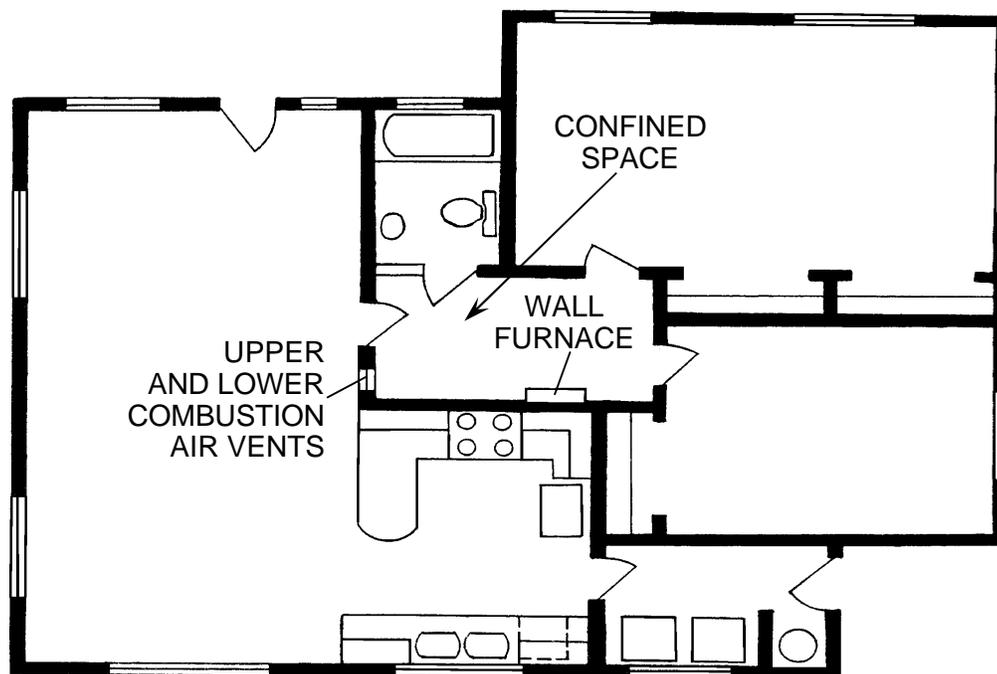
11. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

- When Appliances Draw Combustion Air from Outdoors
 - Combustion air may be obtained from outdoors by means of:
 - Permanent openings (undampened vents) of the required size directly to outdoors through enclosure floor, roof or walls; or
 - Continuous vertical or horizontal ducts of the required cross-sectional area extending from the enclosure to outdoors.
 - Combustion air may be obtained from the attic, provided:
 - Attic vents are not subject to ice or snow blockage.
 - The attic vertical clear height is at least 30" at the peak (from top of ceiling joists to bottom of rafters/ridge board).
 - Attic ventilation is sufficient to provide the required volume of combustion air.
 - Combustion air may be obtained from under the floor, provided:
 - Under-floor spaces have free flow of air.
 - Unobstructed openings to outdoors exist that are at least twice the NFVA of the required combustion air vent openings.
- Combustion-Air Ducts and Sleeves
 - Duct or sleeve into attic shall extend from appliance enclosure to at least 6" above the top of insulation.
 - Ducts and sleeves shall be a minimum of 26 gage galvanized steel or 24 gage aluminum, and ducts shall have a minimum cross-sectional dimension of 3".
- Louvers, Grilles, and Screens
 - Covering of 1/4" corrosion-resistant screen mesh is required on combustion air openings to outdoors, except ducts terminating in an attic, which shall not be screened on either end.
 - Blocking effects of louvers, grilles, and screens shall be considered when calculating NFVA of an opening (see Appendix A).

SOURCES OF COMBUSTION AIR		
OUTDOORS	ATTIC	UNDER FLOOR
<ul style="list-style-type: none"> • Permanent openings with undampened vents <u>or</u> continuous ducts (vertical or horizontal). • Vent directly to outdoors. • 1/4" screen mesh on all CVA openings. 	<ul style="list-style-type: none"> • Minimum 30" attic height at the peak. • Adequate attic ventilation that is unobstructed. • Duct/sleeve extending 6" above top of ceiling joists and insulation. 	<ul style="list-style-type: none"> • Free flow of air. • Unobstructed openings to outdoors with at least twice the area of required combustion air vent NFVA.

11. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

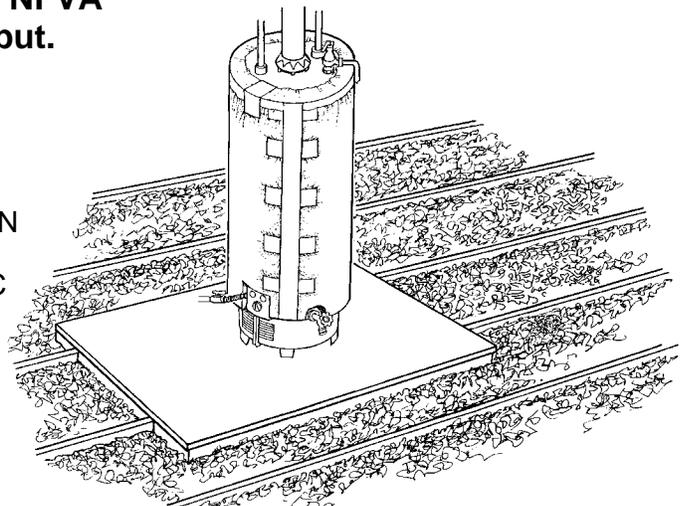
- When Appliances Draw Combustion Air from Indoors
 - Unconfined Space:
 - A room/space that has a volume of at least 50 cu. ft. per 1,000 Btu/hr total input rating of the open combustion furnace and/or water heater in that room/space.
 - Combustion air is considered adequate.
 - Confined Space:
 - A room/space that has a volume of less than 50 cu. ft. per 1,000 Btu/hr total input of the open combustion furnace and/or water heater in that room/space.
 - Combustion air is not adequate.
 - Proper vent openings to adjacent space(s) must be present.
 - Appliances Located in an Indoor Confined Space
 - Upper and lower vent openings shall be present which: (a) freely communicate with other indoor rooms/spaces, and (b) provide a combined volume of at least 50 cu. ft. per 1,000 Btu/hr total input.
 - The vent openings shall meet the following requirements:
 - Each vent opening shall provide 1 sq. in. of NFVA per 1,000 Btu/hr input, and shall be no smaller than 100 sq. in. NFVA.
 - Lower vents shall be located within 12" of the floor, and upper vents shall be located within 12" of the ceiling.
- Exception:** Pre-existing upper vents are acceptable at any height above the draft hood.



11. COMBUSTION AND VENTILATION AIR (CVA) EVALUATION (continued)

- Appliances Located in a Garage
 - When a garage (finished or unfinished) is an unconfined space, combustion air is considered adequate.
 - When a converted (finished) garage is a confined space used as conditioned living space:
 - Appliance(s) shall be isolated from the conditioned space by an enclosure vented to outdoors (as specified on page 29-15).
 - The garage shall not be vented into the main body of the house to obtain additional indoor combustion air.
 - When a garage is a confined space that is (a) unfinished or (b) finished and unconditioned (not living space), upper and/or lower permanent venting to outdoors shall provide at least 1 sq. in. NFVA per 4,000 Btu/hr total input.
- Appliances Located in a Crawlspace or Partial Basement
 - When the underfloor area (crawlspace or crawlspace plus partial basement) is an unconfined space, combustion air is adequate.
 - When the underfloor area is a confined space:
 - The under-floor space shall have free flow of air.
 - Unobstructed openings to outdoors shall provide at least twice the NFVA of the required combustion air vent openings.
- Appliances Located in an Attic
 - When attic is unconfined space, combustion air is adequate.
 - When attic is a confined space:
 - Upper and/or lower permanent attic venting shall be present on two sides/ends of the attic, and
 - Venting on each side/end shall provide at least 1 sq. in. NFVA per 4,000 Btu/hr total input.

OPEN COMBUSTION
WATER HEATER
LOCATED IN ATTIC



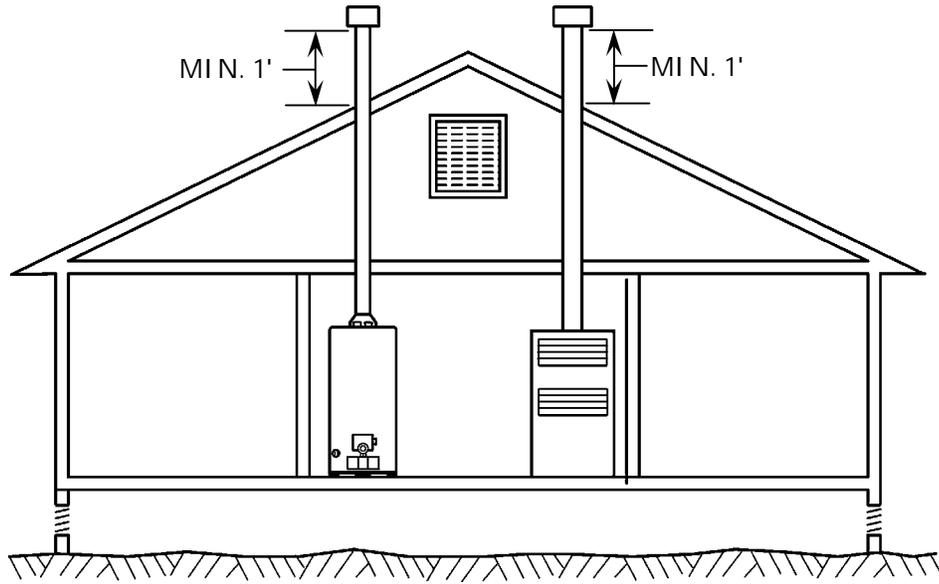
12. FLUE AND VENT SYSTEM EXAMINATION

- All gas vents shall terminate outdoors.
- Flue and vent systems shall be free of:
 - Draft hood defects:
 - Improperly installed or positioned.
 - Multiple (stacked) draft hoods on a single appliance.
 - Missing (no draft hood at all).
 - Disconnections or unsafe joints (e.g., loose, unsecured, etc.).
 - Holes or other hazardous conditions requiring repair.
 - Connection to a solid-fuel appliance chimney.
- Gas vents located 4' or more from a vertical wall or similar obstruction shall **extend at least 1' above the roof in accordance with CMC Chapter 8.**
 - Extend at least 1' above the roof.
 - Comply with Table 29-1.
- Gas vents located less than 4' from a vertical wall or similar obstruction shall terminate at least:
 - 2' above the highest point where they pass through the roof, and
 - 2' higher than any portion of the building within 10'.

Table 29-1: ~~Vent Termination Above a Roof~~

MINIMUM HEIGHT FROM ROOF TO LOWEST DISCHARGE OPENING	
ROOF SLOPE*	HEIGHT ABOVE ROOF
Flat to 6/12	1'–0"
Over 6/12 to 7/12	1'–3"
Over 7/12 to 8/12	1'–6"
Over 8/12 to 9/12	2'–0"
Over 9/12 to 10/12	2'–6"
Over 10/12 to 11/12	4'–0"
Over 11/12 to 12/12	5'–0"

***For other slopes, see CMC Chapter 8.**



12. FLUE AND VENT SYSTEM EXAMINATION (continued)

- Gas vents shall terminate no closer to a door, openable window, or gravity air inlet than the following minimum distances:
 - 4' below, or
 - 4' horizontally from, or
 - 1' above.

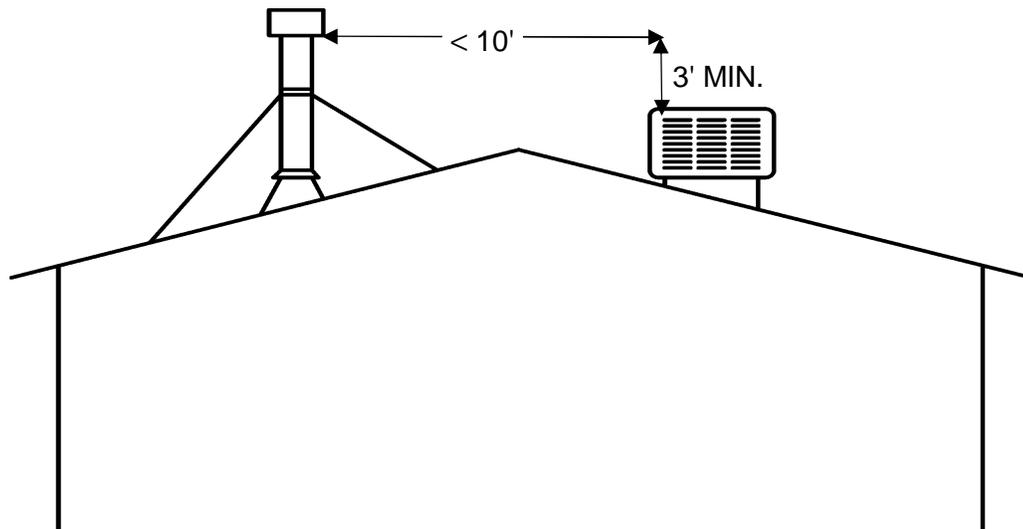
Exception 1: Vent terminals for Direct Vent **furnaces/appliances:**

- At least 9" away for inputs up to 50,000 Btu/hr.
- At least 12" away for inputs 50,100 to 65,000 Btu/hr.

Exception 2: Vent terminals for Forced or Induced Draft systems (e.g., induced draft space/water heater or condensing furnace):

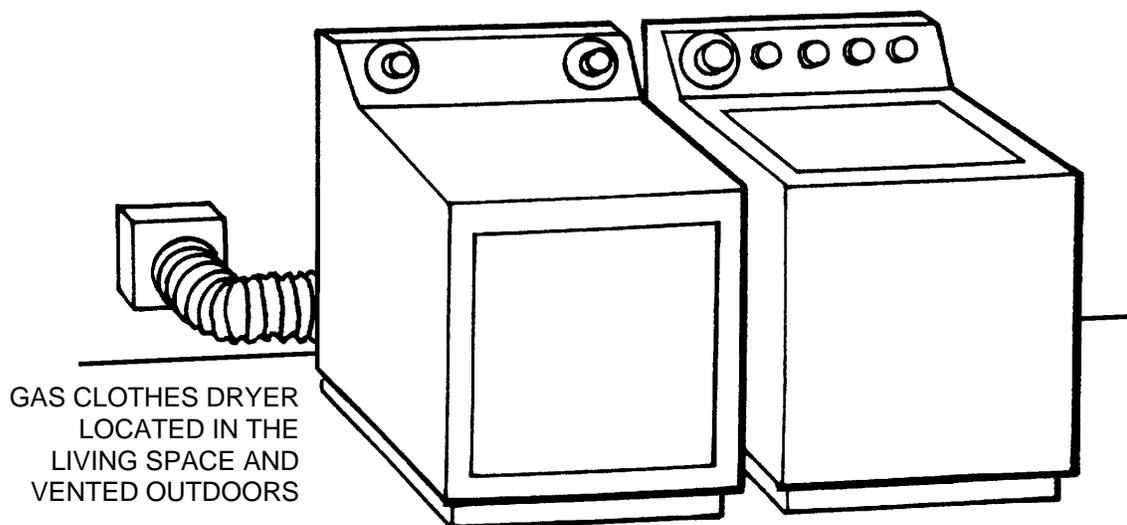
- At least 12" away.

- Outdoor Water Heater Vents
 - When an outdoor water heater is located within 4' of a first-floor wall, the vent pipe must terminate at least 1' above the first-floor roof.
 - The pipe may be offset from the roof overhang.
 - Offsets shall not exceed 45°, except one 60° offset is allowed.
- Flue and Vent Systems Terminating Near an Evaporative Cooler
 - A water heater flue/vent pipe located within 10' of an evaporative cooler shall terminate at least 3' above the cooler intake.
 - Furnace flue/vent pipes within 10' of an evaporative cooler shall terminate at least 3' above the cooler intake unless:
 - All cooler discharge openings are equipped with a vent cover, **and**,
 - The client is informed of the non-conforming flue/vent and advised to keep cover(s) in place during the heating season.



13. VISUAL APPLIANCE CHECKS

- Inoperable Gas Appliances
 - Inoperable natural gas appliances must be checked by a utility gas service technician (or designee), *unless* they are: (a) abandoned*, or (b) inaccessible*.
- The following conditions are not acceptable when Infiltration Reduction Measures are installed:
 - Gas clothes dryer located in the living space but not exhausted outdoors**.
 - Return leak present that can draw in combustion products from the FAU or other open combustion appliances (e.g., in a garage or room containing supply or return plenum/ductwork).
 - Whole house fan vented into an attic that contains a gas water heater or an open combustion furnace with standing pilot.
 - Unvented combustion space heater (e.g., gas or kerosene unit) present in the living space.
 - Open combustion water heater present in a sleeping area.
 - Gas range present which has a space heater or incinerator that is not properly vented outdoors.
 - *Inoperable gas appliance.*

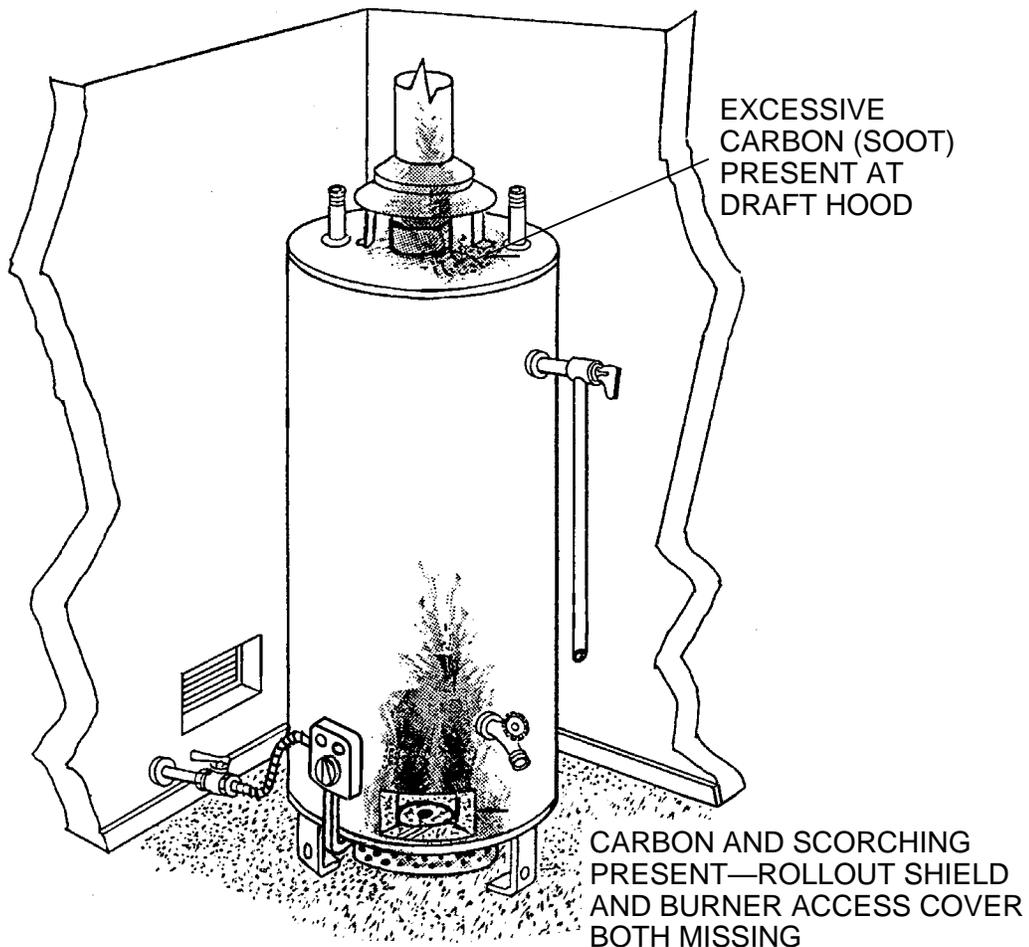


*See Definitions

****Termination in a crawlspace or basement is acceptable when the space: (a) has adequate cross-ventilation, (b) does not have a return air intake in the floor, and (c) does not contain an open combustion furnace or a combustion air vent located in the floor. Any dryer termination in an open combustion appliance enclosure/closet is not acceptable.**

13. VISUAL APPLIANCE CHECKS (continued)

- Appliance Components
 - The following appliance components shall be present:
 - Appliance door(s).
 - Combustion chamber access door(s).
 - Water heater shall have at least one access cover or roll-out shield.
 - Roll-out shield required on furnace when the unit was manufactured with a roll-out shield.
- Carbon and Rust
 - The top of the burner(s), the heat exchanger, draft hood and flue/vent pipe shall be examined for excessive amounts of carbon or rust.

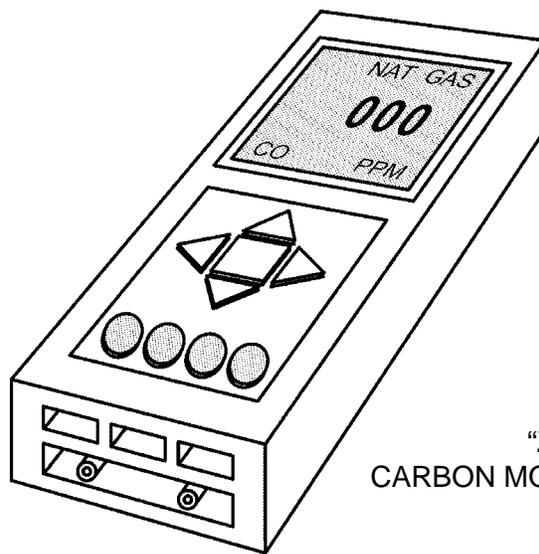


14. TEST CONDITIONS FOR ROOM AMBIENT CO TEST

- Test shall be performed *prior* to operating any appliances.
- Test Conditions
 - All gas appliances in the living space turned off (e.g., at the thermostat).
Exception: Water heater pilot may be operating, but main burner shall not be operating.
 - Air handler and all exhaust fans and air-exhausting devices turned off.
 - Exterior doors and windows closed.
 - Interior doors:
 - All interior room doors open.
 - Appliance enclosure doors closed.
 - Fireplace damper closed when feasible (no fire or hot coals).
 - If an interior cooler cover is available, it shall be in place.

15. CO ANALYZER “ZEROING”

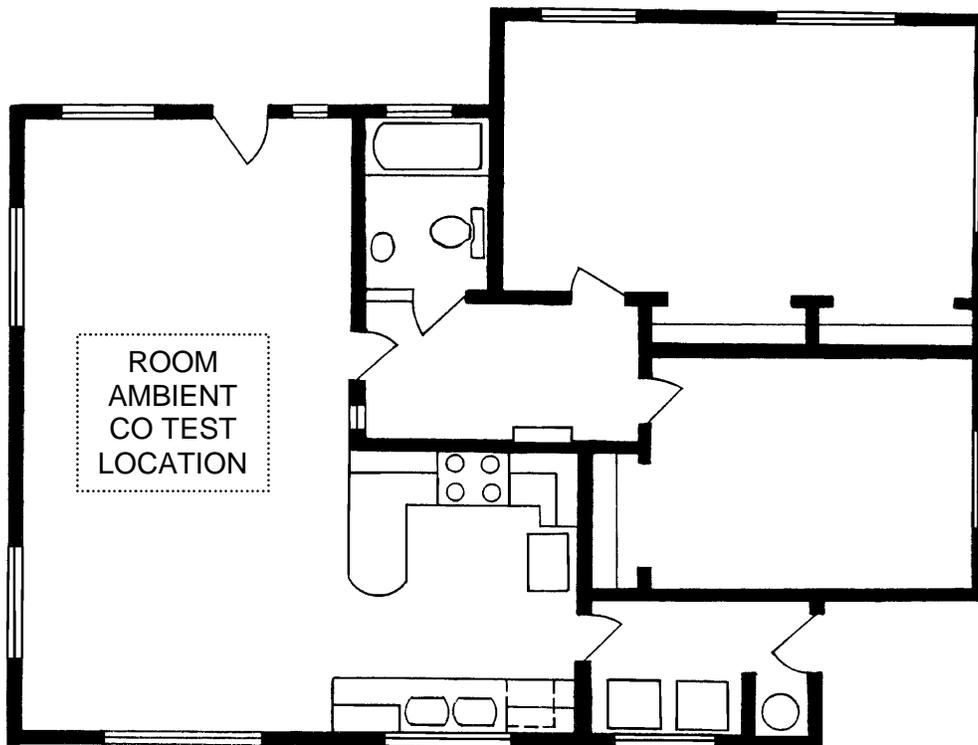
- Just prior to performing *Room Ambient CO Test*, the analyzer shall be adjusted outdoors to read zero ppm CO.
- CO analyzer shall be protected from outdoor sources of CO and from wind bearing pollutants.
- Analyzer shall remain on during entire ambient test sequence when possible.
- If turned off during ambient testing, zeroing process shall be repeated before resuming tests.



“ZEROED”
CARBON MONOXIDE ANALYZER

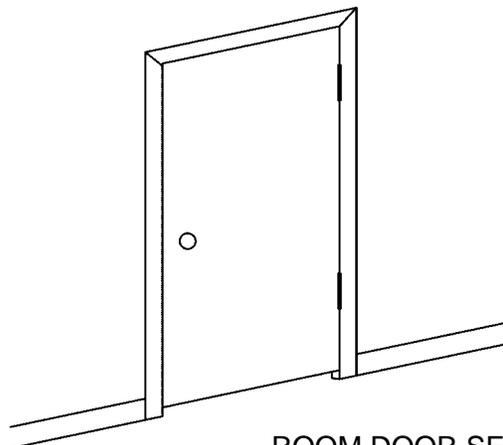
16. CONDUCTING ROOM AMBIENT CO TEST

- Room Ambient CO Test shall be conducted immediately after zeroing the CO analyzer:
 - In an open area in the main body of the living space (e.g., in the center of the living room or living/dining combination area).
 - 10' away from combustion appliances and supply registers (less than 10' away acceptable in smaller rooms).
 - 6' above the floor.
- If Room Ambient CO Test measurement is 10 ppm or greater:
 - The living space shall be ventilated and the test repeated when a condition such as the following exists:
 - Heavy smokers are present, or
 - Wood-burning or unvented heating/cooking appliances were operating within the preceding half hour.
 - Appliance Ambient CO Tests shall be conducted even if CO is 10 ppm or greater after ventilation and repeat of the Room Ambient CO Test.



17. TEST CONDITIONS FOR APPLIANCE-ON CO AND DRAFT TESTS

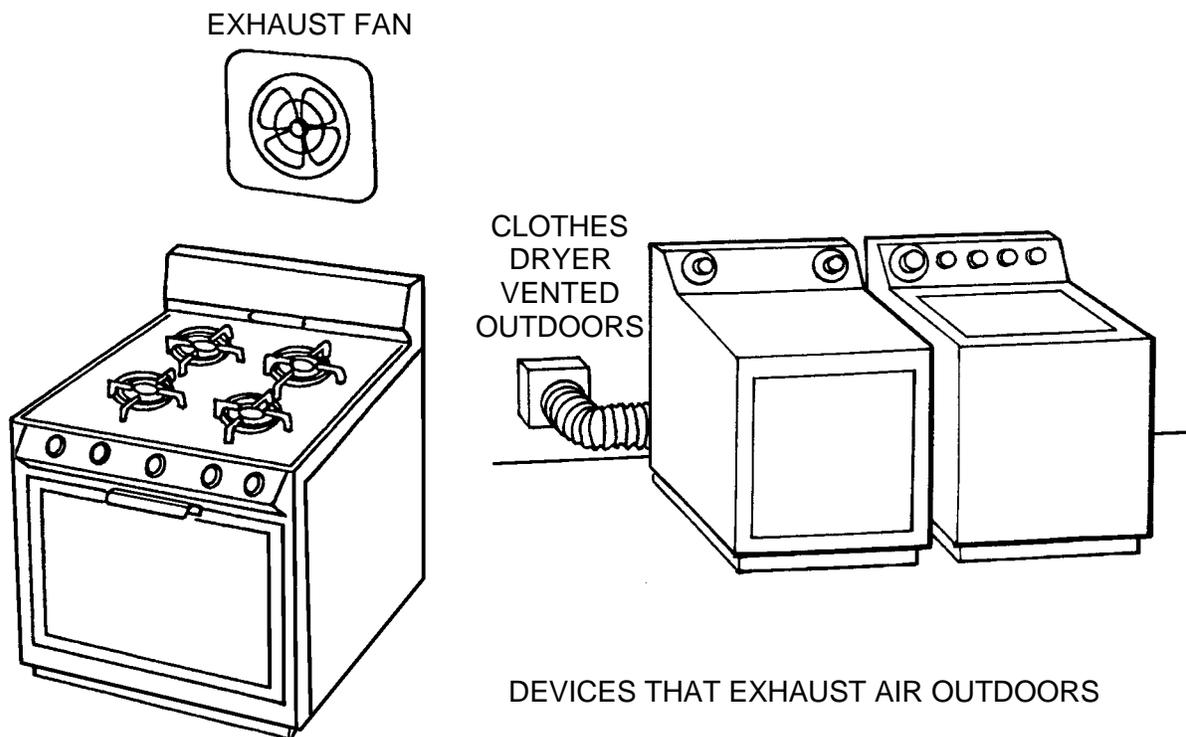
- The following test conditions shall be established for Appliance Ambient CO Tests and Draft Tests.
- Door/Window Positions for Tests in the Living Space
 - The following shall be closed:
 - All exterior doors and windows.
 - Doors to rooms containing a supply register when a central return is outside the room.
 - Appliance enclosure doors (except during tests).
 - The following shall be open:
 - Doors to all other living areas and rooms.
 - Door to utility room with clothes dryer exhausted outdoors.
Exception: When a natural draft appliance in that room is tested, the door shall be closed.
- Door/Window Positions for Tests in an Unconditioned Garage
 - Drive-through door and windows shall remain closed during all tests.
 - Door into the living space shall be opened when exhaust devices are in the living space or an FAU is present.
 - All exhaust devices in the living space and the garage shall be operating.
- Appliances Located in Attic and Crawl-space
 - Devices exhausting into the attic/crawlspace shall be off during Draft Tests on appliances in those locations.



ROOM DOOR SEPARATING
SUPPLY REGISTERS
FROM A CENTRAL RETURN

17. TEST CONDITIONS FOR APPLIANCE-ON CO AND DRAFT TESTS (continued)

- The following must be operating during tests:
 - FAU air handler.
 - All devices that exhaust air from the space containing an appliance being tested:
 - Include kitchen exhaust fans, bathroom and utility room fans, clothes dryer, central vacuum system, and manually-controlled attic ventilators.
 - Exclude whole house fan.
- FAU air filter(s) must be clean or shall be removed prior to testing.
- Clothes dryer lint screen shall be clean.
- Supply registers shall be open.
Exception: Supply register(s) shall be closed when located in a utility room or basement containing a natural draft appliance.
- If an interior cooler cover is available, it shall be in place.



18. TEST PROCEDURES FOR APPLIANCE AMBIENT CO TEST

- Test conditions shall be established as prescribed in Item 17.
- **Natural Gas Heating Appliances**
 - Heating appliance shall be operated for a minimum of 5 minutes.
 - All other gas appliances shall remain off.
Exception: Water heater pilot may be operating, but main burner shall **not** be operating.
 - CO shall be measured in the following locations:
 - Ducted units: In the supply register nearest the furnace.
 - Heaters without ducts (direct vent, wall and floor furnaces, and free-standing heaters): In the atmosphere directly above the top of the unit.
 - The heating system shall be checked by a utility gas service technician (or designee) if Appliance Ambient CO Test CO ppm is:
 - Higher than Room Ambient CO Test CO ppm, or
 - Above 9 ppm.
- **Natural Gas Water Heater**
 - Storage water heater shall be operated for a minimum of 5 minutes.
 - Tankless water heaters shall be operated for a minimum of 1 minute.
 - All other gas appliances shall remain off.
 - CO shall be measured in the atmosphere directly above the top of the water heater (and draft hood or inducer, if applicable).
 - The water heater shall be checked by a utility gas service technician (or designee) if Appliance Ambient CO Test CO exceeds 9 ppm.
- **Natural Gas Log**
 - An exhaust/flue CO test shall be conducted per Item 20.
- **Natural Gas Clothes Dryer**
 - No CO test required.

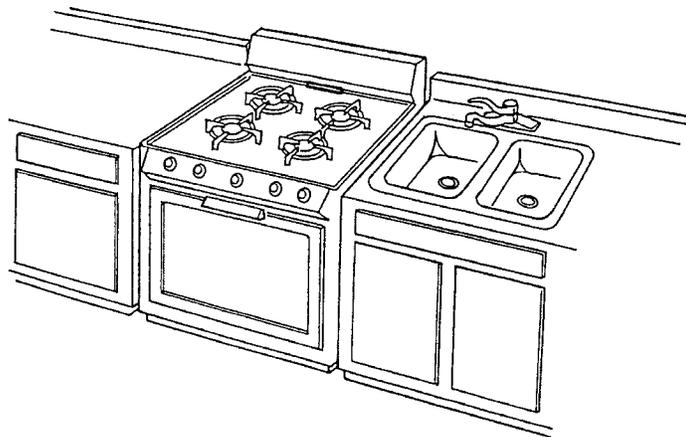
APPLIANCE AMBIENT CO TEST CO ANALYZER PROBE LOCATIONS FOR HEATING APPLIANCES AND WATER HEATERS
• <u>DUCTED UNITS:</u> INSIDE SUPPLY REGISTER NEAREST THE FAU WITH TEST PROBE DIRECTED INTO THE AIR FLOW.
• <u>NON-DUCTED HEATERS:</u> IN THE ATMOSPHERE ABOVE THE UNIT.
• <u>WATER HEATERS:</u> IN THE ATMOSPHERE ABOVE THE UNIT AND DRAFT HOOD.

18. TEST PROCEDURES FOR APPLIANCE AMBIENT CO TEST (continued)

- Natural Gas Kitchen Appliances
 - All other gas appliances shall remain off.
Exception: Water heater pilot may be operating, but main burner shall not be operating.
 - Cooktop:
 - With ovens and broilers off, all cooktop burners, and griddle if present, shall be operated on highest setting for one minute.
 - CO shall be measured in the center of the kitchen.
 - Oven and Broiler Units:
 - With cooktop off, each oven shall be operated on highest setting (i.e., “Broil” when applicable) for a minimum of 5 minutes (with separate broiler burner off).
 - When a separate broiler burner is present, it shall be operated on highest setting for 5 minutes (with oven burner off).
 - CO shall be measured in the center of the kitchen for oven and separate broiler, when present.
 - Range with Space Heater or Incinerator
 - Heater/incinerator shall be operated for a minimum of 5 minutes on highest burner setting.
 - Unit shall be tested prior to operating oven/broiler or at least 15 minutes after oven/broiler has been turned off.
 - CO shall be measured in the atmosphere directly above the top of the unit.
 - CO Action Level
 - The appliance shall be checked by a utility gas service technician (or designee) if Appliance Ambient CO Test CO exceeds 9 ppm.

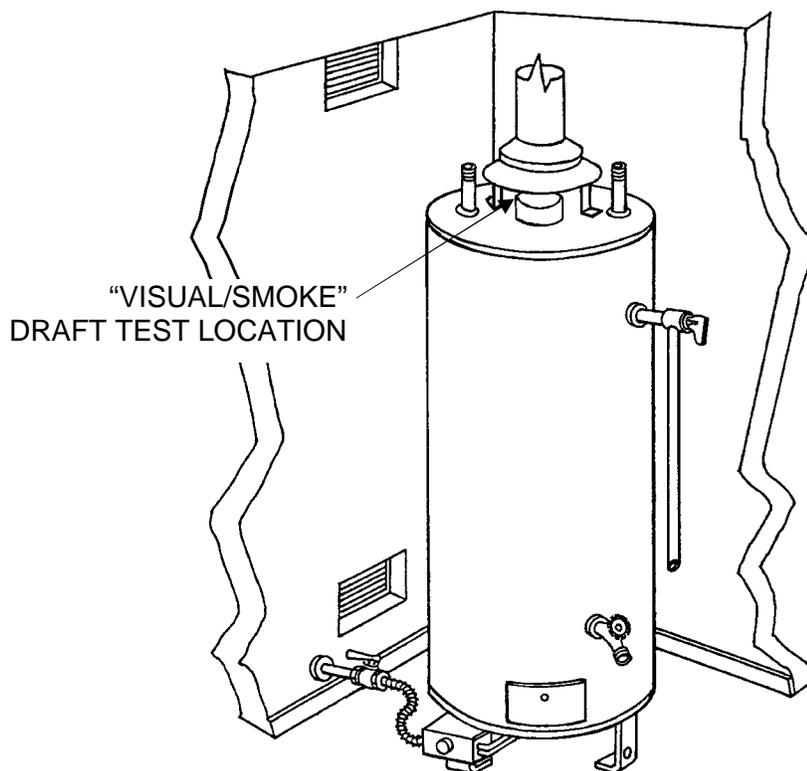
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APPLIANCE AMBIENT
CO TEST LOCATION:
CENTER OF KITCHEN



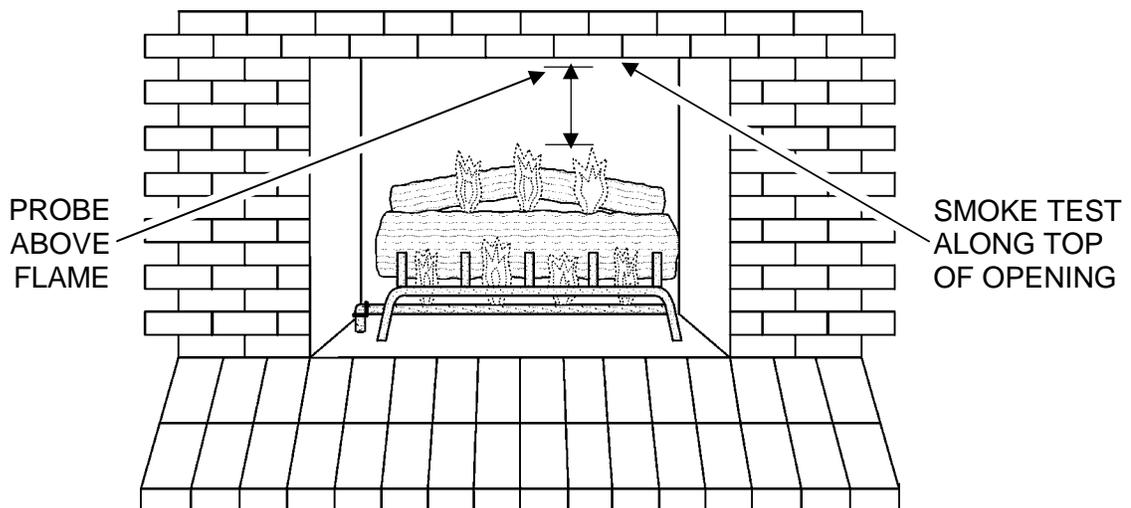
19. DRAFT EXAMINATION

- **Natural Gas Open Combustion Natural Draft Appliances**
 - Draft tests shall be performed after a minimum of 5 minutes of appliance operation.
 - **Visual/Smoke Draft Test** shall be performed on Natural Draft appliances, including ovens vented outdoors.
 - Smoke shall be applied along the entire draft hood opening.
 - Draft is adequate only if smoke is drawn into the draft hood along the entire draft hood opening.
- **Gas Logs**
 - **Visual/Smoke Draft Test** shall be performed as prescribed in Item 20.
- **All Units**
 - Corrective action is required when Draft not adequate.



20. CO AND DRAFT TESTING FOR NATURAL GAS LOGS

- When gas log is the primary heat source:
 - Damper must be blocked partially open (e.g., with a damper clip).
 - Opening shall be sufficient to prevent spillage of combustion products into the room.
- Fireplace glass doors shall be open during tests.
- Exhaust/Flue CO Test
 - Gas burner shall be operated for a minimum of 5 minutes before checking CO.
 - CO shall be sampled just inside the fireplace opening at least 12" above the flame.
 - If CO exceeds action level after 5 minutes, warm up time shall be increased (up to 30 minutes) and unit shall be retested.
 - Service by a utility gas service technician (or designee) is required if CO exceeds action level.
- CO Action Level*
 - ~~As established by the utility.~~
 - **25 ppm As Measured.**
 - **400 ppm Air Free.**
- Visual/Smoke Draft Test
 - Smoke shall be applied along the top of the fireplace opening.
 - Draft is adequate only if smoke is drawn inward along the entire fireplace opening.

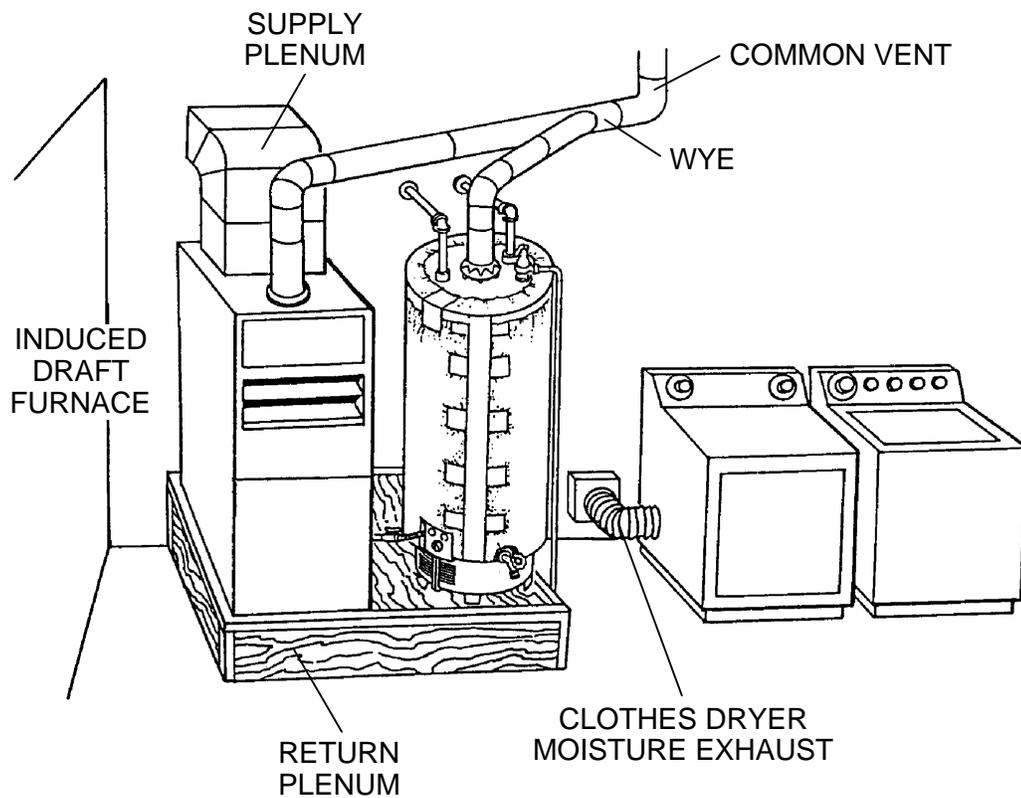


~~*The CPUC is currently considering a proposed settlement that would set statewide flue testing CO thresholds. This section will be updated when the commission has acted upon the proposed settlement.~~

21. MULTIPLE APPLIANCES SHARING A COMMON VENT

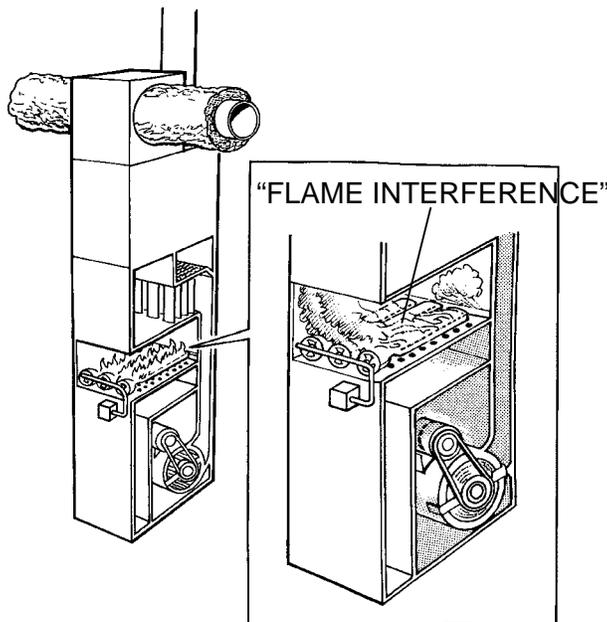
- Draft Tests

- All commonly-vented natural gas appliances shall be operating simultaneously during Draft tests.



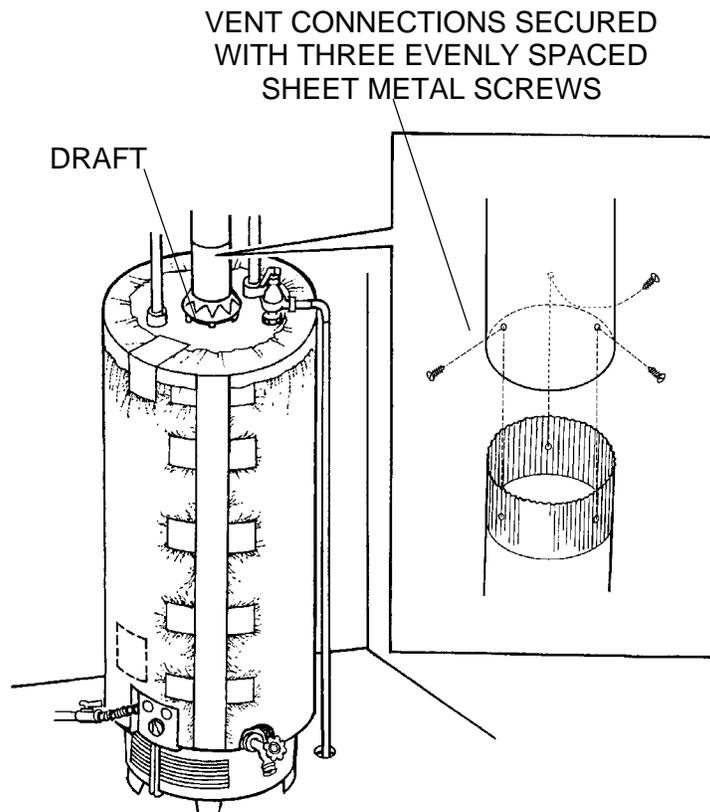
22. ADDITIONAL APPLIANCE EXAMINATIONS

- **Burner Performance**
 - **When the burner(s) ignite, checks shall be made for:**
 - **Delayed ignition.**
 - **Excessive roll-out.**
 - **Burner(s) shall be examined for flame abnormalities, including:**
 - **Large yellow flame (more than 50% yellow).**
 - **Soft lazy flame or smothering flame.**
- **Heat Exchanger Examination on Natural Gas Forced Air Heating Systems**
 - **Each accessible heat exchanger shall be inspected for cracks with a mirror and strong light.**
 - **The unit shall be further examined/serviced by a utility gas service technician (or designee) if any of the following conditions is present:**
 - **Flame interference caused by the air handler in an FAU.**
 - **A visually-detected crack.**
 - **Other evidence of a defective heat exchanger.**
- **If a defect exists, the condition shall be corrected by a utility gas service technician (or designee), or designated contractor licensed to repair HVAC appliances.**



23. FLUE AND VENT SYSTEM REPAIR

- Draft Hoods
 - The following conditions must be corrected:
 - Improperly installed or positioned draft hood.
 - Multiple (stacked) draft hoods on a single appliance.
 - No draft hood present where one is required.
- Repairing Flue and Vent Systems
 - New components shall conform to applicable codes.
 - All single-wall flue and vent pipe joints and connections shall be secured with 3 sheet metal screws (spaced as evenly as possible) where:
 - New components are installed.
 - Existing connections are loose and unsafe.
 - Double-wall Class B and BW flue and vent pipes shall not be drilled or have screws installed if doing so is prohibited by the pipe manufacturer or local code.



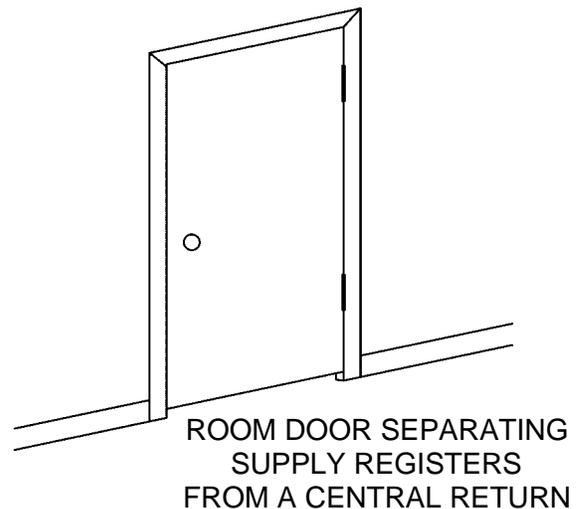
PART 5: POST-REPAIR/REPLACEMENT CHECKS

24. QUALITY ASSURANCE TESTING

- Natural gas appliances that have been repaired or replaced shall be checked for proper operation, which includes:
 - No gas leaks (Item 26)
 - Adequate Draft (Item 27)
 - Acceptable level of Carbon Monoxide (Item 28).
- Problems identified during post-repair/replacement checks must be corrected.

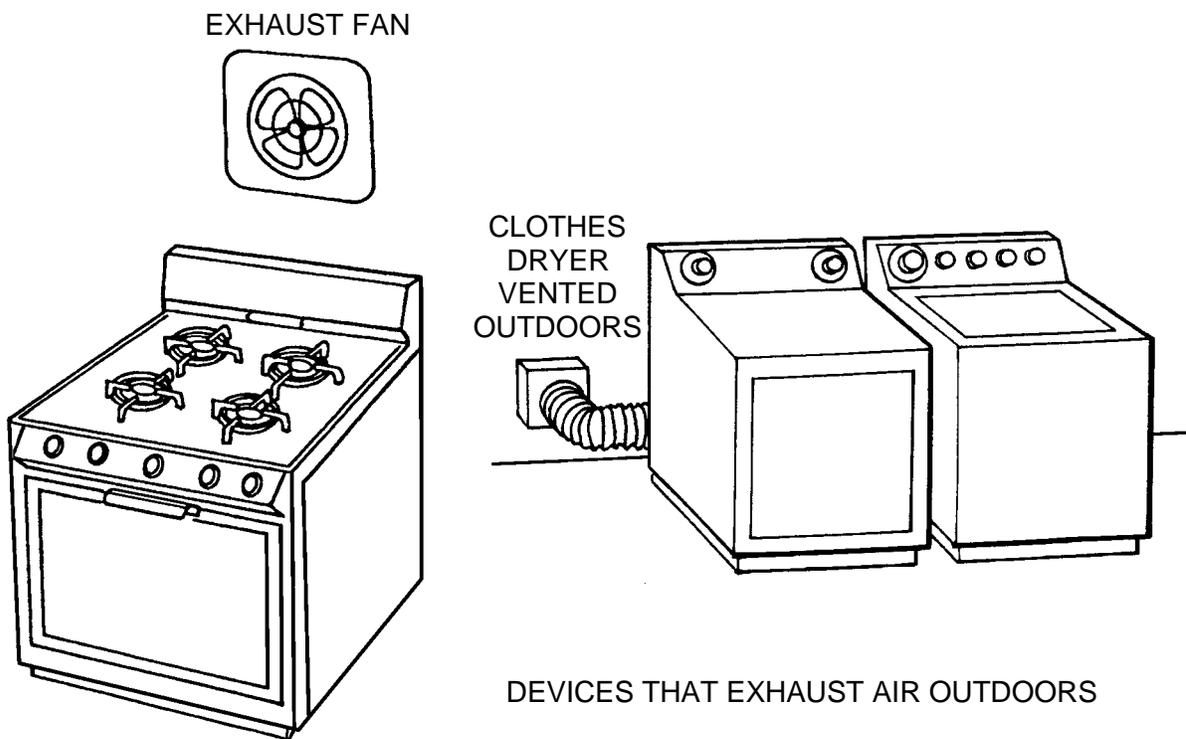
25. TEST CONDITIONS FOR POST-REPAIR/REPLACEMENT CO AND DRAFT TESTING

- Door/Window Positions for Tests in the Living Space
 - The following shall be closed:
 - All exterior doors and windows.
 - Doors to rooms containing a supply register when a central return is outside the room.
 - Appliance enclosure doors (except during tests).
 - The following shall be open:
 - Doors to all other living areas and rooms.
 - Door to utility room with clothes dryer exhausted outdoors.
Exception: When a natural draft appliance in that room is tested, the door shall be closed.
- Door/Window Positions for Tests in an Unconditioned Garage
 - Drive-through door and windows are closed during all tests.
 - Door into the living space shall be opened when exhaust devices are in the living space or an FAU is present.
 - All exhaust devices in the living space and the garage shall be operating.



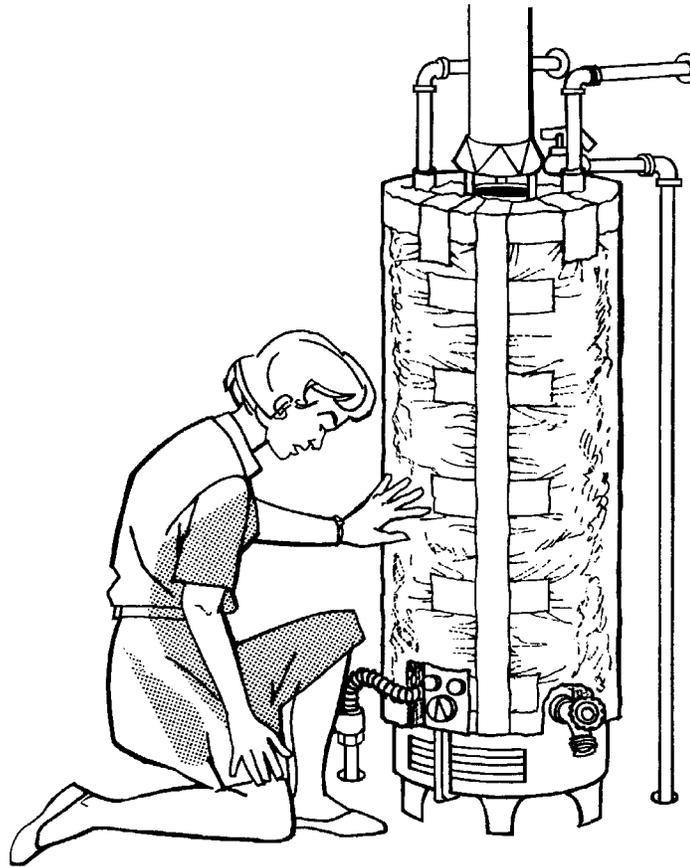
25. TEST CONDITIONS FOR POST-REPAIR/REPLACEMENT CO AND DRAFT TESTING (continued)

- Appliances Located in Attic and Crawl-space
 - Devices exhausting into the attic/crawlspace shall be off during Draft Tests on appliances in those locations.
- The following must be operating during tests:
 - FAU air handler.
 - All devices that exhaust air from the space containing an appliance being tested (*exclude* whole house fan).
- FAU air filter(s) must be clean or shall be removed prior to testing.
- Supply registers shall be open.
Exception: Supply register(s) shall be closed when located in a utility room or basement containing a natural draft appliance.
- If an interior cooler cover is available, it shall be in place.



26. GAS LEAKS

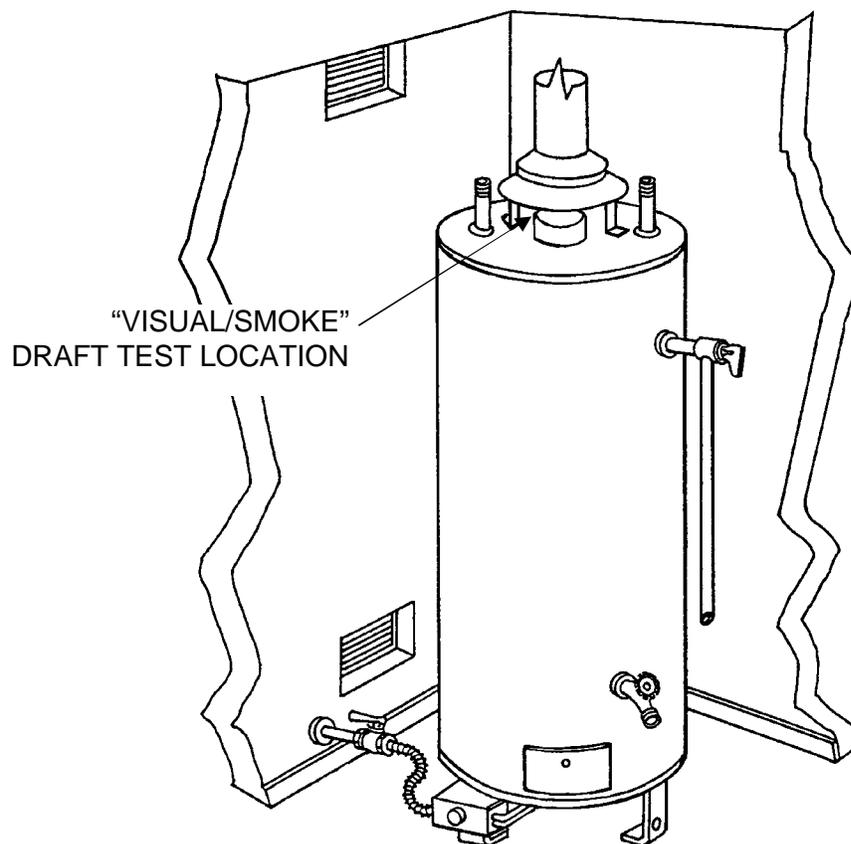
- Repaired/replaced appliances shall be checked for natural gas leaks using one or more of the following methods:
 - Olfactory (Sniff) Test performed above, but within 2' of, all valves and fittings.
 - Application of leak detection liquid to line valves and to fittings on valves, flexible gas connectors, and pipes.
 - Air sampling with electronic leak detection equipment near valves, fittings, flexible gas connectors, and pipes.
- Gas leaks shall be repaired.



CHECKING FOR NATURAL GAS ODOR

27. DRAFT EXAMINATION

- **Natural Gas Open Combustion Heating Systems and Water Heaters**
 - **Test conditions prescribed in Item 25 shall first be established.**
 - **Draft tests shall be performed after a minimum of 5 minutes of appliance operation.**
 - **Visual/Smoke Draft Test shall be performed on Natural Draft appliances.**
 - **Smoke shall be applied along the entire draft hood opening.**
 - **Draft is adequate only if smoke is drawn into the draft hood along the entire draft hood opening.**



28. CO TESTING FOR NATURAL GAS SPACE AND WATER HEATING SYSTEMS

- Appliance Ambient CO or Flue CO testing shall be performed.
- Appliance Ambient CO Tests
 - CO Tests shall be conducted per Items 14 – 18.
- Flue CO Tests
 - Test conditions prescribed in Item 25 shall first be established.
 - CO Tests shall be performed after a minimum of 5 minutes of burner operation.
 - Flue Gas CO measurements shall be:
 - Taken in combustion gases free of dilution air.
 - Conducted in accordance with the Table 29-2.

Table 29-2: Post-Repair/Replacement Flue CO Testing

APPLIANCE	MEASUREMENT LOCATION	MAXIMUM CO-LEVEL
FURNACES		
•Natural Draft	Inside each flue (exhaust port) separately	*
•Induced Draft and Closed Combustion	At flue termination, when accessible from the ground	*
WATER HEATERS		
•Natural Draft	Inside center tube on each side of the baffle	*
•Induced Draft and Closed Combustion	At flue termination, when accessible from the ground	*

~~*The CPUC is currently considering a proposed settlement that would set statewide flue testing CO thresholds. This section will be updated when the commission has acted upon the proposed settlement. During the interim, the maximum allowable CO level following service or replacement shall be as established by the utility.~~

APPLIANCE	CO MAXIMUM PPM		NATURAL DRAFT MEASUREMENT LOCATION*
	"AS MEASURED"	"AIR FREE"	
<i>Forced Air Furnace</i>	—	400	<i>Inside each exhaust port separately</i>
<i>Gravity Furnace</i>	—	400	<i>Inside each exhaust port separately</i>
<i>Wall Furnace</i>	—	200	<i>Inside flue on each side of baffle</i>
Wall Furnace (Direct Vent)	—	400	*
<i>Floor Furnace</i>	—	400	<i>Inside each exhaust port separately</i>
<i>Vented Room Heater</i>	—	200	<i>Inside each exhaust port separately</i>
<i>Water Heater</i>	—	200	<i>Inside flue on each side of baffle</i>
<i>Oven/Broiler</i>	225	—	<i>Inside exhaust port</i>
Top Burner & Griddle	25 (per burner)	—	<i>Burner: 12" above flame Griddle: Inside port opening</i>
<i>Gas Log</i>	25	400	<i>Inside top edge of fireplace opening</i>

**For Induced Draft and Closed Combustion appliances, flue gas CO is measured at the flue termination when it is accessible from the ground.*

NONFEASIBILITY CRITERIA FOR NGAT FOR ENTIRE DWELLING

1. Non-IOU combustion fuel is used for space heating.
2. No infiltration-reduction measures are **being** installed.
3. No natural gas appliance affecting the living space is present.

NONFEASIBILITY CRITERIA FOR NGAT FOR INDIVIDUAL APPLIANCE

1. Non-IOU combustion fuel is used.
 - Exception: Appliances subject to PG&E-specific policy.
2. Appliance is abandoned*.
3. Appliance is inaccessible*.

*See Definitions.

APPENDIX -A-

COMBUSTION *AND VENTILATION* AIR (*CVA*) REQUIREMENTS FOR GAS FURNACES/HEATERS AND WATER HEATERS

APPENDIX -A-

COMBUSTION AND VENTILATION AIR (CVA) REQUIREMENTS FOR NATURAL GAS FURNACES/HEATERS & WATER HEATERS

1.0 PURPOSE

This appendix is based on Chapter 7 of the ~~1998-2001~~ CMC (California Mechanical Code) *and Chapter 3 of the 2003 International Fuel Gas Code (IFGC)*. It is a quick reference to determine room volume or vent size requirements for open combustion *furnaces and water heaters*. This appendix does not apply to direct vent appliances and other closed combustion appliances drawing air from outdoors, listed cooking appliances, refrigerators, and domestic clothes dryers. Definitions listed below include those contained in CMC Chapter 2.

2.0 DEFINITIONS

Confined Space: A room or space having a volume of less than 50 cubic feet per 1,000 Btu/h of the aggregate input rating of all fuel-burning open combustion furnaces/heatings and water heaters installed in that space.

Unconfined Space: A room or space having a volume of at least 50 cubic feet per 1,000 Btu/h of the aggregate input rating of all fuel-burning open combustion furnaces/heatings and water heaters installed in that space. Adjacent rooms communicating directly with the space and not separated by doors are considered part of the unconfined space.

Homes of Ordinary Tightness: Homes not of unusually tight construction.

Homes of Unusually Tight Construction: Homes with the following construction features: (a) walls and ceilings exposed to the outside atmosphere have a continuous water vapor retarder rated 1 perm or less, with all openings sealed; (b) weatherstripping on openable windows and doors; and (c) caulking or sealants are applied to areas such as joints around window and door frames, between sole plates and floors, between wall-ceiling joints, between wall panels, and at plumbing/wiring penetrations and other openings.

NFVA: Net Free Venting Area, which is the gross opening area minus blocking effect of screen and/or louvers (see "Louvers, Grilles and Screens" below).

3.0 CALIFORNIA MECHANICAL CODE (CMC) CRITERIA

Many combustion air code requirements are addressed in the footnotes on page A-3. Others are covered in this section, and formulas used to calculate room volume and vent size are presented in Section 4.0.

Louvers, Grilles and Screens. (CMC 702.3) Combustion air openings must be covered with 1/4-inch mesh (except ducts which terminate in an attic, which are not screened on either end). The blocking affect of louvers, grilles and screens must be deducted from the gross opening of a vent to determine the "net free" venting area (NFVA). When an NFVA is not identified on the vent, it may be estimate by multiplying the *total (gross) opening area* by the suggested "reduction factors" shown in the table below. (Also see the *2003 NFGC 304.10*.)

SUGGESTED SCREEN AND LOUVER REDUCTION FACTORS FOR COMBUSTION AIR VENTS

1/4" Screen (Hardware Cloth)	1/4 Screen with Metal Louvers	1/4 Screen with Wood Louvers	Insect Screen (Mesh under 1/4")	Insect Screen w/ Metal Louvers	Insect Screen w/ Wood Louvers
0.90 (90%)	0.75 (75%)	0.25 (25%)	0.50 (50%)	0.50 (50%)	0.25 (25%)

Prohibited Sources. (CMC 703.3) Vent openings and ducts cannot connect an appliance enclosure with a space in which the operation of a fan may adversely affect the flow of combustion air.

Combustion-Air Ducts. (CMC Section 704) Ducts must be galvanized steel or equivalent corrosion-resistant material approved for the use. A duct must have the same cross-sectional area as the free area of the opening to which it connects.

4.0 USING THE COMBUSTION AIR MATRIX

Column [A] in the CVA Requirements matrix on page A-3 lists several Btu/hour Input Rating totals. Columns [B] through [F] list corresponding room volumes (cu. ft.) and vent sizes (sq. in. of NFVA). For Btu/h totals not shown, the required room volume or vent NFVA can be calculated using the applicable formula from the table below (*note: "KBtu" = 1,000 Btu*).

Column	Application	Requirement [Formula in Brackets]
[B]	All air from <i>indoors</i> , based on room size	50 cu. ft. of room volume per 1,000 Btu/h input. [KBtu x 50] or [Btu / 2 and drop last zero]
[C]	All air from <i>indoors</i> , 1 upper vent <u>and</u> 1 lower vent to another room/space*	When the volume of the room/space containing an appliance is inadequate, an upper <u>and</u> a lower vent may be installed to communicate with an adjacent unconfined space. <u>Each</u> vent must provide 1 sq. in NFVA per 1,000 Btu/h input , with a <i>minimum</i> size of 100 sq. in. [100 + KBtu over 100]
[D]	<i>All air from outdoors, 1 upper vent or duct**</i>	1 upper opening (or vertical or horizontal duct) may be used to provide the combustion air (lower vent <u>not</u> required). The vent/duct must provide 1 sq. in NFVA per 3,000 Btu/h input. [KBtu / 3]
[E]	All air from <i>outdoors</i> , 1 upper vent or vertical duct <u>and</u> 1 lower vent or vertical duct*	<u>Each</u> opening and <i>vertical</i> duct must provide 1 sq. in NFVA per 4,000 Btu/h input. [KBtu / 4]
[F]	All air from <i>outdoors</i> , 1 upper horizontal duct <u>and</u> 1 lower horizontal duct*	<u>Each</u> <i>horizontal</i> duct must provide 1 sq. in NFVA per 2,000 Btu/h input. [KBtu / 2]

*See footnote 5 on page A-3 regarding placement of upper and lower vents and ducts. For ducts, also see the double-asterisk (**) note at the bottom of the page advising that the minimum cross-sectional area of a duct is 3" (3"x3" rectangular, or 3" round).

**See footnote 1 on page A-3 regarding the acceptability of just *one* combustion air vent or duct.

The matrix on page A-3 summarizes most combustion air venting options specified in Chapter 7 of the ~~1998-2001~~ CMC. It is based on CMC Table 7-A (except [D], based on IFGC 304.6.2).

This appendix is only a guide. Each installer is responsible for meeting all requirements of the local jurisdiction and applicable codes and regulations.

CVA REQUIREMENTS FOR GAS FURNACES/HEATERS & WATER HEATERS

OPEN COMBUSTION FURNACE AND/OR WATER HEATER IN A ROOM/SPACE	HOMES OF ORDINARY TIGHTNESS*, WITH APPLIANCES LOCATED IN A CONFINED SPACE*, AND ALL COMBUSTION AIR OBTAINED FROM INDOORS		HOMES OF UNUSUALLY TIGHT CONSTRUCTION*, OR OF INADEQUATE VOLUME, WITH ALL COMBUSTION AIR OBTAINED FROM OUTDOORS		
	TOTAL INPUT	MIN. ROOM VOLUME	MIN. NFVA* PER VENT ⁴	MIN. NFVA* FOR 1 VENT/VERTICAL DUCT ⁴	MIN. NFVA* FOR EACH OF 2 VENTS/VERTICAL DUCTS
[A] BTU/HR	[B] Cu. Ft.	[C] Sq. In.	[D] Sq. In.	[E] Sq. In.	[F] Sq. In.
20,000	1,000	100	6.7**	5.0**	10.0
25,000	1,250	100	8.3**	6.3**	12.5
30,000	1,500	100	10.0	7.5**	15.0
35,000	1,750	100	11.7	8.8**	17.5
40,000	2,000	100	13.3	10.0	20.0
45,000	2,250	100	15.0	11.3	22.5
50,000	2,500	100	16.7	12.5	25.0
55,000	2,750	100	18.3	13.8	27.5
60,000	3,000	100	20.0	15.0	30.0
65,000	3,250	100	21.7	16.3	32.5
70,000	3,500	100	23.3	17.5	35.0
75,000	3,750	100	25.0	18.8	37.5
80,000	4,000	100	26.7	20.0	40.0
85,000	4,250	100	28.3	21.3	42.5
90,000	4,500	100	30.0	22.5	45.0
95,000	4,750	100	31.7	23.8	47.5
100,000	5,000	100	33.3	25.0	50.0
105,000	5,250	105	35.0	26.3	52.5
110,000	5,500	110	36.7	27.5	55.0
115,000	5,750	115	38.3	28.8	57.5
120,000	6,000	120	40.0	30.0	60.0
125,000	6,250	125	41.7	31.3	62.5
130,000	6,500	130	43.3	32.5	65.0
135,000	6,750	135	45.0	33.8	67.5
140,000	7,000	140	46.7	35.0	70.0
145,000	7,250	145	48.3	36.3	72.5
150,000	7,500	150	50.0	37.5	75.0
155,000	7,750	155	51.7	38.8	77.5
160,000	8,000	160	53.3	40.0	80.0

¹Just one opening within 12" of the ceiling (or one vertical or one horizontal duct) is allowed when the appliance has clearances of 1" on sides and back and 6" in front. Vent/duct NFVA must equal the sum of the vent connector areas.

²Combustion air must be obtained air from outdoors or from spaces freely communicating with outdoors.

³Attic must be adequately vented to provide the required volume of combustion air. Attic must have at least 30" clear vertical height at peak. Vent openings must be protected from ceiling insulation (e.g., with sleeve 6" above it).

⁴Vertical ducts must extend 6" above ceiling insulation, and may not be screened on either end.

⁵Upper vent/duct termination shall be installed within 12" of the ceiling, and lower vent/duct termination shall be within 12" of the floor. However, a pre-existing upper vent at any location higher than the draft hood is acceptable.

⁶Crawl space must have free flow of air and unobstructed openings to outdoors totaling twice the required NFVA. Foundation vents should be screened with 1/4" mesh and provide at least twice the NFVA of required CVA openings.

*See definitions on page A-1. **The minimum cross-sectional dimension of ducts is 3". Minimum rectangular duct is 3"x3" (9.0 sq. in.); minimum round duct is 3" diameter ($\pi r^2 = 3.1415 \times 1.5" \times 1.5" = 7.07 \text{ sq. in.}$).

APPENDIX -D-

METHODS FOR ESTIMATING AND MEASURING AIRFLOW

CONTENTS

PART I: SUGGESTED METHODS FOR ESTIMATING AIRFLOW

- 1. Air Conditioning Capacity (Tons)**
 - The Preston Guide or Carrier Blue Book
 - Model Number Nomenclature
- 2. Heating System Capacity (kBtuh)**
 - Btu Output of Gas Furnace
 - Wattage of Electric Furnace

PART II: APPROVED METHODS FOR MEASURING AIRFLOW

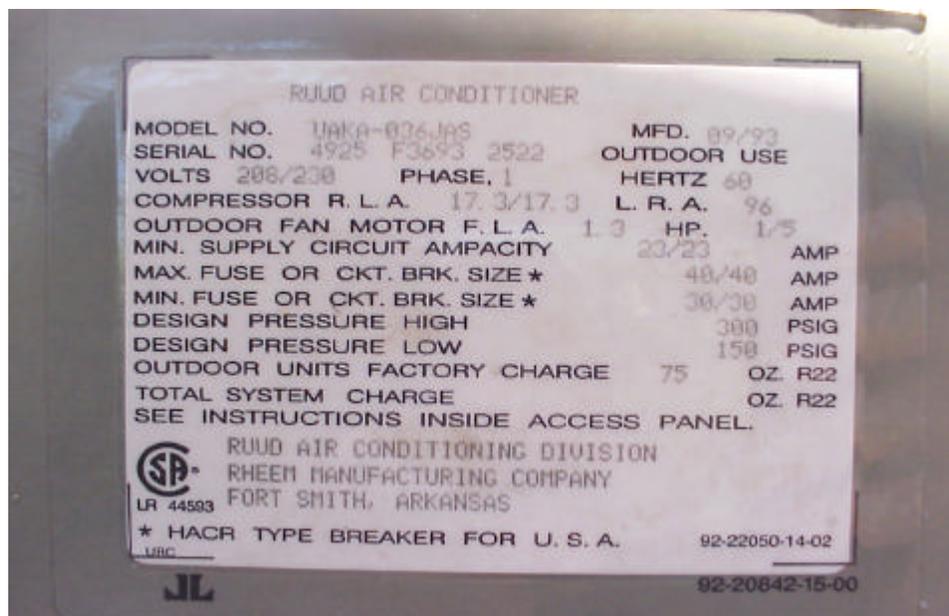
- 1. Flow Grid Measurement**
- 2. Plenum Pressure Matching Measurement (Duct Tester Used as a Powered Capture Hood)**
- 3. Using A Flow Capture Hood**

METHODS FOR ESTIMATING AND MEASURING AIRFLOW

PART I – METHODS FOR ESTIMATING AIRFLOW

1. METHODS

- **The following methods are outlined in this Appendix:**
 - Air Conditioning Capacity (Tons)
 - The Preston Guide or Carrier Blue Book
 - Model Number Nomenclature
 - Heating System Capacity (kBtuh Output)
 - Btuh Output of Gas Furnace
 - Wattage of Electric Furnace
- **Air Conditioner or Heat Pump**
 - AC/HP unit capacity may be determined by the following methods using information obtained from the condenser nameplate:
 - The Preston Guide or Carrier Blue Book
 - Model Number Nomenclature
- **Gas or Electric Furnace**
 - Furnace capacity may be determined by using the unit's Btuh Output.
 - Gas: Directly from the nameplate
 - Electric: Wattage converted to Btuh Output

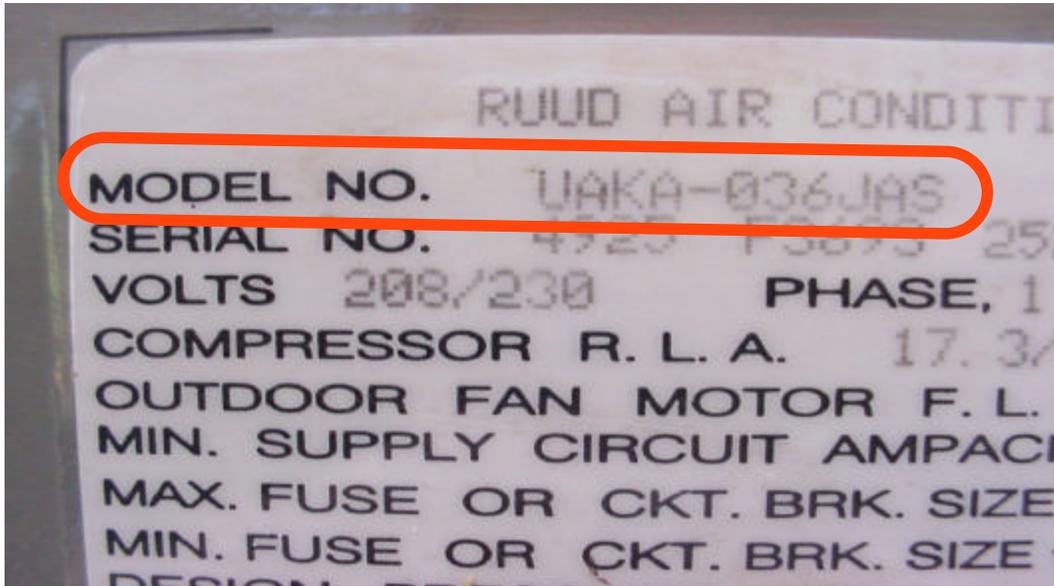


EXAMPLE OF A CONDENSER NAMEPLATE

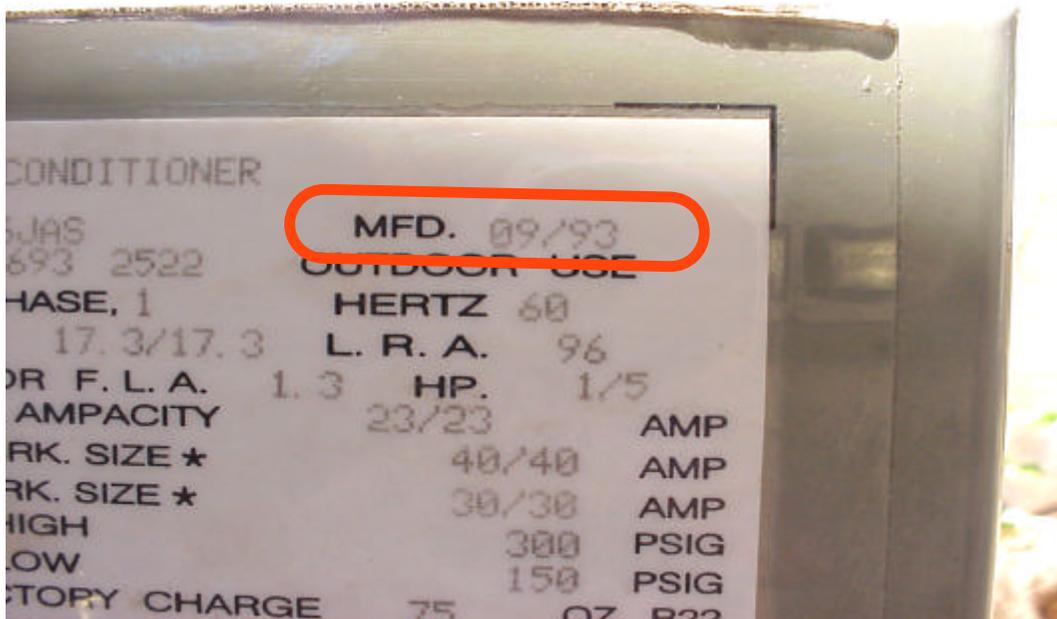
2. AIR CONDITIONER AND HEAT PUMP UNITS

- **Method A—Preston Guide or Carrier Bluebook**

- **Step A-1:** Determine the model number and date of manufacture from the condenser nameplate.



NAMEPLATE SHOWS MODEL NUMBER TO BE "UAKA-036JAS"



NAMEPLATE SHOWS DATE OF MANUFACTURE TO BE "09/93"

Appendix -D-

2. AIR CONDITIONER AND HEAT PUMP UNITS (continued)

- Method A—Preston Guide or Carrier Bluebook (continued)

- **Step A-2:** Check the Preston Guide (or Carrier Bluebook) to determine cooling capacity of the unit, based on model number and date of manufacture.
 - Find model number UAKA-036JA manufactured in 1993.
 - Find cooling capacity, which in this example is 34,400 Btu.

Preston Guide

RUUD				RUUD			
YEAR	BTU	EER/SEER		YEAR	BTU	EER/SEER	
1987	36,600	9.7		1989	45,000	10.8	UAKA-018JA
1987	36,600	9.7		1989	45,000	10.8	UAKA-024JA
1987	39,500	9.5		1991	45,000	10.8	UAKA-036JA
1987	39,500	9.5		1993	45,000	10.8	UAKA-042JA
1987	47,500	9.1		1988	56,500	9.4	UAKA-036CA
1987	47,500	9.1		1989	56,500	9.4	UAKA-042CA
1987	54,000	9.1		1991	56,500	10.0	UAKA-036JA
1987	54,000	9.1		1992	56,500	10.0	UAKA-042JA
1988	18,000	11.3		1993	56,500	10.0	UAKA-036JA
1989	18,000	11.3		1988	56,500	10.0	UAKA-042JA
1990	17,400	11.0		1989	56,500	10.0	UAKA-036JA
1991	17,400	11.0		1991	56,500	10.0	UAKA-042JA
1992	17,400	11.0		1992	56,500	10.0	UAKA-036JA
1993	17,400	11.0		1993	56,500	10.0	UAKA-042JA
1992	24,200	10.7		1988	56,500	10.0	UAKA-036JA
1993	24,200	10.7		1989	56,500	10.0	UAKA-042JA
1988	23,000	9.2		1990	56,500	10.0	UAKA-036JA
1989	23,000	9.2		1991	56,500	10.0	UAKA-042JA
1990	22,200	8.7		1992	56,500	10.0	UAKA-036JA
1991	22,200	8.7		1993	56,500	10.0	UAKA-042JA
1992	22,200	8.7		1988	56,500	10.0	UAKA-036JA
1993	22,200	8.7		1989	56,500	10.0	UAKA-042JA
1988	30,800	11.0		1990	56,500	10.0	UAKA-036JA
1989	30,800	11.0		1991	56,500	10.0	UAKA-042JA
1990	30,800	11.0		1992	56,500	10.0	UAKA-036JA
1991	30,800	11.0		1993	56,500	10.0	UAKA-042JA
1992	30,800	11.0		1988	56,500	10.0	UAKA-036JA
1993	30,800	10.3		1989	56,500	10.0	UAKA-042JA
1988	35,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	35,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	35,000	10.5		1992	56,500	10.0	UAKA-036JA
1991	35,000	10.5		1993	56,500	10.0	UAKA-042JA
1992	35,000	10.5		1988	56,500	10.0	UAKA-036JA
1993	35,000	10.5		1989	56,500	10.0	UAKA-042JA
1988	41,500	10.1		1990	56,500	10.0	UAKA-036JA
1989	41,500	10.1		1991	56,500	10.0	UAKA-042JA
1990	41,500	10.7		1992	56,500	10.0	UAKA-036JA
1991	41,500	10.7		1993	56,500	10.0	UAKA-042JA
1992	41,500	10.7		1988	56,500	10.0	UAKA-036JA
1993	41,500	10.7		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
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1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
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1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.0	UAKA-036JA
1991	45,000	10.8		1993	56,500	10.0	UAKA-042JA
1992	45,000	10.8		1988	56,500	10.0	UAKA-036JA
1993	45,000	10.8		1989	56,500	10.0	UAKA-042JA
1988	45,000	9.5		1990	56,500	10.0	UAKA-036JA
1989	45,000	9.5		1991	56,500	10.0	UAKA-042JA
1990	45,000	10.8		1992	56,500	10.	

2. AIR CONDITIONER AND HEAT PUMP UNITS (continued)

- **Method A—Preston Guide or Carrier Bluebook (continued)**
 - **Step A-3:** Calculate cooling capacity in tons based on KBtu.
 - Per the Preston Guide, unit cooling capacity = 34,400 Btu
 - Divide Unit Capacity by 12,000 Btu/ton to convert Btu to tons:
[34,400 Btu ÷ 12,000 Btu/ton = 2.87 tons]
 - Establish tons of cooling capacity:
 - Round up to 3 tons, or
 - Find “Nominal Tons” using the chart in Figure D-1.
- **Method B—Model Number Nomenclature**
 - This method may be used when KBtu can be determined from the model number.
 - **Step B-1:** Locate model number on the condenser name plate.
 - Refer to the nameplate pictured on pages D-2 and D-3.
 - In this example, the model number is “UAKA-036JAS”.
 - **Step B-2:** Establish cooling capacity in Btu.
 - 36 is the capacity of the unit, and
 - That is equivalent to 36,000 Btu.
 - **Step B-3:** Divide unit capacity in Btu by 12,000 Btu/ton to determine cooling capacity in tons:
 - [36,000 Btu ÷ 12,000 Btu/ton = 3 tons]
 - Cooling capacity is 3 tons.

FIGURE D-1: NOMINAL TONS BASED ON UNIT CAPACITY IN BTU

UNIT CAPACITY (BTU)	CALCULATED TONS	NOMINAL TONS
14,000 – 21,999	1.17 – 1.82	1.5
22,000 – 26,999	1.83 – 2.24	2.0
27,000 – 32,999	2.25 – 2.74	2.5
33,000 – 38,999	2.75 – 3.24	3.0
39,000 – 44,999	3.25 – 3.74	3.5
45,000 – 53,999	3.75 – 4.49	4.0
54,000 – 62,999	4.50 – 5.24	5.0

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3. FURNACES

- **System G: Determining Estimated Airflow for Gas Furnaces**

- **Step G-1:** Determine Btuh output from unit name plate.
 - Locate Btuh output on the nameplate (see picture below).
 - Output is 80,000 Btuh in this example.
 - If only Input is listed, Output = Input x (% efficiency).
 - Example: (100 kBtuh Input) x (0.80 AFUE) = 80 kBtuh.
- **Step G-2:** Convert Btuh output to estimated airflow in cfm.
 - Assume 21.7 cfm per kBtuh.
 - Use the following equation to determine estimated airflow:
[Output kBtuh x 21.7 cfm/kBtuh = cfm system airflow]
 - Example:
[80 (kBtuh) x 21.7 (cfm/kBtu) = 1,736 cfm system airflow]

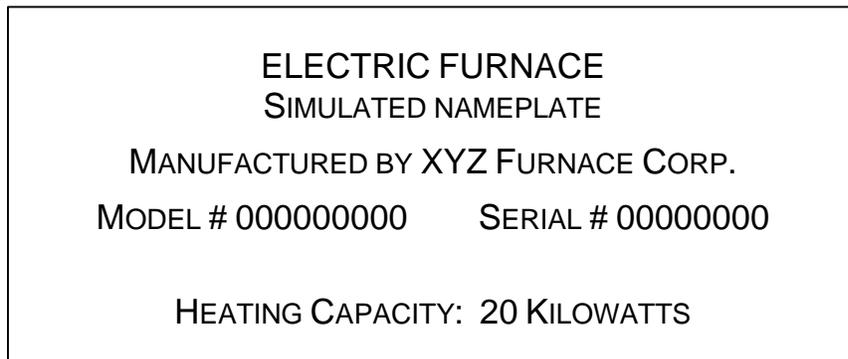


EXAMPLE OF A GAS FURNACE NAMEPLATE SHOWING HEATING CAPACITY (OUTPUT) OF 80,000 BTUH

3. FURNACES (continued)

- **System E: Determining Estimated Airflow for Electric Furnaces**

- **Step E-1:** Determine wattage from unit name plate.
 - Locate heating capacity (in kilowatts) on the nameplate (see graphic below).
 - Heating Capacity (output) is 20 kilowatts in this example
- **Step E-2:** Convert kilowatts to kBtuh output to estimated airflow in cfm, assuming 3.413 kBtuh per kilowatt and 95% efficiency.
- Use the following formula to convert wattage to kBtuh output:
 - $[(\text{watts} \times 3.413 \times 0.95) \div 1,000 = \text{kBtuh output}]$ or
 - $[(\text{kilowatts} \times 3.242) = \text{kBtuh output}]$
 - In this example:
 $[20 (\text{kW}) \times 3.242 = 64.84 \text{ kBtuh output}]$.
- **Step E-3:** Convert kBtuh output to estimated airflow in cfm.
 - Assume 21.7 cfm per kBtuh.*
 - Use the following equation to determine estimated airflow:
 $[\text{kBtuh} \times 21.7 \text{ cfm/kBtuh} = \text{cfm system airflow}]$
 - Example:
 $[64.84 (\text{kBtuh}) \times 21.7 (\text{cfm/KBtu}) = 1407 \text{ cfm system airflow}]$



EXAMPLE OF AN ELECTRIC FURNACE NAMEPLATE
SHOWING HEATING CAPACITY OF 20 KILOWATTS

*May be used until CEC determines cfm/kBtuh default for electric furnaces.

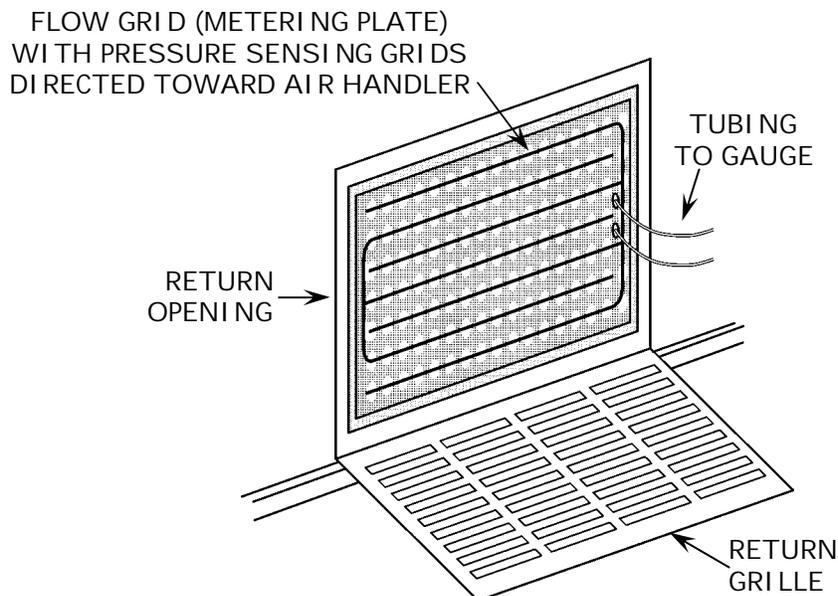
PART II – METHODS FOR MEASURING AIRFLOW

Methods for measuring HVAC system airflow (fan flow) presented in this appendix are methods approved by the California Energy Commission and described in Appendix RE-2005 of the Title 24 “Residential Alternative Calculation Method (ACM) Approval Manual for the 2005 Building Energy Efficiency Standards for Residential and Nonresidential Buildings” — Publication 400-03-003F, available online at: <http://www.energy.ca.gov/title24/2005standards/index.html>

1. FLOW GRID MEASUREMENT

- Overview

- This method uses a “metering plate” containing “pressure sensing grids”, which are directed toward the air handler.
- The metering plate temporarily replaces the filter in a typical air handler system during the air flow measurement procedure.
 - If the filter location is directly adjacent to the air handler, the metering plate will measure the total air handler flow.
 - If the filter is located remotely at a single central return, the metering plate will measure the air flow through the central return. Air-flow measurement through the central return will be very close to the total air handler air flow only if the return duct is very tight.



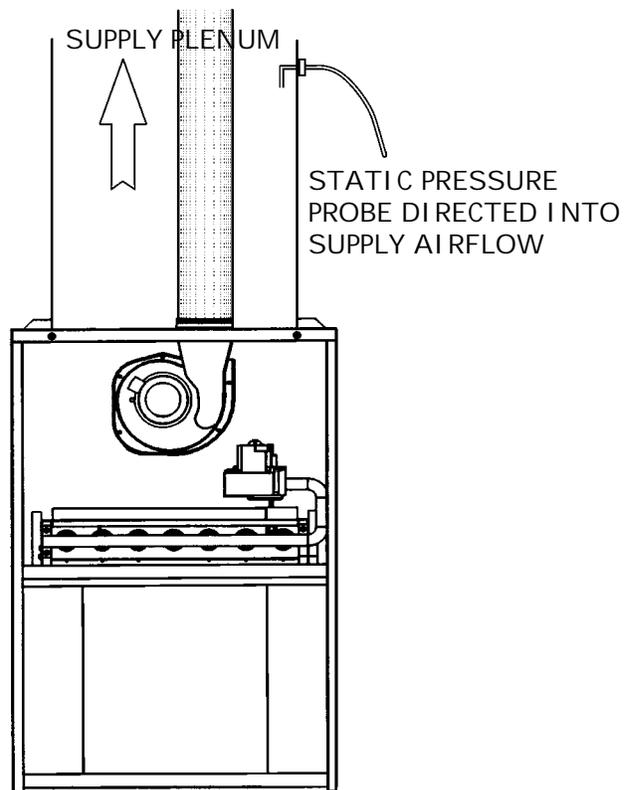
1. FLOW GRID MEASUREMENT (continued)

- Protocol

- Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.3, “Flow Grid Measurement.”
- The following general guidelines are for reference only; measurement shall be:
 - Performed in accordance with test equipment manufacturer’s instructions, and
 - In harmony with ACM Residential Manual Appendix RE-2005, §RE.4.1.3, “Diagnostic Fan Flow Using Flow Grid Measurement”.

- General Guidelines

- **Step 1:** System operating pressure shall be measured with the air handler operating at maximum speed used in the system.
 - Using a digital pressure gauge, pressure difference in Pa shall be measured between the supply plenum and the conditioned space (P_{sp}) using a static pressure probe pointing into the air stream.
 - Probe may be placed in the nearest supply duct when access to the supply plenum is unavailable.
 - Probe shall be adjusted to achieve the highest pressure and then secured in place during the fan flow test.



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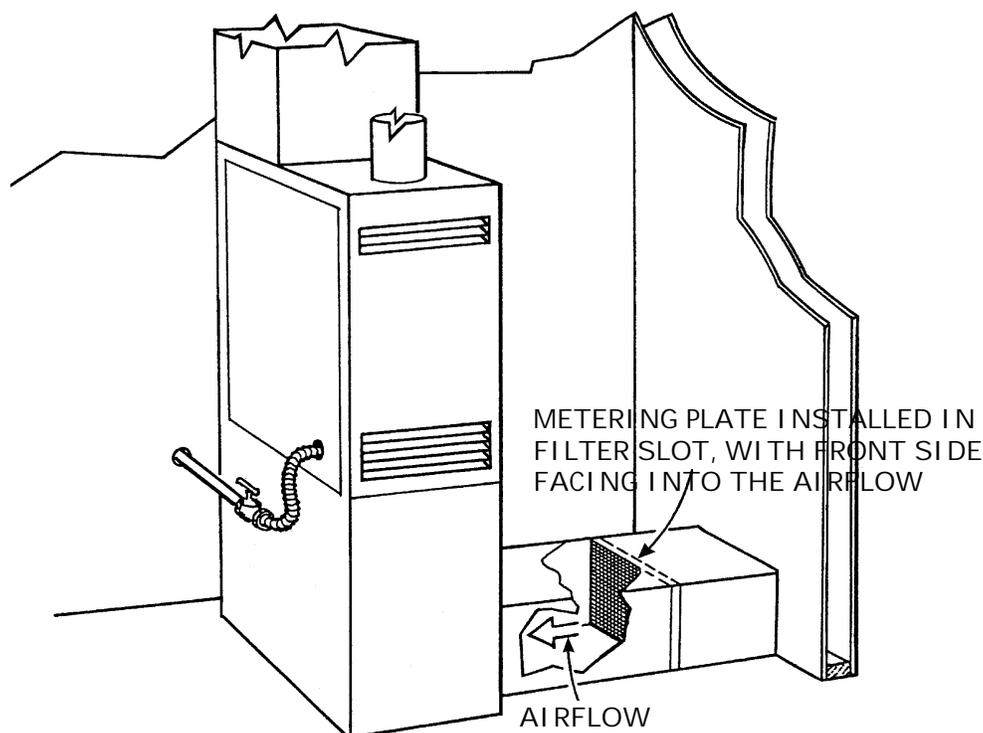
1. FLOW GRID MEASUREMENT (continued)

- General Guidelines (continued)

- **Step 2:** With the air handler off, the flow grid measurement sensor (metering plate) shall be installed, with the pressure sensing grids directed toward the air handler, and with no obstructions within 6" upstream or 2" downstream of the metering plates, in the best available location (filter slot or filter grille) where all system airflow passes through the flow grid:
 - In a filter slot as close to the air handler as possible, or
 - In the filter grille of a single-return duct system, or
 - In each filter grille of a multiple-return duct system simultaneously.

(A) When Using DG-700 Fully-Automated Digital Gauge

- **Step A-3:** Air handler shall be operated again at the same speed as used in Step 1, and time averaging shall be lengthened as needed to maximize accuracy when readings are fluctuating.
- **Step A-4:** Measured system airflow (Q_{ah}) shall be obtained from the digital pressure gauge and recorded.
- **Step A-5:** When the flow grid is installed in a remote filter grille, manufacturer's correction factor shall be used to increase accuracy.



1. FLOW GRID MEASUREMENT (continued)

- General Guidelines (continued)

(B) When Using DG-3 Digital Gauge

- **Step B-3:** With air handler operating again at the same speed as in Step 1, measurements shall be made with the flow grid in place:
 - System operating pressure re-measured (**Ptest**).
 - Airflow through the flow grid measured (**Qgrid**).
- **Step B-4:** System Airflow (**Qah**) shall be calculated by:
 - Multiplying **Qgrid** by equipment manufacturer's Flow Resistance Correction Factors (sample shown below), or
 - Applying the following equation to readings obtained in Steps 1 and B-3:

$$\text{System Airflow (Air Handler Flow)} = Q_{ah} = Q_{grid} \times (P_{sp}/P_{test})^{0.5}$$

- **Step B-5:** When the flow grid is installed in a remote filter grille, manufacturer's correction factor shall be used to increase accuracy.

All Gauges

- **Step 6:** Adjusted Airflow shall be calculated (to correct for differences in system operating pressures measured in Steps 1 and 3) using manufacturer's flow resistance correction procedure.

Appendix B Flow Resistance Correction Factors

Table B.1 Flow Resistance Correction Factors (using Pascals)

Normal System Operating Pressure in Pascals (NSOP)

	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
10	1.00	1.10	1.18	1.26	1.34	1.41	1.48	1.55	1.61	1.67	1.73	1.79	1.84	1.90	1.95	2.00	2.05	2.10	2.14	2.19	2.24
12	0.91	1.00	1.08	1.15	1.22	1.29	1.35	1.41	1.47	1.53	1.58	1.63	1.68	1.73	1.78	1.83	1.87	1.91	1.96	2.00	2.04
14	0.85	0.93	1.00	1.07	1.13	1.20	1.25	1.31	1.36	1.41	1.46	1.51	1.56	1.60	1.65	1.69	1.73	1.77	1.81	1.85	1.89
16	0.79	0.87	0.94	1.00	1.06	1.12	1.17	1.22	1.27	1.32	1.37	1.41	1.46	1.50	1.54	1.58	1.62	1.66	1.70	1.73	1.77
18	0.75	0.82	0.88	0.94	1.00	1.05	1.11	1.15	1.20	1.25	1.29	1.33	1.37	1.41	1.45	1.49	1.53	1.56	1.60	1.63	1.67
20	0.71	0.77	0.84	0.89	0.95	1.00	1.05	1.10	1.14	1.18	1.22	1.26	1.30	1.34	1.38	1.41	1.45	1.48	1.52	1.55	1.58
22	0.67	0.74	0.80	0.85	0.90	0.95	1.00	1.04	1.09	1.13	1.17	1.21	1.24	1.28	1.31	1.35	1.38	1.41	1.45	1.48	1.51
24	0.65	0.71	0.76	0.82	0.87	0.91	0.96	1.00	1.04	1.08	1.12	1.15	1.19	1.22	1.26	1.29	1.32	1.35	1.38	1.41	1.44
26	0.62	0.68	0.73	0.78	0.83	0.88	0.92	0.96	1.00	1.04	1.07	1.11	1.14	1.18	1.21	1.24	1.27	1.30	1.33	1.36	1.39
28	0.60	0.65	0.71	0.76	0.80	0.85	0.89	0.93	0.96	1.00	1.04	1.07	1.10	1.13	1.16	1.20	1.22	1.25	1.28	1.31	1.34
30	0.58	0.63	0.68	0.73	0.77	0.82	0.86	0.89	0.93	0.97	1.00	1.03	1.06	1.10	1.13	1.15	1.18	1.21	1.24	1.26	1.29
32	0.56	0.61	0.66	0.71	0.75	0.79	0.83	0.87	0.90	0.94	0.97	1.00	1.03	1.06	1.09	1.12	1.15	1.17	1.20	1.22	1.25
34	0.54	0.59	0.64	0.69	0.73	0.77	0.80	0.84	0.87	0.91	0.94	0.97	1.00	1.03	1.06	1.08	1.11	1.14	1.16	1.19	1.21
36	0.53	0.58	0.62	0.67	0.71	0.75	0.78	0.82	0.85	0.88	0.91	0.94	0.97	1.00	1.03	1.05	1.08	1.11	1.13	1.15	1.18
38	0.51	0.56	0.61	0.65	0.69	0.73	0.76	0.79	0.83	0.86	0.89	0.92	0.95	0.97	1.00	1.03	1.05	1.08	1.10	1.12	1.15
40	0.50	0.55	0.59	0.63	0.67	0.71	0.74	0.77	0.81	0.84	0.87	0.89	0.92	0.95	0.97	1.00	1.02	1.05	1.07	1.10	1.12
42	0.49	0.53	0.58	0.62	0.65	0.69	0.72	0.76	0.79	0.82	0.85	0.87	0.90	0.93	0.95	0.98	1.00	1.02	1.05	1.07	1.09
44	0.48	0.52	0.56	0.60	0.64	0.67	0.71	0.74	0.77	0.80	0.83	0.85	0.88	0.90	0.93	0.95	0.98	1.00	1.02	1.04	1.07
46	0.47	0.51	0.55	0.59	0.63	0.66	0.69	0.72	0.75	0.78	0.81	0.83	0.86	0.88	0.91	0.93	0.96	0.98	1.00	1.02	1.05
48	0.46	0.50	0.54	0.58	0.61	0.65	0.68	0.71	0.74	0.77	0.80	0.82	0.85	0.87	0.89	0.91	0.93	0.95	0.98	1.00	1.02
50	0.45	0.49	0.53	0.57	0.60	0.64	0.67	0.70	0.73	0.76	0.78	0.81	0.83	0.85	0.87	0.89	0.91	0.93	0.95	0.98	1.00

EXAMPLE OF FLOW RESISTANCE CORRECTION FACTORS USED TO CALCULATE ADJUSTED AIRFLOW

Appendix -D-

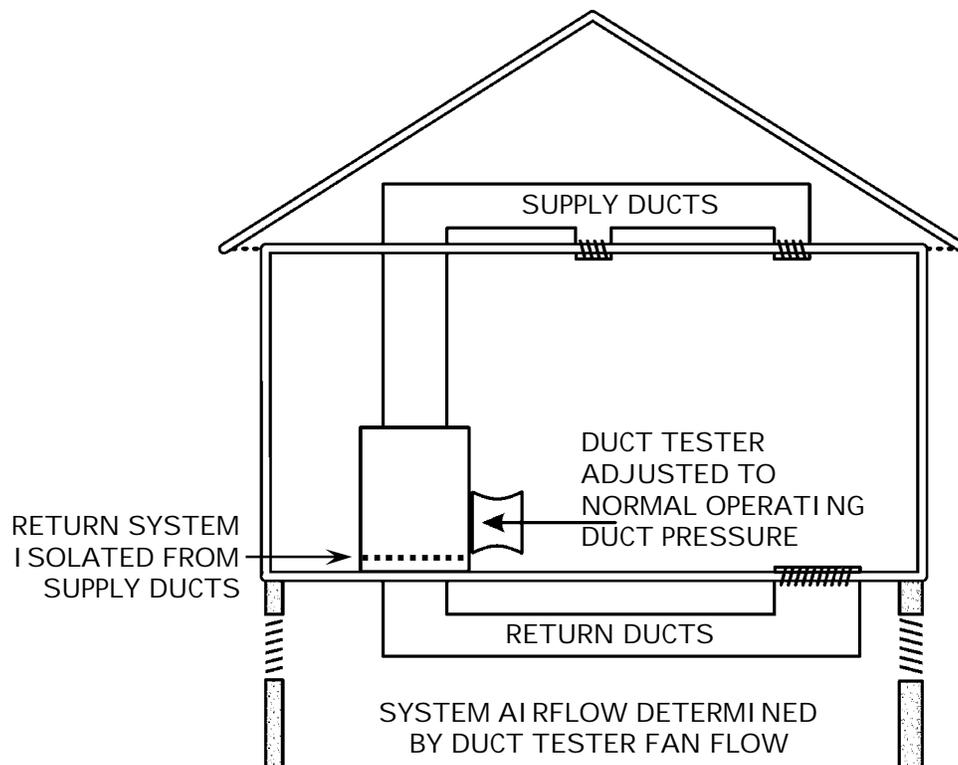
2. PLENUM PRESSURE MATCHING MEASUREMENT

- Overview

- This procedure is also known as “Duct Tester Used as a Powered Capture Hood.”
- The duct tester is used to pressurize the system to equal the pressure created by the air handler, so that airflow through the duct tester represents system airflow (fan flow).

- Protocol

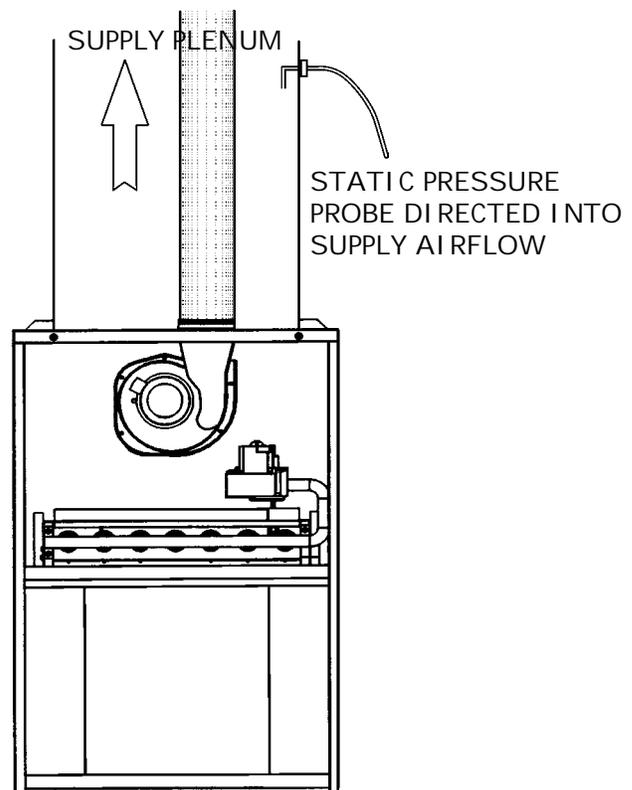
- Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.1, “Plenum Pressure Matching Measurement.”
- The following general guidelines are for reference only; measurement shall be:
 - Performed in accordance with test equipment manufacturer’s instructions, and
 - In harmony with ACM Residential Manual Appendix RE-2005, §RE.4.1.2, “Diagnostic Fan Flow Using Plenum Pressure Matching”.



2. PLENUM PRESSURE MATCHING MEASUREMENT (continued)

- General Guidelines

- **Step 1:** Supply plenum pressure test set-up:
 - Air handler shall be off.
 - Doors, windows, etc. shall be open to prevent pressure changes in the space containing the handler (e.g., outside door/window for air handler in conditioned space; or access doors, vents, etc. for air handler in garage, attic, etc.).
 - All supply and return registers shall be open, and filter(s) clean.
 - Static pressure probe, directed into the airflow, shall be inserted into the supply plenum or in a supply trunk nearby. It shall be adjusted (rotated) to achieve the highest pressure and securely attached.
 - Tubing from the probe shall be attached to **Channel A Input** tap of the digital pressure gauge, and the **Reference** tap shall be open to the conditioned space.
- **Step 2:** With the air handler fan operating at the maximum speed used in the system (e.g., cooling speed when air conditioning is present), the pressure difference in Pa between the supply plenum and the conditioned space (P_{sp}) shall be measured. P_{sp} , the normal operating duct pressure, is the target pressure to be maintained during the system airflow (fan flow) tests.



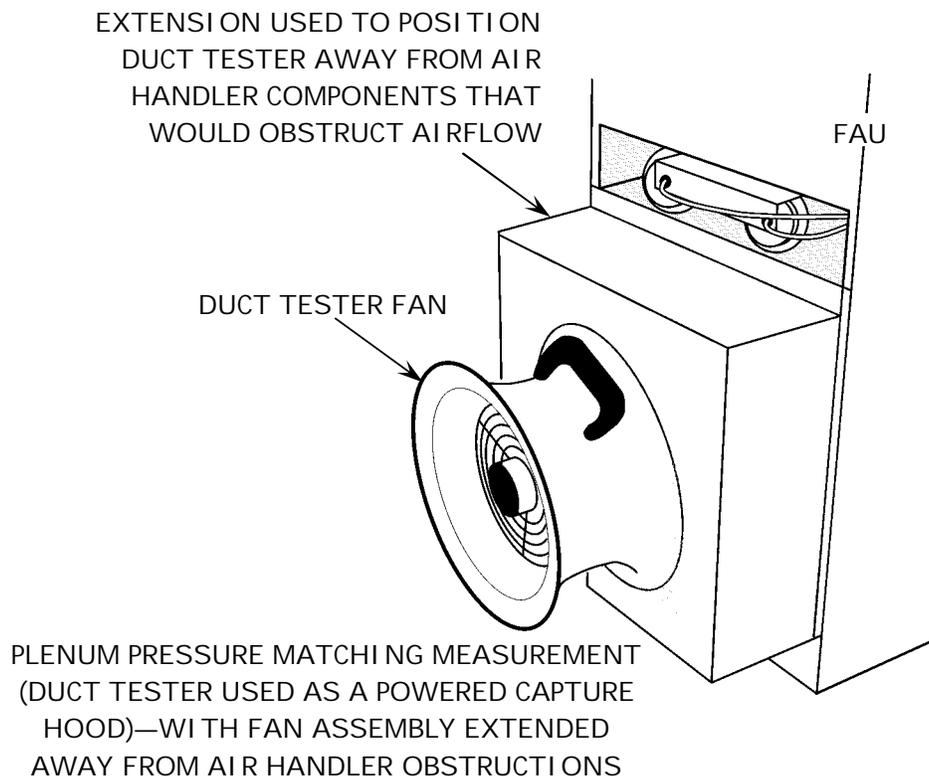
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2. PLENUM PRESSURE MATCHING MEASUREMENT (continued)

- General Guidelines

- **Step 3:** Duct Tester set-up at air handler cabinet:*
 - With the air handler access panel removed, the return air opening inside the air handler cabinet shall be sealed (e.g., with cardboard and tape) to isolate the return system from the supply system.
 - The Duct Tester shall be installed in place of the air handler access panel. If air handler components will obstruct airflow, the Duct Tester shall be mounted on an extension/box (illustrated below) that holds it away from the furnace cabinet.
 - Tubing shall connect the Duct Tester to the **Channel B Input** tap on the digital pressure gauge, and the **Reference** tap shall be open to space where the Duct Tester is located.

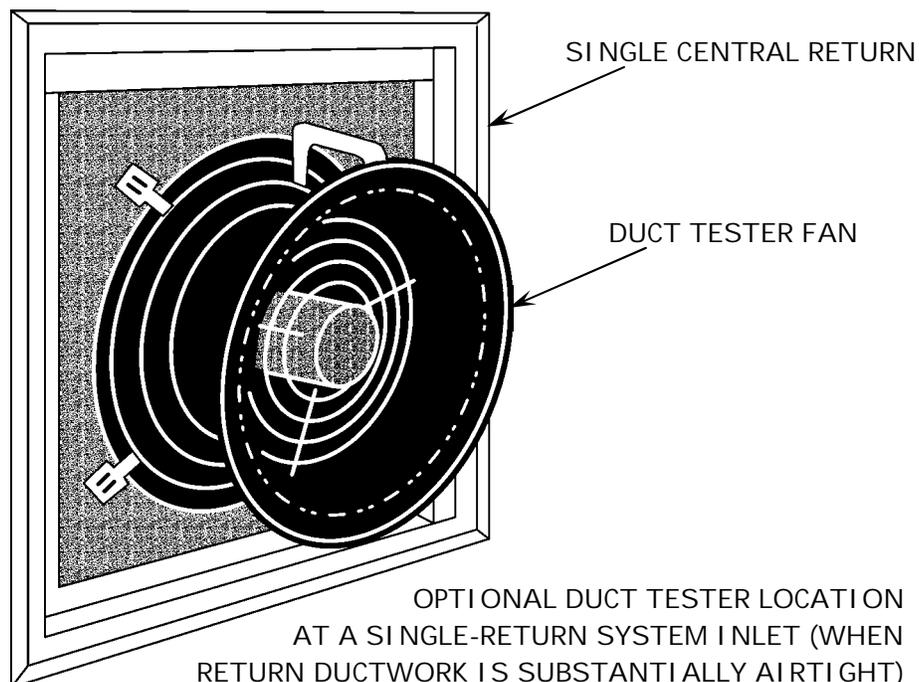
*Attachment to the return grille of a single-return system (pictured on page D-15) is possible. However, if the return duct is not substantially airtight, leaks will cause the airflow measurement to be inaccurate.



2. PLENUM PRESSURE MATCHING MEASUREMENT (continued)

- General Guidelines (continued)

- **Step 4:** With the air handler operating,
 - Duct Tester shall be turned on and adjusted until the duct pressure on **Channel A** equals the normal operating duct pressure (**P_{sp}**) measured in Step 2.
 - Airflow through the Duct Tester shall be determined (calculated or measured using the digital gauge fan flow feature), which is the estimated cfm system airflow through the air handler (**Q_{ah}**).
- **Step 5:** Correction shall be made when Duct Tester cannot adequately pressurize the system to equal the normal operating duct pressure (**P_{sp}**) recorded in Step 2:
 - With the Duct Tester producing the maximum attainable duct pressure on **Channel A (P_{max})**, the airflow through the Duct Tester (**Q_{max}**) shall be determined.
 - System airflow at normal operating duct pressure (**P_{sp}**) shall be estimated using the following equation:
 - System (Air Handler) Airflow = **Q_{ah} = Q_{max} x (P_{sp}/P_{max})^{0.5}**



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3. USING A FLOW CAPTURE HOOD

- Overview

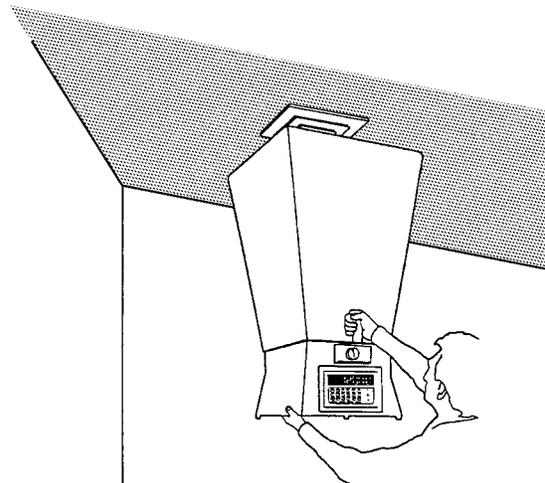
- The procedure utilizes a “capture flow hood” to directly measure air-flow through the return or supply system.
- The flow hood covers the entire register/grille and captures the airflow going into it.

- Protocol

- Equipment used for measurements shall meet the requirements specified in ACM Residential Manual Appendix RE-2005, §RE.3.1.2, “Flow Capture Hood Measurement.”
- The following general guidelines are for reference only; measurement shall be:
 - Performed in accordance with test equipment manufacturer’s instructions, and
 - In harmony with ACM Residential Manual Appendix RE-2005, §RE.4.1.1, “Diagnostic Fan Flow Using Flow Capture Hood.”

- General Guidelines

- **Step 1:** Fan switch shall be set to “On” position with system air handler operating on maximum speed for the unit. To get highest speed in systems without a fan “On” switch, unit must be run in:
 - Cooling mode for heating and air conditioning systems.
 - Heating mode for heating-only systems.
- **Step 2:** System airflow (fan flow) shall be measured at the return grille(s) with a calibrated Flow Capture Hood. When multiple return grilles are present, airflow at each shall be measured.
- **Step 3:** The Total System Airflow in cfm (Q_{ah}) shall be the sum of the measured return flows.



MEASURING AIRFLOW WITH
A FLOW CAPTURE HOOD