

Measure Guideline: Combustion Safety for Natural Draft Appliances Through Appliance Zone Isolation

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NorthernSTAR

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Measure Guideline: Combustion Safety for Natural Draft Appliances Through Appliance Zone Isolation

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Contents

List of Figures	vii
List of Tables	vii
Definitions	viii
Acknowledgments	1
Abstract	2
Foreword	2
Progression Summary	3
1 1 Introduction	3
2 Screening Protocol	5
2.1 Combustion Appliance Assessment.....	6
2.1.1 Identify Natural Draft and/or Category I Combustion Appliances in Isolatable Spaces	6
2.1.2 Check Entry Conditions and Combustion.....	7
2.2 Isolated Appliance Zone Work Scope	8
2.2.1 Assess and Specify Work To Isolate Appliances From Living Space.....	8
2.2.2 Assess and Specify Work for Proper Combustion Gas Venting.....	9
2.2.3 Determine Outside Combustion Air Requirement.....	9
2.3 Job Cost Estimation	9
3 Isolation Work Protocol	10
3.1 Creating the Isolated Zone	11
3.1.1 Venting System.....	11
3.1.2 Air Sealing the Enclosure	12
3.1.3 Duct and Cabinet Sealing.....	12
3.1.4 Combustion Air.....	12
3.1.5 Makeup Air and Exhaust Fans	15
3.2 Field Confirmation.....	15
3.2.1 Visual Inspection of Air Handler	15
3.2.2 Smoke Test of Duct and Cabinet Leakage.....	15
3.2.3 Isolation Pressure Test	16
4 Isolation Examples.....	17
4.1 Furnace in Attic.....	17
4.1.1 Furnace in Attic Open to Garage	18
4.2 Combustion Appliances in Attached Garages	19
4.2.1 Separation Wall From Garage	20
4.3 Combustion Appliances in Mechanical Closets	20
4.3.1 Air Handlers on Enclosed Support Platform	20
4.4 Combustion Appliances in a Closet or Separate Room With a Door That Opens to a Bedroom or Bathroom	22
4.5 Building Cavities Used as Returns, Opening Into Combustion Appliance Space.....	22
5 Materials	24
5.1 Rigid Air-Impermeable Panel Materials.....	24
5.2 Sealants	24
5.3 Materials for Ductwork and Duct Sealing	24
5.4 Materials for Filling Cavities	25

5.5 Additional Resources	25
References	26
Appendix	27
Additional Resources	33

List of Figures

Figure 1. Two openings method	13
Figure 2. Two openings method with vertical duct.....	13
Figure 3. Two openings method with horizontal ducts	14
Figure 4. One opening method.....	14
Figure 5. Attic bypasses	17
Figure 6. Category 1 fan assisted attic furnace with no gaskets or sealing will pull air from mechanical room until properly sealed.	18
Figure 7. New return added to attic furnace: joints sealed with mastic and cabinet seams taped	18
Figure 8. Metal elbow for new return to inlet side of attic fan compartment	19
Figure 9. Not acceptable: As-found view inside platform return: debris, moisture, wall cavities potentially open to combustion vent, burner, and attic above	21
Figure 10. Not acceptable: Restricted platform return in newer home	21
Figure 11. Acceptable: View after opening inlet to fan cabinet	21

Unless otherwise noted all figures were created by NorthernSTAR.

List of Tables

Table 1. Screening Protocol Job Breakdown.....	5
Table 2. Isolation Job Breakdown.....	10
Table 3. Carbon Monoxide Thresholds (Table A.4.1 of NFGC Annex).....	32

Unless otherwise noted all tables were created by NorthernSTAR.

Definitions

ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BA	Building America
Btu	British thermal unit
CO	Carbon monoxide
ICC	International Codes Council, Inc.
ICC ES	International Codes Council Evaluation Service
IFGC	International Fuel Gas Code
IRC	International Residential Code
NFGC	National Fuel Gas Code
NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
UL	Underwriters Laboratories

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Abstract

This Measure Guideline covers how to assess and carry out the isolation of natural draft combustion appliances from the conditioned spaces of low-rise residential buildings. It deals with combustion appliances located either within the living space in enclosed closets or side rooms or outside the living space in an adjacent area like an attic or garage.

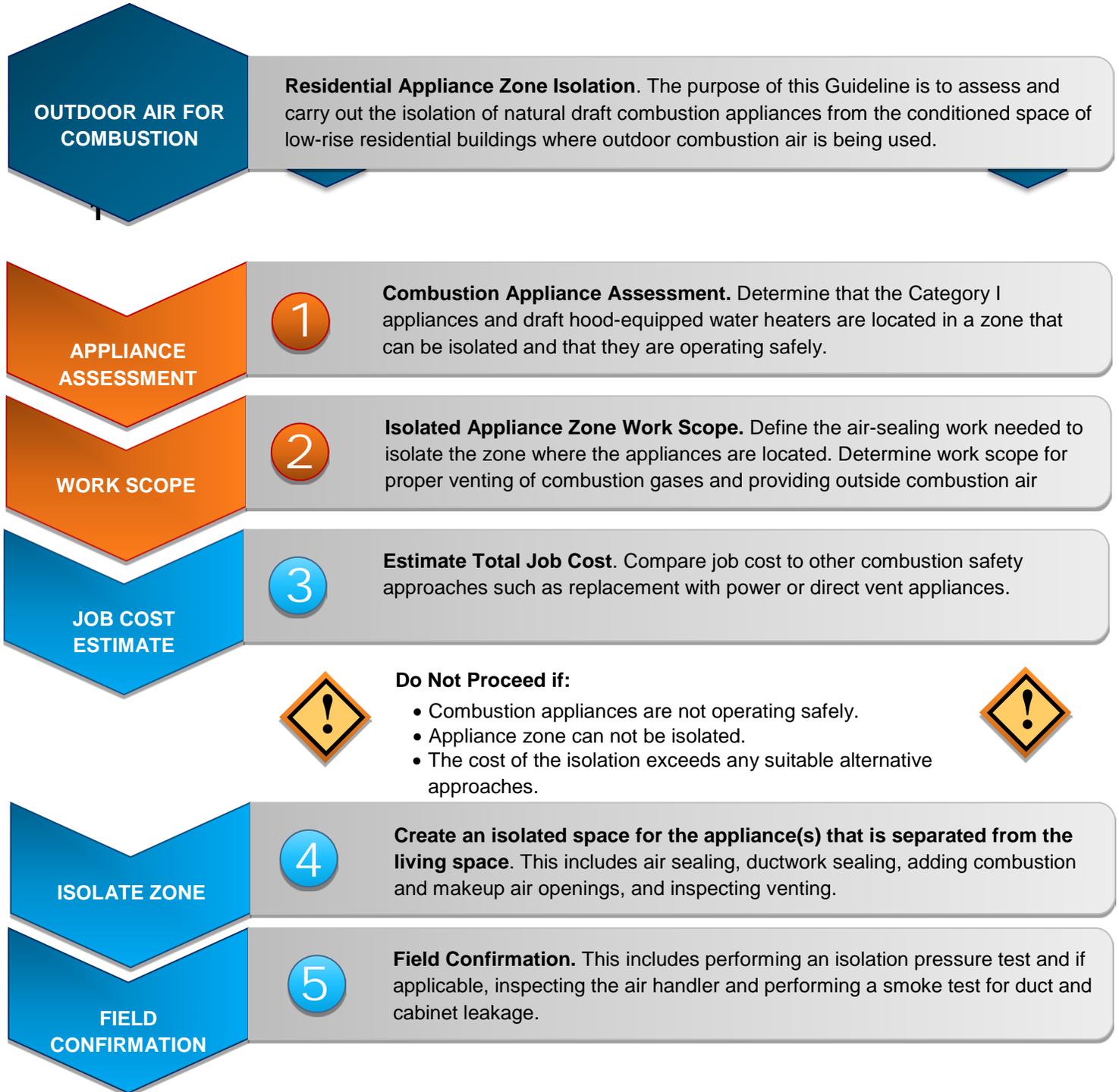
This subset of houses does not require comprehensive combustion safety tests, and simplified prescriptive procedures can be used to address safety concerns. This allows residential contractors inexperienced in advanced combustion safety testing to effectively address combustion safety issues and allow retrofits, including air sealing and changes to distribution and ventilation systems, to proceed.

Foreword

It is often challenging for residential contractors to conduct appropriate combustion safety test procedures in existing homes and use effective actions to address failures. However, there are situations where comprehensive combustion safety tests are not required and prescriptive procedures can be used to address safety concerns. A method to easily identify those situations and conduct the required actions will reduce test costs and provide a higher level of confidence that contractors are adequately addressing combustion safety issues. For this reason, this Measure Guideline has been created for a subset of these types of houses—houses that have or can have an isolated combustion appliance zone. This situation allows for combustion appliances with draft diverters to be segregated from the living space.

This guide uses existing code requirements for Category I appliances installed in isolated spaces. Those requirements may not always be sufficient and have been augmented with performance tests and additional details to ensure safe operation for houses that are undergoing weatherization. The purpose of this guide is to achieve similar protection against depressurization as is provided by direct-vent appliances installed in the living space. Consequently, successful application of this guide will allow houses to be tightened and ventilation added without having to be concerned with the effect on the combustion appliances.

Progression Summary



1 Introduction

This Measure Guideline covers how to assess and carry out the isolation of natural draft combustion appliances from the conditioned space of low-rise residential buildings. It deals with combustion appliances located either within the living space in enclosed closets or side rooms or outside the living space in an adjacent area like an attic or garage. This Measure Guideline concentrates on these house characteristics in order to provide general contractors a process to proceed with work on existing homes with legacy combustion appliances without the need for extensive diagnostics or performance-based protocols.

The purpose of this Measure Guideline is to define a subset of houses where the combustion appliances are or can be effectively isolated from the living space, allowing retrofits, including air sealing and changes to distribution and ventilation systems, to proceed.

According to the National Fuel Gas Code (NFGC) (Section 3.3.6.11), a Category I Vented Appliance is “an appliance that operates with a non-positive vent static pressure and with a gas temperature that avoids excessive condensate production in the vent.”

The isolated zone approach deals with a subset of houses in which combustion safety issues do not require extensive diagnostics or performance-based protocols. Other conditions that allow retrofit work to proceed without extensive combustion safety diagnostics or performance-based protocols include:

1. No vented combustion appliances are present.
2. All combustion appliances are depressurization resistant.
3. Extremely leaky houses with little or no potential for depressurization.
4. Tighter house with high depressurization potential so that only option is replacement of depressurization susceptible appliances.
5. All vented combustion appliances are located in a space isolated from living space.

This Guideline:

1. Provides a guide to the conditions that can allow natural draft appliance locations to be isolated from house pressures.
2. Clarifies requirements for the separation of Category I natural draft combustion appliances or draft-hood equipped water heaters from living spaces so that all flue gases go outdoors and all air for combustion and dilution comes from outdoors.
3. Defines a screening protocol to assess whether the assessment and protocols are applicable to the home.
4. Describes the work required to achieve an isolated appliance zone.
5. Describes some specific cases

2 Screening Protocol

The goals of the screening protocol are to determine whether the isolation approach is:

1. Applicable for the types of combustion appliances that are being used in the house.
2. Compatible within the elements, structure, and conditions of the building.
3. Cost effective compared to alternative methods; for example, replacement with power-vented or direct vent appliances.

The screening will determine if the isolation approach is applicable to the home. Table 1 shows the job breakdown for the screening protocol.

Table 1. Screening Protocol Job Breakdown

Important Steps	Key Points	Reasons
1. Combustion Appliance Assessment	a. Natural draft and/or fan-assisted Category I appliances are located in a space that can be isolated. b. Combustion appliances do not pose an immediate hazard.	a. Determine if Measure Guideline can be applied. b. Safe working and living conditions exist.
2. Isolated Zone Work Scope	c. Define air sealing work to isolate appliance from living space. d. Define venting work needed to vent combustion gases to the outside. e. Define work required to provide outside combustion air to the zone.	c. Determine need for air sealing and work required. d. Determine need for mechanical contractor and work required. e. Determine need for mechanical contractor and work required.
3. Estimate Cost of Total Job	f. Compare cost to other combustion safety approaches such as replacement with power or direct vent appliances.	f. Adopt the most cost-effective combustion safety strategy.

2.1 Combustion Appliance Assessment

The initial combustion appliance assessment needs to determine that:

1. The natural draft and fan-assisted Category I appliances are located in areas that can be isolated.
2. These combustion appliances are operating safely.
3. The work needed to isolate those appliances is feasible.
4. The estimated cost of the work justifies the deployment of this measure with respect to other combustion safety measures such as replacement with power or direct vented appliances.

The findings from these steps will determine whether isolation work will continue.

2.1.1 Identify Natural Draft and/or Category I Combustion Appliances in Isolatable Spaces

Conduct a house walkthrough to identify any natural draft and/or Category I combustion appliances that are located in spaces that can be isolated. The primary concern is furnaces, boilers, and water heaters, with special interest in those having venting systems that can allow combustion gases to spill through draft hoods.

The second requirement for this measure is that these appliances must be located in spaces that are capable of being isolated. This means that a pressure boundary separating the location of the combustion appliances from the living space can be defined and that this boundary can be made airtight with respect to the living space. Likely locations for these appliances are:

- Mechanical closets open to the outdoors
- A separate room open to the outdoors
- The garage
- An attic.

If not installed properly, combustion appliances represent a potential source of hazardous pollutants that should be kept out of the living space and away from its occupants. Specifically, this Measure Guideline is concerned with natural draft and Category I combustion appliances (water heaters, furnaces, and boilers) that can spill combustion gases back into the living space.



Based on the walkthrough, this Measure Guideline should NOT be used if no natural draft or Category I combustion appliances are found in the house or if the natural draft or Category I combustion appliances are located in areas that are not airtight and not amenable to air sealing.



2.1.2 Check Entry Conditions and Combustion Appliances, as Found

Make sure that the screening is taking place under safe entry working conditions and that appliance operation does not pose an immediate hazard to the tester and occupants. Confirm that the indoor air has safe levels of fuel gas and carbon monoxide (CO) before conducting the inspection. Remedy any immediate hazards before continuing with this Measure Guideline.

2.1.1.1 On Entry and With Equipment Off

The following assessment should be performed with the combustion appliance equipment off (see the Appendix for procedures):

- House CO level
- Gas odor
- Venting system sizing and installation (compliant with manufacturers' instructions and code)
- Check installed combustion air (International Fuel Gas Code [IFGC] and National Fire Protection Association [NFPA] outdoor combustion air requirements, net free area of louvers and grilles)
- Appliance equipment inspection that includes safety systems, inside-wiring, burners, heat exchanger, etc.

2.1.1.2 Combustion Appliance Tests With Equipment On

The following assessments should be performed with the combustion appliance equipment running:

- Check house CO level during operation.
- Check ignition and controls function.
- Conduct a spill/draft check.
- Check input for over-firing: clock meter or measure the size of the orifice and pressure.
- Oil smoke check and set draft at barometric damper.
- Check flue CO (manufacturer recommendations, American National Standards Institute [ANSI] standards) % carbon dioxide, and % oxygen with a gas analyzer.

Combustion appliance testing should be performed under two conditions: with the equipment off and then with the equipment running. Portions of the combustion equipment check require a qualified technician. The entire test requires skilled staff with access to and knowledge of specific code requirements and test equipment. Below are the tests that should be performed during the two conditions. These tests are to be performed with the appliance zone open to the house and in standby conditions (e.g. all exhaust fans and air handlers off).

Many of the tests and inspection items can be performed by a home performance contractor. Others will require a qualified mechanical technician:

1. Compare chimney vent sizing and installation to code requirements.
2. Inspect appliance equipment inspection.
3. Confirm proper operation of appliance safety and protective devices.

- Verify that there is no flame distortion when the fan is running (furnaces only).
- Measure temperature rise to determine if it is within the manufacturer’s recommendation.
- Check safety and protective devices: pilot shut off, high temperature limit, low water cutout, and temperature pressure relief.

A worst-case appliance zone depressurization test is not applicable. Do not open the isolated appliance zone to the house to perform a worst-case test.

2.2 Isolated Appliance Zone Work Scope

The next step of the screening process is to determine the scope for the isolation work that results in:

1. A code-compliant vent system
2. Adequate combustion air
3. No combustion gases entering the living space through the wall, ceiling, and/or floor of the zone or via the air handler.

2.2.1 Assess and Specify Work To Isolate Appliances From Living Space

The first step is to confirm that there is a continuous, durable boundary separating the appliances from the house. If the boundary is not complete, the work scope must include work necessary to complete the boundary. The next step is to specify air sealing work such that:

1. The combustion appliances are isolated from the living space. Adequate isolation is achieved when the pressure difference between the appliance zone and outside is less than 5 Pa for a blower door induced house depressurization of 50 Pa or 1/10 of the house depressurization for houses that can’t reach 50 Pa. If isolation is not achieved, include isolation work as per Section 3.1.2.
2. Ductwork and cabinet within the isolation zone are completely sealed so that while operating they will not create a negative pressure in the space with the burner and vent openings, and during off cycle they will not allow house pressures to interfere with other combustion appliances in the isolated space or reverse furnace startup firing before the fan-on temperature is reached. Adequate sealing is achieved when the exterior duct leakage is less than 6% of the nominal system flow rate

When the air handler fan is on, return leaks can capture combustion air and draw in products of combustion.

Depressurization Test Protocol

1. Measure and record the pressure in the space where the combustion appliance is located with respect to outside.
2. Turn on any central forced air system blowers and measure and record the pressure in the space where the appliance is located with respect to outside.
3. The depressurization is equal to the pressure with the fans on minus the pressure with the fans off.

The screening protocol may uncover current hazards that must be remedied before screening continues. However, even with no immediate hazard, alterations to meet standards in appliance operation, chimney and vent capacity, and combustion air are still needed for long-term safe use.

and a smoke test shows that there is no return duct leakage (see Section 3.2.2). Measure the amount of duct leakage to the exterior in accordance with ASTM E1554-2007 C. The total duct leakage test can be used (method D) as long as the total leakage is less than 6% of the system flow rate. If adequate sealing is not achieved, include work as per Section 3.1.3.

2.2.2 Assess and Specify Work for Proper Combustion Gas Venting

The vent system inspection shall identify any work required to ensure compliance with the NFGC (NFPA 54, 31, and 211) or local code requirements. This inspection should be performed by a qualified mechanical technician. A qualified mechanical technician should perform the venting work and ensure that it complies with code requirements.

2.2.3 Determine Outside Combustion Air Requirement

The work specified by the auditor or mechanical technician must allow for outside combustion air as required by the NFGC (NFPA 54) or local code requirements. It is recommended that practitioners either be provided guidance to implement minimum requirements or carry a recognized credential such as the International Code Council (ICC) Fuel Gas Inspector certificate.

2.3 Job Cost Estimation

The final step of the screening process is to determine the least cost option. For instance, when the appliances can either be isolated or replaced with power/direct vent appliances, select the least expensive option.

3 Isolation Work Protocol

Once it has been established that natural draft and/or Category I appliances will continue to be operated in the house and that an isolated zone can be created, the next course of action is to successfully perform the work necessary to create an isolated zone or to repair the one that exists if the pressure testing in Section 2 fail. This work is defined as:

- The combustion appliance equipment is documented to be installed and is operating within manufacturer’s recommendations and according to code.
- The venting system meets code.
- All combustion air is supplied from the outside.
- The appliance space is partitioned off as a separate room or enclosed space from the living space, per the 5 Pa at 50 Pa rule.
- Ductwork, including air handler cabinets, in the isolated combustion zone is sealed so that the exterior duct leakage is less than 6% of the system flow and the smoke test indicates no return leakage.
- No return air is drawn from a garage, boiler room, furnace room, unconditioned attic, or areas with flammable vapors.

This section details the necessary steps for the physical creation of the isolated zone and the commissioning process to be used to ensure that the system is working properly. Table 2 shows the job breakdown for the isolation protocol.

Table 2. Isolation Job Breakdown

Important Steps	Key Points	Reasons
<p>1. Create an isolated space that is separated from the living space</p>	<ul style="list-style-type: none"> a. Inspect venting system. b. Air seal the enclosure from the house. c. Seal ducts and cabinets. d. Provide combustion air from outside to zone. e. Provide makeup air for clothes dryer and remove all other exhaust fans. 	<ul style="list-style-type: none"> a. Identify any work required to ensure that venting system is within manufacturers’ spec and codes. b. Minimize impact of living space depressurization on combustion gas venting. c. Limit the effect that the ductwork leakage and air handler have on the zone pressure and the movement of zone air into the house. d. Comply with code for outside combustion air. e. Minimize opportunity for depressurization in the zone.

Important Steps	Key Points	Reasons
<p>2. Field Confirmation</p>	<p>f. Visually inspect air handler and measure exterior duct leakage.</p> <p>g. Perform smoke test of duct and cabinet leakage.</p> <p>h. Perform isolation pressure test.</p> <p>i. Visually inspect venting, combustion air, and makeup air systems.</p>	<p>f. Ensure that sealing work on air handler has been done.</p> <p>g. Confirm completion and/or compliance of duct and cabinet sealing work.</p> <p>h. Confirm that zone is air sealed to within sufficient isolation.</p> <p>i. Confirm that venting and combustion and makeup air comply with code and/or manufacturer’s instructions.</p>

3.1 Creating the Isolated Zone

There are five steps to creating an isolated zone:

-  1. Ensure that the venting system complies with manufacturer’s specifications and local codes.
-  2. Air seal cracks, gaps, or openings in the physical boundary to ensure that it is airtight to the living space.
-  3. Seal all ducts and cabinet leakage located in the zone to ensure that ducts and cabinet meet the leakage requirements.
-  4. Provide code required outside combustion air openings.
-  5. Remove all exhaust devices located in the area that can depressurize the zone or provide makeup air if there is a clothes dryer in the isolated zone.

3.1.1 Venting System

The chimney venting system should be installed to manufacturer’s specifications and in accordance with specifications detailed in NFPA 54 chapter 12. The chimney vent sizing should meet the capacity requirements of the vent tables published in NFPA 54 chapter 13, NFPA 31, NFPA 211, and IFGC chapter 5. This is true for both the common vent and vent connector(s) after all requirements are evaluated including number of elbows, length of lateral runs, vertical height, and actual input/firing rate.

3.1.2 Air Sealing the Enclosure

Once the structural enclosure has been completed, the boundary needs to be made airtight. A blower door and smoke pencil should be employed to find any air leaks. Seal air leakage with caulk, gaskets, weather-stripping or other closure methods and materials to limit flow. Any louvers between the zone and conditioned space shall be removed and the opening covered with sheet metal or gypsum board. Fill in large openings in the wall, ceiling, or floor with ½-in. gypsum board or its equivalent. Seal all joints, seams, and penetrations between the zone and living space with joint tape, sealant foam listed for use as a fire stop and approved for uncovered use, or sealant caulk (see International Residential Code [IRC] 314.6).

Weather-strip the door to the inside of the house (if any) and provide a door sweep and make sure the door is self-closing and self-latching. Any louvers in doors to the inside of the house shall be removed and filled with metal or gypsum board.

3.1.3 Duct and Cabinet Sealing

Seal all joints, penetrations and openings in the cabinets of the air handling unit. Use metal tape or suitable gaskets on service openings and permanent seals on fixed joints and seams. All air handling units should be mechanically attached to other air distribution system components.

Provide access as needed to seal all return and fan cabinet leaks in the space. Provide continuous sealed ductwork from the living space directly into the blower housing for the forced air furnace, or other air handler. Maintain at least the cross sectional area of the return inlet and size the liner or duct to meet the manufacturers' required airflow without restriction.

Furnace returns without manufacturers' information must provide at least 2 in.² of total cross-sectional area for every 1000 Btu of output (IMC-2012 918.2).

Mechanically fasten the duct to the furnace cabinet and at the connection to the interior. Tape all cabinet service openings and joints. Seal all joints and seams with mastic and mesh tape meeting Underwriters Laboratories (UL)181-M, or foil tapes meeting UL 181 A-P and UL 181 B-FX. Sealant foam approved for use as a fire stop in combustible construction is acceptable at the connection to the interior construction materials.

No return air can be taken from a garage, boiler room, furnace room, crawlspace, or unconditioned attic. Line any enclosed support platform or building cavity used as a return air duct with continuous, durable, air impermeable material and seals that show a flame spread of 25 or less and smoke developed of 50 or less when tested to ASTM E 84 or UL 723 or use a standard material listed for use in duct systems, i.e., sheet metal, duct board, flexible duct.

3.1.4 Combustion Air

Combustion air supplied to the appliances shall meet the requirements set forth by the NFGC or applicable local codes. Do not use house indoor air for combustion air when following this Measure Guideline. (A separate Measure Guideline for houses using indoor air for combustion is available.) All combustion air must be supplied from the outside or from spaces that freely communicate with the outside such as a vented attic (minimum vent to attic area = 1:300) or vented crawlspace (1:150 minimum) with house to attic bypasses and attic duct leakage sealed.

The permanent air openings to the outdoors cannot be smaller than 3 in. diameter. Two methods based on fuel gas code (IFGC and NFPA 54) can be employed:

1. A two openings method with one within 12 in. of the top and the other within 12 in. of the bottom of the zone. If the opening is directly to the outside or connected through vertical ducts, the minimum net free area of each opening should be $1 \text{ in.}^2/4,000 \text{ Btu/h}$ of the total input of all the appliances in the zone. If the openings are connected to the outside through horizontal ducts, the minimum net free area of each opening should be at least $1 \text{ in.}^2/2,000 \text{ Btu/h}$ of the total input of all the appliances in the zone.

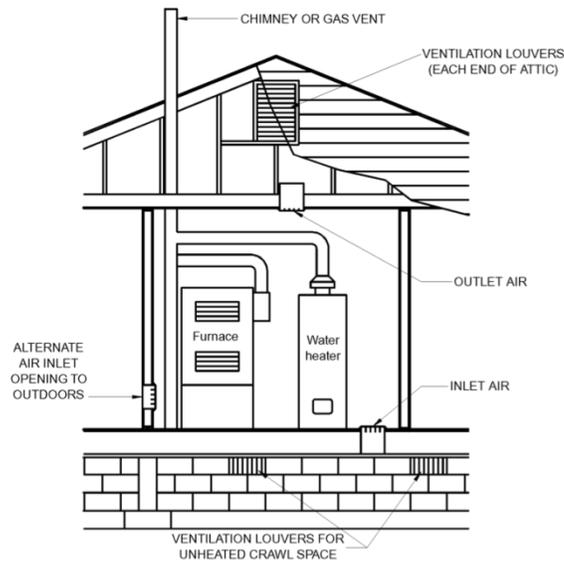


Figure 1. Two openings method

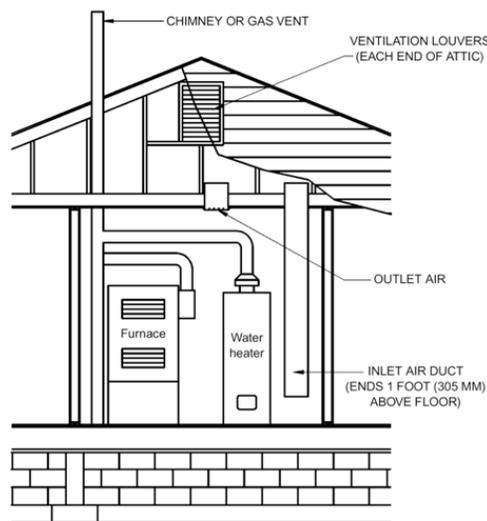


Figure 2. Two openings method with vertical duct

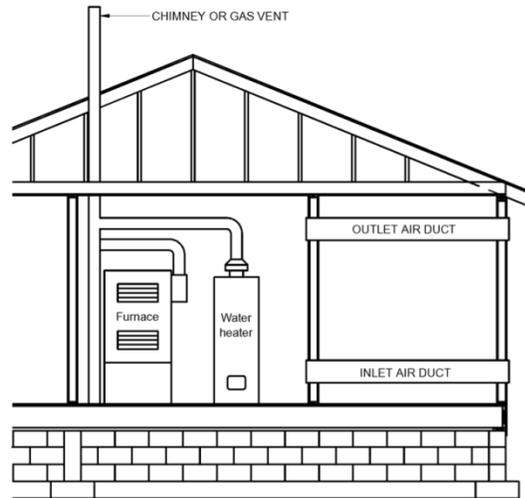


Figure 3. Two openings method with horizontal ducts

2. A one opening method with the opening within 12 in. of the top of the zone. The minimum net free area of the opening should be $1 \text{ in.}^2/3,000 \text{ Btu/h}$ of the total input of all the appliances and not smaller than the sum of all the vent connectors in the space.

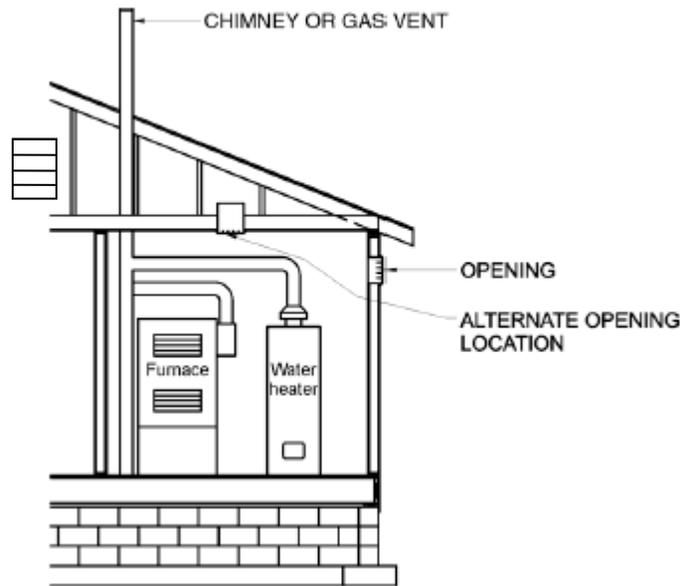


Figure 4. One opening method

If a mechanical damper is installed in the combustion air opening, interlock this with the furnace or boiler but provide a passive combustion air opening in the same space for a natural draft water heater, if present, because there is no electrical control circuit on residential water heaters.

Consider the presence of louvers, screens, or grilles over the openings when calculating the free area of the opening(s). Use manufacturers' labeled free air where provided. If unlabeled, assume free air is 75% of the metal louver area and 25% of the wood louver area. Refer to NFGC 2012 section 9.3.7.1, IFGC, NFPA 54, and NFPA 31.

3.1.5 Makeup Air and Exhaust Fans

Makeup air is required for clothes dryers located in the zone. Each clothes dryer should be provided with 100 in.² of makeup air. If closure is required during the off cycle of the dryer, a mechanical damper interlocked with the dryer should be provided. The interlock should be wired to prevent dryer operation if the damper fails. An interlock with the furnace, boiler, or water heater is not needed if dedicated combustion air is provided with those appliances. Refer to IFGC 614.5, IRC-2012 G2439.4 and IMC 504.5.

All other exhaust fans should be removed from these isolated combustion appliance zones.

If the appliances are installed in an attic, powered attic fans in an attic space should either be disconnected or additional air inlets should be provided as per the requirements of the fan manufacturer.

3.2 Field Confirmation

Field confirmation of the isolated zone ensures that the system is operating as designed and meets code requirements. This section is adapted from California Energy Commission 2008, Reference Appendixes for the 2008 Building Efficiency Standards for Residential and Non-Residential Buildings RA3.1.4.3.7-8 2010, p. 249.

3.2.1 Visual Inspection of Air Handler

Visually inspect to verify that the following locations have been sealed. These locations include:

1. Seams, joints, and openings at the fan cabinet, furnace cabinet, the cabinet section with the air conditioner coil, and connections to return and supply plenums
2. Refrigerant line and other penetrations into the forced air unit
3. Tape or adjust approved gasket at air handler door and other service panels (no permanent sealants)
4. Plenum and duct seams
5. Return plenum joints at filter grille and to the back side of interior finish materials
6. Gap between any duct and duct chase where it passes out of the combustion space.

3.2.2 Smoke Test of Duct and Cabinet Leakage

Perform a smoke test to confirm completion or compliance of duct and cabinet sealing work:

1. With the furnace fan and service disconnect off, set up for fan pressurization of the duct system for the furnace or air handler located in the combustion space. Close registers to limit smoke entry to the interior. Seal the grilles and registers necessary to reach +25 Pa inside the ducts in the specific combustion space.

2. With the duct pressurization fan running, inject theatrical fog or equivalent non-toxic smoke into the fan inlet while observing smoke coming out of the ducts and cabinet. Mark the spots and stop adding smoke.
3. Seal all joints, penetrations, and seams where smoke came out, use foil tape or approved gasket on service openings in the cabinet and permanent seals on all other openings.
4. Inject additional smoke and inspect the seals. If smoke continues to come out of the return plenum or cabinet, turn off the pressurization fan and open the air handler fan cabinet to access and seal the remaining return leaks in the combustion space.
5. Ensure that there are no return leaks. Return air from outside the combustion space must be brought to the furnace fan through “continuous airtight ducts.”
6. The furnace duct section is sealed when smoke no longer comes out of any openings in the combustion space.

Note any smoke coming out of the burner area, heat exchanger, or vent connector for follow-up service.

3.2.3 Isolation Pressure Test

The following conditions must be met, as applicable:

1. Appliance zone pressure change to outside is not more than 5 Pa. To check, perform a blower door test placing the house at 50 Pa house depressurization.
2. Appliance zone pressure change to outside with dryer and makeup air is not greater than 2.5 Pa during dryer operation. Note:
 - a. If the mechanical damper does not open, the dryer operation is prevented.
 - b. For dryer makeup air, the airflow through 100 in.² net opening is approximately 165 cfm at -2.5 Pa, 200 cfm at -3 Pa depressurization, with a metal louver reduction factor of 0.55.
3. Garage pressure change to outside is not greater than 2.5 Pa during garage exhaust fan operation if the appliances are located in the garage.

Windy conditions will cause greater uncertainty in the pressure measurements. The uncertainty can be reduced by averaging the pressures over longer periods. When the outdoor reference tube is placed outside the house, locate the end of the tube at the intersection of an exterior wall with grade on the leeward side of the house.

4 Isolation Examples

In this section we describe the application of this guide to six specific situations.

4.1 Furnace in Attic

The attic must be vented with the net vent area meeting combustion air requirements. Connect combustion air openings directly to the outside and select louvers to maintain free air. The minimum recommended proportion of attic vents to attic area is 1:300 ratio, with 3.3 ft² of venting per 1,000 ft² of attic area. Seal bypasses and duct leakage to the outside before adding any additional attic vents.



Photo Rick Chitwood 2010

Photo Anthony Cox 2008

Figure 5. Attic bypasses

Attic bypasses should be sealed wherever practical. The minimum bypass sealing should result in an attic pressure less than 5 Pa at 50 Pa house depressurization with a blower door. If after bypass sealing, the attic pressure is greater than 5 Pa, perform additional sealing or increase the amount of attic vents to 1:150 ratio or the amount needed to reduce the pressure to 5 Pa. Refer to IRC, NFPA 54, and IFGC for details.

As described in Section 3, continuous sealed ductwork must be provided from the living space directly into the blower housing for the forced air furnace, or other air handler with a return open in the combustion space.



Photo Rick Chitwood 2010

Figure 6. Category 1 fan assisted attic furnace with no gaskets or sealing will pull air from mechanical room until properly sealed.



Photo Rick Chitwood 2010

Figure 7. New return added to attic furnace: joints sealed with mastic and cabinet seams taped

4.1.1 Furnace in Attic Open to Garage

Use sheet metal ductwork to connect the return to the interior, as only sheet metal ductwork can be exposed to the garage. Alternatively, provide taped ½-in. gypsum board on the garage side of the wall that is open to the attic with all penetrations sealed.



Photo Rick Chitwood 2010

Figure 8. Metal elbow for new return to inlet side of attic fan compartment

4.2 Combustion Appliances in Attached Garages

In the attached garage, add combustion air openings that comply with the combustion appliance manufacturers' recommendation and according to code, as defined in Section 2. Any garage exhaust fans must have the appropriate amount of makeup air required. Garage depressurization with respect to the outdoors caused by exhaust fans should not exceed 2.5 Pa.

Seal openings in the garage walls and ceiling adjacent to the living space with a material approved to resist the free passage of flames and products of combustion. Fill in large openings to the living space with ½-in. gypsum board on the garage side of wall to the living space, garage side of wall to attic, and any walls or columns supporting a living space above the garage. As necessary, reduce cavity leakage by installing dense pack insulation using approved materials. Fill in openings in the ceiling to living space with ⅝-in. Type X gypsum board. Weather-strip garage door to house and seal trim. Confirm that the garage door is solid, has a 20-minute fire rating (if new), is equipped with a door closer, and has a self latching mechanism. Tape all joints, seal gypsum gap to foundation at sill, and seal penetrations to the house with sealant or foam listed for use as a fire stop in wood frame construction. For details refer to IBC 406.4, IRC-R302.5.2, and IRC-R302.11.

Use sheet metal ductwork to connect the return to the interior, as only sheet metal ductwork can be exposed to the garage. Seal any exposed sheet metal ducts in the garage with mastic and mesh tape and seal any penetrations through walls or ceilings. Enclose nonmetal ducts with taped ½-in. gypsum board or replace with metal. Seal between ducts and duct enclosure. Seal air handler cabinet operable doors with tape and other openings with mastic and mesh tape or other approved sealant listed below. Attach air handlers to continuous sealed ducts that extend to the return grille at interior, close all openings and joints (see IMC 603.7 and 918.5).

For water heaters made before July 2003 and for any combustion appliances: the ignition source must be at least 18 in. above the floor of the garage. Raise the appliance or replace it with a current flammable vapor ignition resistant model. For details refer to IRC M1307.3 and ANSI Z21.10.1-2001. Follow local codes if they are more restrictive. Spaces with openings to the garage are considered as part of the garage.

4.2.1 Separation Wall From Garage

For some appliance(s) that are located in a garage or a space that is open to the garage, it may be most efficient to construct walls that separate the appliance(s) from the garage. Provide a continuous wall between the combustion appliances and the rest of the garage. Tape joints in a ½-in. gypsum board covered separation wall between the garage and combustion appliances, with no openings to the garage. Seal top and bottom gaps in wall to garage. The door to the space should be from the outside. If the door to the space is to the garage, the appliance ignition source must be at least 18 in. above the floor of the garage. Raise the appliance or replace it with a current flammable vapor ignition resistant model.

4.3 Combustion Appliances in Mechanical Closets

For mechanical closets located within the living space, seal the walls, floor, ceiling, and door from the house. Bring all combustion air from the outside. Fill in large openings at interior finish with ½-in. gypsum board, duct board or equivalent air impermeable sheet material, tape seams. Seal all joints, seams and penetrations in the ceiling floor and walls with mastic and tape, foam listed for use as a fire stop and approved for uncovered use, sealant meeting the standards set forth in ASTM814-09 ASTM C 920, and ASTM C1193-09.

Remove and infill louvers in walls or door to the house living space with metal or gypsum board. Provide a closet door with weather-stripping and a bottom sweep or threshold. Provide a door closer or other self-closing mechanism that confirms closing and self-latching.

Provide a sealed duct from the return grille in the room to the inlet of the fan cabinet as above. The return cabinet also should be sealed. Zero leakage for returns is allowed in the zone. Refer to NFPA 54, IFGC, and IRC.

4.3.1 Air Handlers on Enclosed Support Platform

Sealing alone is not adequate for air handler platforms. Code and this Guideline do not allow adjacent construction materials to be in contact with return air. The minimum requirement is to line the support platform with sealed duct board, sheet metal, or other air barrier material rated for use in ducts. No adjacent walls, floors, ceilings, or other part of the building can be used as part of the return duct or plenum in the combustion space. (cf. NFPA54 10.3.7.4, IFGC, 618.5.EX2.3, NFPA 90B 4.2.5, 2010 FL mechanical code table 603, and California title 24 parts 4 and 6. Install, line, or extend a properly sized duct section constructed entirely of rigid metal, rigid fibrous glass duct board, or flexible duct between the return air inlet(s) in conditioned space and the inlet of the air handling unit or furnace. Mechanically fasten one end to the return fan inlet at the cabinet and the opposite end to the return grille inside occupied space. Seal both attachments completely without obstructing airflow. Fasten and seal all joints in between to allow no return leakage into the mechanical space.



Photo: J Fitzgerald 2005

Figure 9. Not acceptable: As-found view inside platform return: debris, moisture, wall cavities potentially open to combustion vent, burner, and attic above



Photo Rick Chitwood 2010

Figure 10. Not acceptable: Restricted platform return in newer home



Photo Rick Chitwood 2010

Figure 11. Acceptable: View after opening inlet to fan cabinet



CRITICAL DETAIL:

SUCCESS WITH HOME ENERGY UPGRADES

SEALING FRAMED RETURN PLATFORMS

Remove grille or cut access hole into framed platform.

1 ACCESS RETURN



Clean out debris and dirt from return platform.

2 PREP RETURN



Line plenum with duct board. Mechanically fasten duct board to framing.

3 INSTALL DUCT BOARD



Seal the inside of the return. Choose the appropriate sealing technique based on hole size.

4 FIBERGLASS



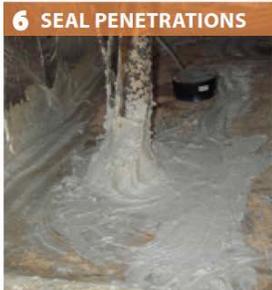
If refrigerant and condensate lines penetrate the platform return, provide infill and seal as needed.

5 SEAL PENETRATIONS



If refrigerant and condensate lines terminate to the outside, install hardware cloth or equivalent rodent barrier.

6 SEAL PENETRATIONS



Notes:

Scrap flashing material can make great washers for use when securing duct board. If using this technique, exercise caution and make sure to wear gloves to protect your hands from the sharp edges.

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Figure 12. How to seal existing platform returns

Illustration by Ray David, NREL/PIX 19500. Photos from Warren Gretz (NREL/PIX 10929) and Iberdola Renewables Inc. (NREL/PIX 15185)
 For further information refer to the NREL Standard Work Specifications Tool (<https://sws.nrel.gov/spec/316025>).

4.4 Combustion Appliances in a Closet or Separate Room With a Door That Opens to a Bedroom or Bathroom

Provide combustion safety check and re-vent to code as needed and provide all combustion air from outside. Weather-strip the door and provide a door closer. Seal all openings to adjacent spaces. Seal all ductwork openings including air handler as above. Cf. IFGC 303.3.5 and NFPA 54 10.3.11, 10.28.1.

4.5 Building Cavities Used as Returns, Opening Into Combustion Appliance Space

Line building cavity with continuous, durable, non-porous, air-impermeable material and seals that show a flame spread of 25 or less and smoke developed of 50 or less when tested to ASTM

E 84 or UL 723. Or use a standard material listed for use in duct systems, such as sheet metal, duct board, or flexible duct.

Seal joints and penetrations with a suitable long-life mastic material. Mechanically fasten and seal to the return inlet, extend and seal to a grille, filter grille or duct section at the interior. Seal the annular space between the building cavity and new air impermeable liner to prevent all return leakage in the combustion space.

Maintain at least the cross sectional area of the return inlet and size the liner or duct to meet the manufacturers required airflow without restriction. Furnace returns must provide at least 2 in.² of total cross-sectional area for every 1000 Btu of output.

5 Materials

Use materials and sealants that match the listing where they are applied.

5.1 Rigid Air-Impermeable Panel Materials

Acceptable rigid air-impermeable materials include:

- ½-in. gypsum board
- ⅝-in. Type X gypsum board
- ¾-in. and 1-in. thick FSK faced duct board labeled for use in ducts and installed to Sheet Metal and Air Conditioning Contractors' National Association fibrous Glass Duct Construction Standards and North American Insulation Manufacturers Association Fibrous Glass Duct Construction Standards
- Attic: rigid foil faced foam board rated for use exposed to interior (Thermax or equivalent) with ICC Evaluation Service (ES) report confirming testing to code requirements
- Rigid extruded polystyrene insulation board for use where ½-in. gypsum board separation to interior is in place.

5.2 Sealants

Acceptable sealants include:

- Joint compound and tape on gypsum board joints
- High temperature room temperature vulcanizing silicone for use on gas vent gaps to metal barriers
- Meets or exceeds Federal Specification TT-S-001543a, TT-S-00230c, A-A-272, Type IV, C.G.S.B. 19 GP-9B and ASTM C 920-86,2008
- Furnace cement, ASTM E 136-09 non-combustible sealant for masonry chimney gaps
- Acrylic and silicone sealant caulks for attics and closets
- 15-minute rated sealants caulks for small gaps, penetrations, and seams in garage wall to house or similarly rated areas.

5.3 Materials for Ductwork and Duct Sealing

Acceptable materials for ductwork and duct sealing include:

- Tapes for metal ductwork marked UL 181A-P
- Mastic that meets UL 181 A-M
- Fiberglass duct board that meets UL 181A
- Non-metallic flexible duct (do not use cloth backed tapes):

- Tape labeled UL 181B FX
- Mastic that meets UL 181B-M
- Mechanical fasteners labeled UL 181B-C.
- Aerosol sealant with 25/50 class 1 flame spread is approved for all joint seals when applied by manufacturer certified installers to manufacturer's standards.
- Duct coverings, linings and adhesives flame/smoke 25/50 on ASTM E 84 or UL 723.
- Two part spray foam meeting IRC 2012 M1601.4.1, and IRC R316.6 tested for its intended uses to: NFPA 286 within acceptance criteria of IRC R 302.9.4, FM 4880, UL 1040, or UL 1715 and reported in an ICC ES report as meeting requirements of code, requires no additional sealants.
- Single component sealant foam: use material accepted as fire stop in wood frame construction and approved for limited exposed use in ICC ES reports see ESR 1961-12, ESR 1862-11, ESR 1926-12.

5.4 Materials for Filling Cavities

For performing practical retrofit air flow separation and firestop in cavities to rooms over a garage or other cavity airflows:

- Select cellulose tested with ICC ES reports see ESR 1996, ESR 2217-09, or
- Select engineered fiberglass wool tested for BPI 104 to ASTM C 522, E 283 or E 2178 for use in BPI-102 "Standard for Air Resistance of Thermal Insulation Used in Retrofit Cavity Applications – Material Specification."

5.5 Additional Resources

For additional information on how to provide specific details see a recognized provider.

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Appendix

Safe Entry

Only after the indoor air environment is found to be safe shall further work be undertaken. In the event that the indoor air environment is determined to be unsafe to the auditor and/or occupant(s), the auditor shall not conduct further work and shall take action in accordance with guidance provided in the subsections that follow.

Combustible Gas Detectors and Carbon Monoxide Measurement Instruments

Calibrate instrument outside the building away from any combustion outlets or automobile traffic areas, or in accordance with manufacturer's instructions.

Combustible Fuel Gases

If at any time the auditor smells combustible fuel gas (characterized by a garlic, rotten egg, or "gassy" odor) the auditor and occupants upon notification by the auditor, shall leave the house, and the appropriate emergency services (typically fire services) and fuel gas providers shall be notified from outside the home.

If the auditor uses a combustible gas detector to determine hazards from combustible concentrations of fuel gas (as in cases where sense of smell may be compromised), indoor air will be sampled at least one location per floor of occupied space upon entering the home. If any measured concentrations exceed 20% lower explosive limit (1% concentration in air by volume), the occupants and Auditor shall leave the house, and the appropriate emergency services and fuel gas providers shall be notified from outside the home.

The audit shall not proceed until emergency services have deemed it safe to re-enter the home and proceed with audit activities.

Where called for by the local authority having jurisdiction, the response procedures documented in the NFGC, ANSI Z223.1/NFPA 54, Annex D, "Suggested Emergency Procedures for Gas Leaks" shall be carried out.

Carbon Monoxide

Carbon monoxide measurements upon entry shall be made and actions taken in accordance with the U. S. Consumer Products Safety Commission document, "Responding to Residential Carbon Monoxide Incidents: Guidelines for Fire and Other Emergency Response Personnel," section "CO Levels: Advice to Give, Actions to Take," available at: www.cpsc.gov/PageFiles/117067/coguide.pdf.

Ambient Atmosphere Safety Action Levels

Based on CO detector readings, the auditor should take the following actions:

If the CO detector indicates an ambient carbon monoxide level of 70 ppm or higher, the auditor shall immediately notify the occupant of the need for all building occupants to evacuate the building; the auditor shall immediately leave the building.

If the CO detector indicates an ambient reading between 36 ppm and 69 ppm, the auditor shall advise the occupant that elevated levels of ambient CO have been detected and recommend that all possible sources of CO be turned off immediately and windows and doors opened. Where it appears that the source of CO is a permanently installed appliance, the appliance shall be turned off and serviced by a qualified servicing agent.

If the CO detector indicates an ambient reading between 9 ppm and 35 ppm, the auditor shall advise the occupant that CO has been detected and recommend that all possible sources of CO be checked and windows and doors opened. Where it appears that the source of CO is a permanently installed appliance, the appliance shall be inspected and serviced by a qualified servicing agent.

If the CO detector indicates ambient CO below 9 ppm, the inspection can proceed.

Building Fuel Gas Distribution Systems

Fuel Gas Distribution System Inspection

Accessible interior piping and tubing shall be visually inspected for general condition of materials, connections, components, and supports. Where the auditor suspects deficiencies of any kind in materials, connections, components, or supports, he/she should note the deficiencies in the audit report and recommend to the owner to contact a qualified plumber or other gas piping expert to review the fitness of the system.

Review to Minimum Code Requirements

Systems shall be inspected and tested in accordance with the NFGC, ANSI Z223.1/NFPA 54, Chapter 8, "Inspection, Testing, and Purging" and, where called for by local authority having jurisdiction, shall be tested in accordance with Annex C of the NFGC, "Suggested Method for Checking for Leakage."

Inspection of Combustion Appliances and Venting Systems

Combustion appliances and venting systems serving those appliances shall be inspected for damage, leaks, disconnections, inadequate vent and vent connector slope and other safety hazards.

Temporarily disable from operating the appliance to be inspected by means of a consumer-accessible switch or control such as switching off power at the electrical panel or lowering the thermostat setting.

Gas-Fired Appliance Venting Systems

The auditor shall carry out one of the following procedures to evaluate venting system design and installation for gas-fired appliances:

1. Determine whether the existing venting system complies with Chapters 12 and 13 of the NFGC, ANSI Z223.1/NFPA 54) and its requirements for terminations, sizing of chimneys, vents, and vent connectors, conditions of chimneys, venting system materials, draft hoods and other components for Category I (atmospherically vented, including fan assisted) appliances and Category II, III, and IV appliances.
2. Recommend the owner contact a qualified gas appliance installer to review venting system conformance to Chapters 12 and 13 of the NFGC.

Oil-Fired Appliance Venting Systems

The auditor shall carry out one of the following procedures to evaluate venting system design and installation for oil-fired appliances:

1. Determine whether the existing venting system complies manufacturer's installation instructions and its requirements for terminations, sizing of chimneys, vents, and vent connectors, conditions of chimneys, venting system materials, draft hoods and other components for Category I (atmospherically vented, including fan assisted) appliances and Category II, III, and IV appliances. If the manufacturer's installation instructions are not available refer to NFPA 31.
2. Recommend the owner contact a qualified gas appliance installer to review venting system conformance to Chapters 12 and 13 of the NFGC.

Gas-Fired Appliance Inspection

CO measurements associated with flue gases and normal operating conditions of gas-fired appliances shall be conducted in accordance with NFGC, Annex G and evaluated in accordance with thresholds shown in Table A.4.1 of that Annex (reproduced in this Guideline as Table 3).

The following appliance-specific inspections are performed either with the appliance in the off or standby mode (indicated by "OFF") or on an appliance that is operating (indicated by "ON"). The CO measurements are to be undertaken only after the appliance is determined to be properly venting.

Forced Air Furnaces

- a. OFF. Verify that an air filter is installed and that it is not excessively blocked with dust.
- b. OFF. Inspect visible portions of the furnace combustion chamber for cracks, ruptures, holes, and corrosion. A heat exchanger leakage test should be conducted.
- c. ON. Verify both the limit control and the fan control for proper operation. Limit control operation can be checked by blocking the circulating air inlet or temporarily disconnecting the electrical supply to the blower motor and determining that the limit control acts to shut off the main burner gas.
- d. ON. Verify that the blower compartment door is properly installed and can be properly resecured if opened. Verify that the blower compartment door safety switch operates properly.
- e. ON. Check for flame disturbance before and after blower comes on which may indicate heat exchanger leaks.
- f. ON. Measure CO in the vent after 5 minutes of main burner operation. The CO should not exceed threshold in Table 3.

Boilers

- a. OFF and ON. Inspect for evidence of water leaks around boiler and connected piping.
- b. ON. Verify that the water pumps are in operating condition. Test low water cutoffs, automatic feed controls, pressure and temperature limit controls, and relief valves in accordance with the manufacturer's recommendations to determine that they are in operating condition.
- c. ON. Measure CO in the vent after 5 minutes of main burner operation. The CO should not exceed threshold in Table 3.

Water Heaters

- a. OFF. Verify that the pressure temperature relief valve is in operating condition. Water in the heater should be at operating temperature.
- b. OFF. Verify that inspection covers, glass, and gaskets are intact and in place on a flammable vapor ignition resistant type water heater.
- c. ON. Verify that the thermostat is set in accordance with the manufacturer's operating instructions and measure the water temperature at the closest tub or sink that it is no higher than 120°F.
- d. OFF. Where required by the local building code in earthquake prone locations, inspect that the water heater is secured to the wall studs in two locations (high and low) using appropriate metal strapping and bolts.
- e. ON. Measure CO in the vent after 5 minutes of main burner operation. The CO should not exceed threshold in Table 3.

Gas Clothes Dryer

- a. OFF. Where installed in a closet, verify that a source of make-up air is provided and inspect that any make-up air openings, louvers, and ducts are free of blockage.
- b. OFF. Inspect for excess amounts of lint around the dryer and on dryer components. Inspect that there is a lint trap properly installed and it does not have holes or tears. Verify that it is clean condition.
- c. OFF. Inspect visible portions of the moisture exhaust duct and connections for loose fittings and connections, blockage, and signs of corrosion. Verify that the duct termination is not blocked and that it terminates in an outdoor location. Verify that only approved metal vent ducting material is installed (plastic and vinyl materials are not approved for gas dryers).
- d. ON. Verify mechanical components including drum and blower for proper operation.
- e. ON. Operate the clothes dryer and verify that the exhaust system is intact and exhaust is exiting the termination.
- f. ON. Measure CO in at the exhaust duct or termination after 5 minutes of main burner operation.

Table 3. Carbon Monoxide Thresholds (Table A.4.1 of NFGC Annex)

Appliance	Threshold Limit
Central Furnace (All Categories)	400 ppm* air free
Floor Furnace	400 ppm air free
Gravity Furnace	400 ppm air free
Wall Furnace (BIV)	200 ppm air free
Wall Furnace (Direct Vent)	400 ppm air free
Vented Room Heater	200 ppm air free
Vent-Free Room Heater	200 ppm air free
Water Heater	200 ppm air free
Oven/Boiler	225 ppm as measured
Top Burner	25 ppm as measured (per burner)
Refrigerator	25 ppm as measured
Gas Log (Gas Fireplace)	25 ppm as measured in vent
Gas Log (Installed in Wood-Burning Fireplace)	400 ppm air free in firebox

* Parts per million

From ANSI/BSR Z223.1/NFPA 54

Additional Resources

Air Conditioning Contractors of America

2800 Shirlington Road, Suite 300
Arlington, VA 22206

ASHRAE

1791 Tullie Circle, NE
Atlanta, GA 30329

ASTM International

100 Barr Harbor Drive
West Conshohocken, PA 19428-2959

ICC

International Code Council, Inc.
500 New Jersey Ave, NW
6th Floor
Washington, DC 20001

ICC-Evaluation Service

5360 Workman Mill Road
Whittier, California 90601
Phone: 800-423-6587 ext. 66546
Fax: 562-695-4694
www.icc-es.org

North American Insulation Manufacturers Association

44 Canal Center Plaza, Suite 310
Alexandria, VA 22314

NFPA

National Fire Protection Association
1 Batterymarch Park
Quincy, MA 02169-7471

Sheet Metal and Air Conditioning Contractors National Association, Inc.

4201 Lafayette Center Drive
Chantilly, VA 20151-1209

UL

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062-2096

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Cummings, J., Withers, C., “Problems Related to Air Handler Leakage,”

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.,

ASHRAE Journal, January 2008.

2010 California Energy Code

California Code of Regulations, Title 24, Part 6

California Building Standards Commission

2525 Natomas Park Drive, Suite 130

Sacramento, CA 95833-2936

American Gas Association

NFPA (FIRE) 54/ANSI Z223.1

400 North Capitol Street, NW

Washington, DC 20001

California Energy Commission

2008 Title 24 California Building Energy Efficiency Standards for low-rise residential buildings

2008 Residential Compliance Manual

California Energy Commission

1516 Ninth Street, MS-13

Sacramento, CA 95814

916-654-5200

California Energy Commission

Reference Appendices to the 2008 Building Energy Efficiency Standards

1516 Ninth Street, MS-13

Sacramento, CA 95814

916-654-5200

Reference Residential Appendix RA3 Field Verification

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Efficiency Characteristics and Opportunities for New California Homes.

California Energy Commission.

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2010 California Mechanical Code

California Code of Regulations Title 24, Part 4

California Building Standards Commission

Based on the 2009 Uniform Mechanical Code

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2525 Natomas Park Drive, Suite 130

Sacramento, CA 95833-2936

IMC 2012

918.2 Minimum duct sizes.

The minimum unobstructed total area of the outdoor and return air ducts or openings to a forced-air warm-air furnace shall be not less than 2 square inches per 1,000 Btu/h (4402 mm²/kW) output rating capacity of the furnace and not less than that specified in the furnace manufacturer's installation instructions. The minimum unobstructed total area of supply ducts from a forced-air warm-air furnace shall not be less than 2 square inches for each 1,000 Btu/h (4402 mm²/kW) output rating capacity of the furnace and not less than that specified in the furnace manufacturer's installation instructions.

Exception: The total area of the supply air ducts and out- door and return air ducts shall not be required to be larger than the minimum size required by the furnace manufacturer's installation instructions.”

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