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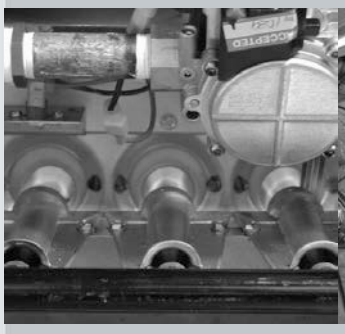
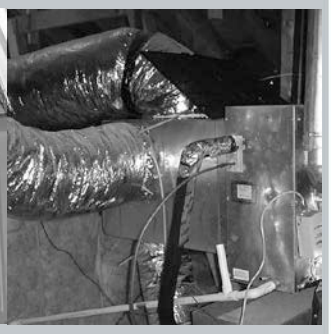
Measure Guideline: Combustion Safety for Natural Draft Appliances Using Indoor Air

L. Brand
Partnership for Advanced Residential Retrofit

April 2014





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Measure Guideline: Combustion Safety for Natural Draft Appliances Using Indoor Air

Prepared for:

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On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

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Contents

List of Figures

Unless otherwise noted, all figures were created by PARR.

List of Tables

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Definitions

ACH	Air changes per hour
AGA	American Gas Association
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BPI	Building Performance Institute
CO	Carbon monoxide
HVAC	Heating, ventilation, and air conditioning
IFGC	International Fuel Gas Code
IMC	International Mechanical Code
IRC	International Residential Code
NFGC	National Fuel Gas Code
NFPA	National Fire Protection Association
NREL	National Renewable Energy Laboratory
RESNET	Residential Energy Services Network
UL	Underwriters Laboratories

Abstract

This Measure Guideline provides guidance on combustion safety inspection procedures for appliances and heating equipment that use indoor air for combustion and dilution of flue gases in low-rise residential buildings. Appliances of interest in this Guideline include Category I and II gas-fired residential furnaces and other natural draft appliances that are not represented by a code-based categorization approach for venting at this time. Only natural draft (i.e., nonpositive vent static pressure) gas-fired combustion appliances installed in the living space or in an area freely communicating with the living space, vented alone or in tandem with another appliance are considered here. A separate Measure Guideline addresses combustion appliances located either within the living space in enclosed closets or side rooms or outside the living space in an adjacent area such as an attic or garage that use outdoor air for combustion and venting.

This document is for building performance inspectors and auditors working in homes where energy upgrades are being conducted. Advanced steps are provided for auditors with special traning or trained heating and cooling technicians. Normal operation of combustion appliances can be affected by building alterations whether or not air infiltration control is included in the package of measures being applied.

The information provided here is based on requirements provided in several of the codes and echoed in the test procedures used by building performance testing agencies, including inspection of the vent, creating a depressurized environment that may impact natural draft appliances, and conducting tests to determine excessive spillage. The prescriptive guildelines in the code are also covered as a reference. The Guideline allows trained residential energy retrofit inspectors to confirm that combustion appliances can operate as expected, or provides guidance so the inspector can refer problem areas to a qualified technician.

This document does not provide sufficient information to assure code compliance and is not a guideline for repair or modification of mechanical systems requiring a qualified contractor or service person.

Acknowledgments

This Guideline is the product of a collaborative effort. The author acknowledges the funding and support of the U.S. Department of Energy's Building America Program. Special thanks to Jim Fitzgerald, Minnesota Center for Energy and Environment; Paul Cabot and Ted Williams, American Gas Association; and Paul Francisco, Illinois Sustainable Technology Center.

Progression Summary

INDOOR AIR FOR COMBUSTION

Combustion Safety When Using Indoor Air for Combustion. The purpose of this Guideline is to provide minimum requirements and recognized test procedures for evaluating safe installation and operation of combustion appliances in homes undergoing energy efficiency upgrades where indoor air is used for combustion and venting. Recommendations for remedial measures are provided where necessary.

APPLIANCE ASSESSMENT

1. **Appliance Assessment.** Determine that the Category I appliances using indoor air for combustion freely communicate with the indoor environment. (Advanced Step) Also determine that the appliances meet code requirements for indoor combustion air, the vent system is properly sized, and that both are operating safely.

TEST-IN

2. **Inspection and Test.** Inspect the vent system for corrosion or blockage and perform spillage and combustion tests.

Do Not Proceed if:

- Combustion appliances are not operating safely.
- Vent system spills for more than 5 minutes after startup

UPGRADE

3. **Upgrade.** Perform upgrade or retrofit measures.

TEST-OUT

4. **Test-Out.** Perform a standard combustion safety test procedure to ensure that upgrade measures do not impact combustion safety. If the gas appliances fail combustion safety tests, proceed to Estimate Remediation Cost.

REMEDIATION COST ESTIMATE

5. **Cost Estimate**. (Advanced Step) Where remediation is required, determine work scope for proper venting of combustion gases or provide an alternate solution. Compare job cost to other combustion safety approaches such as replacement with power or direct vent appliances.

REMEDIATION

6. **Remediation Options**. (Advanced Step) Where required, add combustion air openings to larger indoor spaces, provide mechanical combustion air supply, provide combustion air ducts, provide an engineered solution, or replace with direct vent appliances.

1 Introduction

This Measure Guideline covers how to assess and carry out combustion safety procedures for appliances and heating equipment that use indoor air for combustion and dilution of flue gases in low-rise residential buildings. Only Category I and II gas-fired residential furnaces and other natural draft appliances that are not represented by a code-based categorization approach for venting at this time are addressed. Only natural draft (i.e., nonpositive vent static pressure) gas-fired combustion appliances installed in the living space or in an area freely communicating with the living space, vented alone or in tandem with another appliance are considered here. Appliances installed in a zone isolated from the indoor air in enclosed closets, side rooms, or outside the living space in an adjacent area such as an attic or garage that use outdoor air for combustion and venting are covered in a separate Measure Guideline (Fitzgerald and Bohac 2013).

The purpose of this Measure Guideline is to provide inspection guidelines for a subset of houses where the combustion appliances are in the living space or communicating freely with the living space. The goal is to allow energy retrofits including tightening and changes to distribution and ventilation systems to proceed, while verifying that the upgrades did not negatively impact combustion safety. A list of possible remedial measures, if required, is provided in this document.

This Guideline will:

1. Provide a guide to the general code requirements and inspection procedures that allow natural draft appliances to comply with combustion safety guidelines.
2. Provide some remediation options where these appliances fail the combustion safety test.

This Guideline applies to Category I and II appliances only and largely focuses on Category I appliances using atmospheric venting systems that employ a draft hood. According to American National Standards Institute (ANSI) z223.1/National Fire Protection Association (NFPA) 54 (NFPA 2012a), a Category I appliance is defined as an appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent. The same source defines a Category II appliance as having a nonpositive vent static pressure and with a vent gas temperature that may cause excessive condensate production in the vent. The U.S. Department of Energy (DOE 2013) defines Category I appliances as having a flue-loss efficiency of less than 83% and operate under *negative* pressure in the vent. Some Category I appliances rely on the natural draft of their hot combustion products for venting. Others rely on fans or blowers to overcome the flow resistance through a heat exchanger and push or pull the combustion products through the appliance, although the vent still operates under negative pressure. Residential draft hood-equipped water heaters and boilers, though not categorized, are included in this Measure Guideline.

The current minimum code in this area is the ANSI z332.1 National Fuel Gas Code (NFGC), which is also published by the National Fire Protection Association as NFPA 54. The International Code Council includes the same language in the International Fuel Gas Code (IFGC) (ICC 2013). For simplicity these codes will be referred to as the “NFGC and IFGC” except where specific sections of the code are cited. The inspector/auditor should have a good understanding of the minimum code to use this Measure Guideline.

Building Performance Institute (BPI 2012) and Residential Energy Services Network (RESNET) (RESNET 2010) provide test procedures that go beyond the minimum code. If the auditor is BPI or RESNET certified, those test procedures should be consulted.

This Guideline:

- Defines the screening protocol in the codes for Category I atmospheric appliance combustion safety
- Describes the inspection procedure summarized from the codes and building performance inspection procedures
- Describes remediation measures, where necessary, including some illustrative examples.

2 Measure Implementation—Appliance Assessment

This section of the Guideline provides an assessment tool for the inspector to determine if the vent size and combustion air openings are adequate for the installation. The procedure in Section 2.1 should be conducted at minimum. Inspectors skilled in vent sizing and combustion air opening analysis should also perform Sections 2.2 and 2.3.

The goals of the appliance assessment are to determine if using indoor air for combustion 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, e.g., replacement with power-vented or direct vent appliances.

The assessment will determine if the appliance installation meets minimum requirements, or for advanced inspections, meets code prior to conducting any combustion safety testing. Table 1 shows the job breakdown for the appliance assessment.

Several computer-based software packages and applications are available for vent system inspection.

Table 1. Appliance Assessment Job Breakdown

Important Steps	Key Points	Reasons
1. Appliance Draft and Venting System Type Identification	Natural draft and/or fan-assisted Category I and II appliances are located in a space that is freely communicating with the conditioned space.	Determine if Measure Guideline can be applied.
2. Vent Inspection	Determine that vent connector(s) and common vents are sized and installed according to either the NFGC, Chapters 12 and 13 (NFPA 2012), or the IFGC Chapter 5 (IRC 2013).	Determine need for mechanical contractor and work required.
3. Indoor Combustion Air Code Compliance	Determine if indoor combustion air meets the requirements of the Standard Method or Known Infiltration Rate Method either in the NFGC Section 9.3 or the IFGC, Section 340.	Ensure code requirements are being met before work begins.

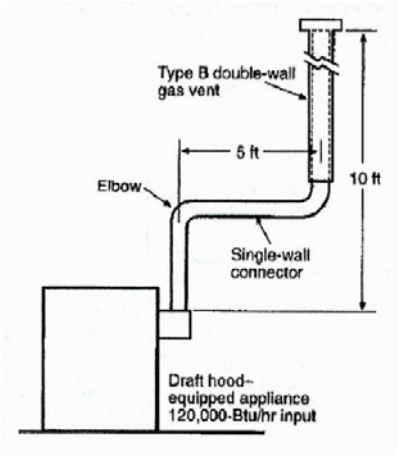


Figure 1. Draft hood-equipped appliance

Source: American Gas Association (AGA) and NFPA. ANSI Z223.1 NFPA 54 NFGC 2012 Edition. Figure 1.1 p. 54-162 (p. Z223.1-162).

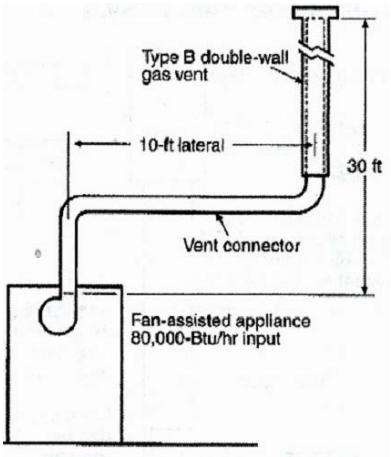


Figure 2. Fan-assisted appliance

Source: AGA and NFPA. ANSI Z223.1/ NFPA 54 NFGC 2012 Edition. Figure 1.2 p. 54-162 (p. Z223.1-162).

2.1 Appliance Draft and Venting System Type Identification

Vent systems are designed to carry products of combustion (mostly carbon dioxide and water vapor) away from the appliance to the outdoors. If a vent system fails, flue gases may enter the indoor space and create a hazard, including unsafe carbon monoxide (CO) levels. There are provisions in the NFGC and IFGC to mitigate the combustion safety hazard and those steps are provided later in this report.

For this Measure Guideline, the focus is on natural draft appliances. Fan-assisted Category I and II appliances are also an important consideration where they are common vented with natural draft appliances. Natural draft appliances are sometimes referred to as *draft hood-equipped appliances* or *atmospheric appliances*. Draft hoods are included in these designs to separate the vent system from the appliance burner to decouple the outdoor weather conditions from burner performance. Installation of these appliances is covered by the NFGC and IFGC and become code when adopted by the authority having jurisdiction. Category III–IV appliances are installed according to the manufacturers' installation instructions and are not a part of this Measure Guideline.

Category I appliances (water heaters, furnaces, and boilers) are used singly in homes or in combination (common vented). They are installed using Type B vent systems or masonry chimneys according to the NFGC and IFGC with Type B or single wall vent connectors. These appliances can have a draft hood (Figure 1) or a fan-assisted combustion system (Figure 2), they can be vented alone (Figure 1 and Figure 2), or can be common vented with one or more other Category I appliances (Figure 3 and Figure 4). Residential water heaters and boilers are not formally categorized, but the NFGC and IFGC provide guidance for venting draft hood-equipped residential water heaters and boilers in single appliance or in common vent mode.

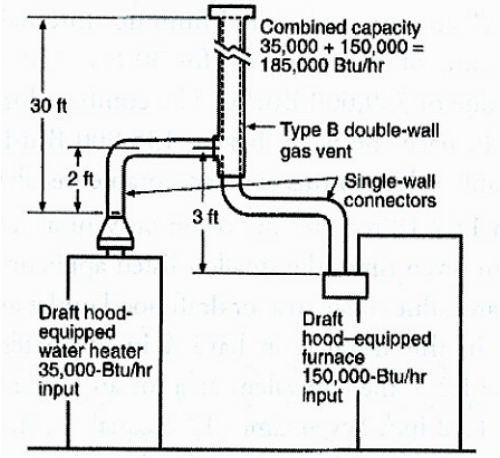


Figure 3. Common venting two draft hood-equipped appliances

Source: AGA and NFPA. ANSI Z223.1 NFPA 54 NFGC 2012 Edition. Figure 2.1 p. 54-163 (p. Z223.1-163).

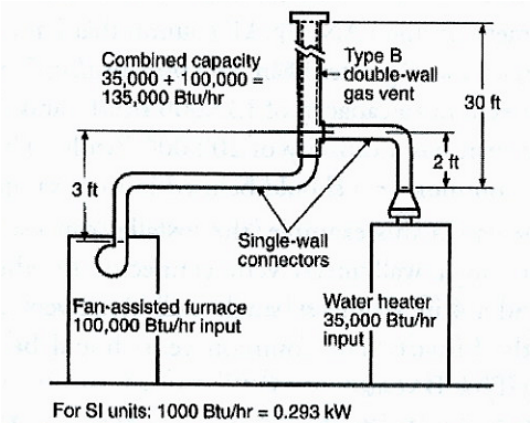


Figure 4. Common venting a draft hood-equipped water heater with a fan-assisted furnace into a Type B common vent

Source: AGA and NFPA. ANSI Z223.1 NFPA 54 NFGC 2012 Edition. Figure 2.2 p. 54-163 (p. Z223.1-163).

For this initial assessment, we need to confirm that:

1. The appliances have a draft hood (or draft diverter) and are labeled Category I on the manufacturers nameplate (CAT I in Figure 5). Appliances that use air from outdoors and vent directly outdoors or appliances with mechanical or engineered venting systems are not Category I appliances.
2. The appliances use indoor air for combustion and venting.
3. The appliances are installed in a space that freely communicates with the indoor environment of the home. Appliances in a ventilated closet that is sealed from the indoor space are addressed in a separate Building America Measure Guideline. Appliances in an unsealed attic, garage, or outdoor ventilated closet are considered to use outdoor air for combustion.

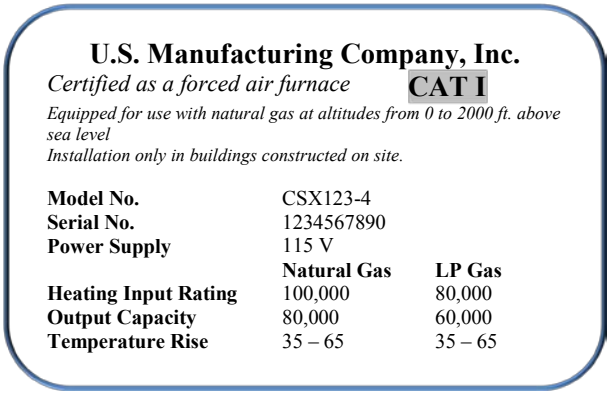
Once this condition is satisfied, proceed to Section 2.2, Vent Inspection. Inspectors not skilled in vent sizing and combustion air opening sizing should proceed to Section 3.

2.2 Vent Inspection

The objective of the vent inspection is to determine if the appliance vent system meets the minimum sizing guidelines in the code prior to performing combustion safety testing. If the vent or vent connector is corroded or disconnected it must be repaired (see Section 3 for guidance on repairs). For vent inspection:

Advanced Steps (for those with proper training)

1. Inspect the vent connectors first, then the common vent or masonry chimney.



U.S. Manufacturing Company, Inc.

Certified as a forced air furnace **CAT I**

Equipped for use with natural gas at altitudes from 0 to 2000 ft. above sea level

Installation only in buildings constructed on site.

Model No.	CSX123-4	
Serial No.	1234567890	
Power Supply	115 V	
	Natural Gas	**LP Gas**
Heating Input Rating	100,000	80,000
Output Capacity	80,000	60,000
Temperature Rise	35 – 65	35 – 65

Figure 5. Example gas furnace nameplate

Source: Gas Technology Institute

Nominal Liner Size (in.)	Inside Dimensions of Liner (in.)	Inside Diameter or Equivalent Diameter (in.)	Equivalent Area (in.²)
4 × 8	2 ½ × 6 ½	4.0	12.2
		5.0	19.6
		6.0	28.3
		7.0	38.3
8 × 8	6 ¾ × 6 ¾	7.4	42.7
		8.0	50.3
8 × 12	6 ½ × 10 ½	9.0	63.6
		10.0	78.5
12 × 12	9 ¾ × 9 ¾	10.4	83.3
		11.0	95.0
12 × 16	9 ½ × 13 ½	11.8	107.5
		12.0	113.0
		14.0	153.9

Figure 6. Masonry chimney liner dimensions with circular equivalents

Source: AGA and NFPA. ANSI Z223.1 NFPA 54 NFGC 2012 Edition. Figure 2.3 p. 54-165 (p. Z223.1-165). Table abbreviated.

2. Make sure that vent connectors are sized according to Tables 3.1(a)–3.2(i) in NFPA 54 with additional requirements for manifolds, offsets, three or more elbows, corrugated liners, etc. as listed in 13.1.2–13.2.30 of the Code to ensure minimum performance.
3. For draft hood-equipped appliances, determine the height of the vent connector above the draft hood opening (rise), the lateral distance of the vent connector before it enters the common vent (T or Y fitting), or the masonry chimney and the height of the common vent from the connector to the vent terminal above the roof.
4. Note the diameter of the vent connector, usually 3, 4, or 5 in., the material (single wall or Type B), and the number of elbows in the connector. Note the diameter of the common vent.
5. Verify that the slope of the vent connector is upward away from the appliance and no less than ½ inch per foot of length.
6. Determine the appliance input rating from the nameplate (Figure 5).
7. Using the single-wall or Type B vent connector table, look up the height and connector rise row and move across to the vent connector diameter. The appliance input rate should be less than the NAT Max value for draft hood-equipped appliances and between the FAN Min and Max values for fan-assisted appliances. Repeat for all vent connectors.
8. If all vent connector diameters are within range, continue to the common vent table and find the appropriate vent height row and follow across to the common vent diameter column. Add the input ratings from all common vented appliances together and determine if the value is

below the maximum value in the table. If all appliances are draft hood-equipped, use NAT + NAT, if all are fan assisted combustion systems, use FAN + FAN, and otherwise use FAN + NAT. If the vent connector or vent is not properly sized, replace it. The only exception to the rule is if the vent connector and/or common vent will be modified as a part of the upgrade process. If that is the case, the vent and vent connector need not be replaced, but the equipment must still pass the test-in requirements in the Section 3 and the test-out requirements in Section 5 of this guideline.

9. For appliances using masonry chimneys, if the vent connector is not properly sized, identify the correct size using the procedure in Section 2.2 step 7 of this guideline with the exception that the internal area of the masonry chimney must be calculated (Figure 6). The combined capacity of the common vented appliances must be between the minimum and maximum capacity listed in the tables. If the chimney is too large, it should be relined with a metal liner or Type B vent.
10. For external masonry chimneys, special rules apply. A metal liner may be required depending on the appliance input rate, the installation type, and the local 99% winter design temperature.
11. For vent connectors with more than two elbows, long lateral lengths beyond 18 in./in. of diameter, manifold offsets, or other geometries, the capacity in the tables is reduced. (See additional requirements for reductions for manifolds, offsets, more than two elbows, corrugated liners, and other modifications in Sections 13.1.2–13.2.30 of NFPA 54.)

Once the vent system meets code, the adequacy of indoor air for combustion should be addressed.

Example:

A 40,000-Btu/h natural draft water heater and an 80,000-Btu/h fan-assisted Category I furnace are installed. The appliances are common vented into a 20-ft. tall 6-in. diameter Type B common vent. The water heater uses a 4-in. vent connector and the furnace a 5-in. vent connector, both Type B. Both connectors have two elbows and a lateral length of 3 ft (see Table 2).

1. To check the water heater vent connector for compliance, follow the left column down to the 20-ft vent height.
2. Select the 2-ft vent connector rise row and follow it to the 4-in. vent connector column.
3. The capacity of the water heater is less than the NAT Max value of 66,000 Btu/h, so the 4-in. vent connector is acceptable. Note that the 3-in. vent connector with a maximum capacity of 37,000 Btu/h would not be acceptable in this case.
4. To check the furnace, repeat steps 2 and 3 but follow the row to the 5-in. vent connector column.
5. The 80,000-But/h furnace capacity is between the FAN Min and FAN Max values (48,000–67,000), so this connector diameter is acceptable.
6. For the connectors, use of two elbows does not require a capacity adjustment, and a 3-ft lateral is within the 18 in./in. of diameter restriction (18 * 4 = 72 in. or 6 ft. for the water heater and 18 * 5 = 90 in. or over 7 ft for the furnace).
7. To check the common vent, in the Common Vent Capacity table at the bottom of Table 2, follow the left column down to the 20-ft vent height and follow that row across to the 6-in. vent diameter. The FAN + NAT maximum capacity is 255,000 Btu/h. The furnace plus water heater capacity is 120,000 Btu/h, so the common vent diameter is acceptable.

Table 2. Vent Connector Capacity in Relation to Chimney Height

Table 13.2(a) Type B Double-Wall Vent

Number of Appliances:	Two or More
Appliance Type:	Category I
Appliance Vent Connection:	Type B Double Wall Connector

Vent CONNECTOR Capacity

Height H (ft)	Connector Rise R (ft)	Type B Double-Wall Connector Diameter — D in.																					
		3			4			5			6			7			8			9			10		
		Appliance Input Rating Limits in Thousands of Btu per Hour																					
		FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT
		Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max
6	1	22	37	26	35	66	46	46	106	72	58	164	104	77	225	142	92	296	185	109	376	237	128	466	289
	2	23	41	31	37	75	55	48	121	86	60	183	124	79	253	168	95	333	220	112	424	282	131	526	345
	3	24	44	35	38	81	62	49	132	96	62	199	139	82	275	189	97	363	248	114	463	317	134	575	386
8	1	22	40	27	35	72	48	49	114	76	64	176	109	84	243	148	100	320	194	118	408	248	138	507	303
	2	23	44	32	36	80	57	51	128	90	66	195	129	86	269	175	103	356	230	121	454	294	141	564	358
	3	24	47	36	37	87	64	53	139	101	67	210	145	88	290	198	105	384	258	123	492	330	143	612	402
10	1	22	43	28	34	78	50	49	123	78	65	189	113	89	257	154	106	341	200	125	436	257	146	542	314
	2	23	47	33	36	86	59	51	136	93	67	206	134	91	282	182	109	374	238	128	479	305	149	596	372
	3	24	50	37	37	92	67	52	146	104	69	220	150	94	303	205	111	402	268	131	515	342	152	642	417
15	1	21	50	30	33	89	63	47	142	83	64	220	120	88	298	163	110	389	214	134	493	273	162	609	333
	2	22	53	35	35	96	63	49	153	99	66	235	142	91	320	193	112	419	253	137	532	323	165	658	394
	3	24	55	40	36	102	71	51	163	111	68	248	160	93	339	218	115	445	286	140	565	365	167	700	444
20	1	21	54	31	33	99	66	46	157	87	62	246	125	86	334	171	107	436	224	131	552	285	158	681	347
	2	22	57	37	34	105	66	48	167	104	64	259	149	89	354	202	110	463	265	134	587	339	161	725	414
	3	23	60	42	35	110	74	50	176	116	66	271	168	91	371	228	113	486	300	137	618	383	164	764	466
30	1	20	62	33	31	113	59	45	181	93	60	288	134	83	391	182	103	512	238	125	649	305	151	802	372
	2	21	64	39	33	118	70	47	190	110	62	299	158	85	408	215	105	535	282	129	679	360	155	840	439
	3	22	66	44	34	123	79	48	198	124	64	309	178	88	423	242	108	555	317	132	706	405	158	874	494
50	1	19	71	36	30	133	64	43	216	101	57	349	145	78	477	197	97	627	257	120	797	330	144	984	403
	2	21	73	43	32	137	76	45	223	119	59	358	172	81	490	234	100	645	306	123	820	392	148	1014	478
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	2	19	83	44	30	161	79	42	267	123	55	447	178	75	619	242	94	822	316	115	1054	405	139	1306	494
	3	20	84	50	31	163	89	44	272	138	57	452	200	78	627	272	97	834	355	118	1069	455	142	1327	555

Common VENT Capacity

Vent Height H (ft)	Type B Double-Wall Common Vent Diameter — D in.																							
	4			5			6			7			8			9			10					
	Combined Appliance Input Rating in Thousands of Btu per Hour																							
	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT
6	92	81	65	140	116	103	204	161	147	309	248	200	404	314	260	547	434	335	672	520	410			
8	101	90	73	155	129	114	224	178	163	339	275	223	444	348	290	602	480	378	740	577	465			
10	110	97	79	169	141	124	243	194	178	367	299	242	477	377	315	649	522	405	800	627	495			
15	125	112	91	195	164	144	283	228	206	427	352	280	556	444	365	753	612	465	924	733	565			
20	136	123	102	215	183	160	317	255	229	475	394	310	621	499	405	842	688	523	1035	826	640			
30	152	138	118	244	210	185	361	297	266	547	459	360	720	585	470	979	808	605	1209	975	740			
50	167	153	134	279	244	214	421	353	310	641	547	423	854	706	550	1164	977	705	1451	1188	860			
100	175	163	NA	311	277	NA	489	421	NA	751	658	479	1025	873	625	1408	1215	800	1784	1502	975			

Source: AGA and NFPA. ANSI Z223.1 NFPA 54 NFGC 2012 Edition. Figure 2.3 p. 54-120 (p. Z223.1-120).

2.3 Indoor Combustion Air Code Compliance

According to the NFGC and IFGC, there are two alternative paths for determining if combustion air from the indoors is adequate for the home: the Standard Method and the Known Air Infiltration Rate Method. Both methods calculate the minimum volume of the space required for the total appliance input rate. The Standard Method is to be used unless the air infiltration rate is known to be less than 0.4 air changes per hour (ACH) of natural infiltration measured without a blower door. If the natural infiltration rate exceeds 0.4 ACH, the Known Air Infiltration Rate Method is to be used. Where louvers or grilles are employed to allow adjoining space to communicate freely, follow the sizing guidelines and use the net free area of louvers and grilles. Additional detail regarding a combination of indoor and outdoor air, engineered installations, and supplying makeup air is provided in the NFGC and IFGC.

Research is underway to investigate the impact of depressurization on using indoor air for combustion and dilution. Results will be included in the NFGC and IFGC or updated Measure Guidelines when they are available.

2.3.1 Standard Method—Required Volume

The total required volume is calculated by adding the volume of the space in which the appliance is installed and rooms communicating directly with the space through openings not furnished with doors and through combustion air openings sized and located in accordance with NFPA 54 Section 9.3.2.3. The minimum required volume in the Standard Method is 50 ft^3/1,000 Btu/h.

Example:

A 40,000-Btu/h Category I water heater has a required volume of 50 × 40 = 2,000 ft^3.

If the water heater is installed in a 20 ft × 20 ft open basement with an 8-ft ceiling, the volume of the space is 20 × 20 × 8 = 3,200 ft^3.

The volume of the space is above the minimum and the Standard Method is satisfied.

For a 40,000-Btu/h water heater and an 80,000-Btu/h furnace in the same basement space, the required volume is 50 ×120 = 6,000 ft^3

The basement volume of 3,200 ft^3, above, would not meet the requirement.

If there is a louvered door to a finished basement room or to the first floor of the home that meets the requirements of the NFGC and IFGC, that volume can be included in the calculation to meet the required volume.

$$Required\ Volume_{standard} = 50 ft^3 \left(\frac{I}{1{,}000\ Btu/h}\right)$$

Where I is the total input of all appliances in the space in Btu/h.

2.3.2 Known Air Infiltration Rate Method

If the natural air infiltration rate in the home is known to be less than 0.4 ACH, an alternate method is used. For other than fan-assisted combustion systems, the required volume is:

$$Required\ Volume_{other} \geq \frac{21\ ft^3}{ACH}\left(\frac{I_{other}}{1{,}000\ Btu/h}\right)$$

Where I_{other} is the total input of all other than fan-assisted appliances in the space in Btu/h.

Example:

A 40,000-Btu/h draft hood-equipped water heater in a house with 0.4 ACH infiltration rate requires a volume ≥ 21/0.4 * (40,000/1,000) = 2,100 ft^3.

If there is a louvered door to a finished basement room or to the first floor of the home that meets the requirements of the NFGC and IFGC, that volume can be included in the calculation to meet the required volume.

Example:

An 80,000-Btu/h fan assisted furnace in a house with 0.4 ACH infiltration rate requires a volume ≥ 15/0.4 * (80,000/1,000) = 3,000 ft^3. If the two appliances in the examples in this section were installed in the same house, the required volume is 2,100 + 3,000 = 5,100 ft^3. This value is slightly lower than the value in Section 2.3.1 because fan-assisted combustion systems require less air for combustion and dilution.

For appliances with fan-assisted combustion systems, the required volume is:

$$Required\ Volume_{fan} \geq \frac{15\ ft^3}{ACH}\left(\frac{I_{fan}}{1{,}000\ Btu/h}\right)$$

Where I_{fan} is the total input of all fan-assisted appliances in the space in Btu/h.

3 Inspection and Test-In

In this step, the vent system and chimney are inspected for corrosion and blockage, and the performance of the vent system is verified. This step is required to provide a safe working condition for the upgrade at test-in, and to ensure combustion safety is met when performed at test-out.

Table 3. Inspection and Test Job Breakdown

Important Steps	Key Points	Reasons
1. Vent System and Chimney Inspection	Inspect the vent system for proper sizing and then for corrosion, blockage, and gaps, and the masonry chimney for blockage, holes, and the presence of a liner if required.	Ensure that the vent system is in good working order.
2. Building Exhaust Systems and Air System Inspection	Inspect exhaust fans, clothes dryers, and kitchen ventilation systems for provision of makeup air in accordance with NFGC Section 9.3.1.5 (or as required in operational testing and comformance to safe performance under that section), and Section 504.5 of the IMC. Return air intakes and their locations shall conform to the requirements of IMC Section M1602.	Ensure minimum code compliance to avoid known potential sources of house depressurization and interference with proper appliance venting.
3. Vent Performance Testing	Determine that the vent system is performing as designed.	Ensure a safe working environment at test-in and combustion safety when performed at test-out. Find and reduce interference from other house systems during operation.

3.1 Vent System and Chimney Inspection

Visually inspect vent connectors, vertical vents and masonry chimneys for perforated corrosion, gaps, and missing sections (see BPI 1200 and NFPA 54 chapter 12). Chimneys should be lined in accordance with NFPA 211, *Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances* (NFPA 2012b). Relining may be required by the NFGC and IFGC if the capacity of the chimney is too large for the vented appliances. Evidence of liquid water in a vent connector, vent, below the chimney cleanout, or from the base of a chimney liner that penetrates indicates the need for repairs. Repairs should be completed before vent performance testing begins.

3.2 Vent Performance and Combustion Testing

The next step is to make sure that the home upgrade is taking place under safe working conditions. A combustion safety check shall be performed for each appliance. If for any reason the combustion appliances are deemed to be operating unsafely during this visit, the Measure Guideline should be abandoned and the homeowner advised that further inspection, repair, tune-up, or replacement may be necessary by an appropriately licensed technician.

The procedure provided in this section is based on NFPA 54 Annex G with some modifications to CO testing and door positions to reflect changes being considered by NFPA and other organizations. Similar procedures are available from BPI and RESNET. These procedures are all undergoing revision at the time of this publication. Following this Measure Guideline does not assure code compliance.

Establishing depressurization limits for Category I appliances and draft hood-equipped water heaters is not yet a part of the appliance certification process, so this procedure omits the discussion of depressurization limits in the area of the appliance until that research has been conducted.

Figure 7. Category I furnace

Source: Gas Technology Institute

Combustion appliance testing should be performed under two conditions: with the equipment off and then with the equipment running. Minimum steps are listed for the basic trained inspector and advanced steps are provided for those with advanced training or for skilled heating, ventilation, and air conditioning (HVAC) technicians. If the auditor is not trained in an area, that step should not be attempted.

Check the ambient CO level and combustible gas concentration. If the results of this inspection identify a baseline house CO level above the 35 ppm National Renewable Energy Laboratory (NREL) Standard Work Specification Limit (https://sws.nrel.gov/spec/202011) or a gas leak above the 10% lower explosive limit OSHA standard (OSHA 2011) limit for confined spaces), the homeowner should be notified and the inspection should stop until the situation is corrected.

If the any appliance is going to be replaced in the upgrade step and can be removed from service, it need not be tested. If all natural draft appliances are going to be replaced with appliances that are not natural draft, and they can be removed from service, then remove them from service and proceed with the upgrade in Section 4 of this Guideline.

3.2.1 On Entry and With Equipment Off

The following tests should be performed with the combustion appliance equipment off:

Minimum Steps

1. Conduct a test for gas leakage.
2. Visually inspect the venting system to determine that there is no blockage, restriction, leakage, corrosion, or other deficiencies that could cause an unsafe condition (NFPA 54 Chapter 13, IFGC Chapter 5).

Advanced Steps (for those with proper training)

1. Identify type of vent connector and common vent materials.
2. Take basic measurements and check them against the tables in the NFGC and IFGC to determine that the vent system is properly sized:
    a. Check the vertical common vent/chimney diameter and approximate height and note offsets.
    b. Measure the common vent manifold diameter and horizontal length.
    c. Check each appliance vent connector diameter, rise, length, and number of elbows.
3. Shut off all gas to the appliance and shut off any other fuel gas burning appliance within the same room. Shut off electrical power at the service disconnect. Use the shutoff valve in the supply line to each appliance.
4. Inspect burners and crossovers for blockage and corrosion.
5. For furnace installations, inspect the heat exchanger for cracks, openings, or excessive corrosion.
6. For boiler installations, inspect for evidence of water or combustion product leaks.

If the vent system sizing, installation, or combustion air requirement is not met, the deficiency should be noted and addressed after combustion testing in Section 3.2.2 is complete.

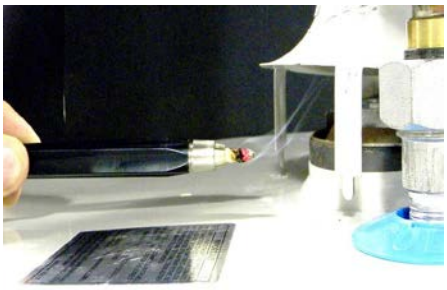

Figure 8. Draft hood-equipped water heater smoke pen testing

Source: Gas Technology Institute

3.2.2 Combustion Appliance Tests With Equipment On

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

Minimum Steps

1. Close all exterior doors, windows, and fireplace dampers. Open all interior doors. Leave open all combustion air openings to the outdoors.
2. If there is a central air handler and a bedroom or separate room without a ducted return grille, close the door(s) to those rooms.

3. Turn on any clothes dryers. Turn on any exhaust fans, such as range hoods and bathroom exhausts, so they will operate at maximum speed. Do not operate a summer exhaust fan. Close fireplace dampers.
4. Place the appliance being inspected in operation. Follow the lighting instructions, if required. Adjust the thermostat so the appliance will operate continuously.
5. Measure the CO level in the flue and determine that the value is not above the ANSI certification limit for that type of appliance (Table 4).
6. Test for spillage at the draft hood relief opening after 5 minutes of main burner operation. Use the flame of a match or candle or smoke (Figure 8).

Table 4. CO Thresholds

CO **THRESHOLDS**

(Excerpted from Proposed National Fuel Gas Code 2015 Annex G Ver 2-27-14, printed with permission of the American Gas Association)

Appliance	Threshold Limit
Central Furnace (all categories)	400 ppm[1] air free[2,3]
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
Water Heater	200 ppm air free

[1] Parts per million

[2] Air free emission levels are based on a mathematical equation (involving carbon monoxide and oxygen or carbon dioxide readings) to convert an actual diluted flue gas carbon monoxide testing sample to an undiluted air free flue gas carbon monoxide level utilized in the appliance certification standards. For natural gas or propane, using as-measured CO ppm and O2 percentage:

$$CO_{AFppm} = \left(\frac{20.9}{20.9 - O_2}\right) \times CO_{ppm}$$

Where:

CO_{AFppm} = Carbon monoxide, air-free ppm

CO_{ppm} = As-measured combustion gas carbon monoxide ppm

O_2 = Percentage of oxygen in combustion gas, as a percentage

[3] An alternate method of calculating the CO air free when access to an oxygen meter is not available:

$$CO_{AFppm} = \left(\frac{UCO_2}{CO_2}\right) \times CO$$

Where:

UCO_2 = Ultimate concentration of carbon dioxide for the fuel being burned in percent for natural gas (12.2 percent) and propane (14.0 percent)

CO_2 = Measured concentration of carbon dioxide in combustion products in percent

CO = Measured concentration of carbon monoxide in combustion products in percent

7. Turn on all other fuel gas burning appliances within the same room so they will operate at their full inputs. Follow lighting instructions for each appliance. Circulating air blowers (if any) should be operating.
8. Repeat step 6 (Section 3.2.2), above, on the appliance being inspected.
9. If another appliance is to be inspected, shut off all appliances and return to Step 1 in this section (3.2.2).
10. Return doors, windows, exhaust fans, fireplace dampers, and any other fuel gas burning appliance to their previous conditions of use.

If the combustion appliance tests fail the spillage test with other equipment on but passes under natural conditions with other equipment off, the cause and potential improvement is most likely with the availability of combustion air, not with the performance of the vent system. Proceed to Section 4 and re-evaluate at Test-Out in Section 5. If the combustion appliance fails the spillage or combustion tests under natural conditions, a service technician should be called before proceeding to upgrade in Section 4 (also see Sections 6 and 7 for remediation).

Advanced Steps (for those with proper training)

1. Determine that the pilot(s), where provided, is burning properly and that the main ignition is satisfactory, by interrupting and re-establishing the electrical supply to the appliance in any convenient manner. If the appliance is equipped with a continuous pilot(s), test all pilot safety device(s) to determine whether it is operating properly by extinguishing the pilot(s) when the main burner(s) is off and determining, after 3 minutes that the main burner gas does not flow upon a call for heat. If the appliance is not provided with a pilot(s), test for proper operation of the ignition system in accordance with the appliance manufacturer's lighting and operating instructions.
2. Visually determine that the main burner gas is burning properly (i.e., not floating, lifting, or flashing back). Adjust the primary air shutters as required. If the appliance is equipped with high and low flame controlling or modulation, check for proper main burner operation at low flame.
3. Furnace installations. Check 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.
4. Boiler installations. 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 proper operating condition.

4 Upgrade

Once the house passes the combustion safety requirements at test-in, or provision is made to replace the failed appliances, the upgrades can be performed. For inspectors performing the minimum test, procede to Section 5 after Upgrade.

5 Test-Out

The next step of the screening process is test-out. The same procedure used in Section 3.2 for test-in should be used for test-out. An inspector conducting the minimum combustion safety test need not proceed beyond test-out. Failures, if any, should be noted.

For inspectors with advanced training or HVAC technicians, if it is anticipated that the air sealing measures will reduce the infiltration rate below 0.4 ACH, as in Section 2.3.2., the combustion air requirements should be rechecked with the known air infiltration rate method and adjustments should be made as appropriate.

Test-out failures are addressed in Section 6, Estimate Remediation Cost, and Section 7, Remediation. Remediation is an advanced step that should only be conducted by an inspector with proper training or an HVAC technician.

6 Estimate Remediation Cost

Remediation is an advanced step that should only be conducted by an inspector with proper training or an HVAC technician.

Where the Standard Method in Section 2.3.1, the Known Air Infiltration Rate Method in Section 2.3.2, the vent testing procedure in Section 3.2, the test-in procedure in Section 3, or the test-out procedure in Section 5 fail, remediation will be required to bring the house up to code. Details of the remediation measures are covered in Section 7. The remediation cost shoud be estimated before remediation is initiated by following the guidance in this section.

If the remediation cost exceeds the cost of replacing one or both appliances with direct vent appliances or an alternative, and no other repairs are possible to provide adequate combustion and dilution air to the appliances, appliance replacement should be added to the list of measures to be performed on the home. If the draft hood appliances are to be replaced, the remediation step associated with combustion safety may be omitted.

6.1 Estimate Remediation Cost at Code Compliance Inspection

If the vent system does not conform to code, it must be replaced before proceeding with the upgrade.

If the inspection fails the Standard Method, or the Known Air Infiltration Rate Method for calculating required volume in the space, the ventilation air is insufficient for the Category I or draft hood-equipped appliances. In either case, additional volume needs to be added to the space communicating with the appliances. A contractor who can perform modifications to the house such as adding louvered doors and makeup air, should be consulted for a cost estimate.

6.2 Estimate Remediation Cost at Test-In

If the house fails at test-in due to appliance combustion or ambient CO level issues, a trained HVAC technician will be required to correct the problem before additional work can be performed, and that cost should be considered. If the house fails at test-in due to long spillage time, a contractor who can perform the remediation steps identified in Section 7.3 should be consulted to determine project cost. If the appliances are to be replaced, the house upgrade can proceed as long as an unsafe condition is not detected; see Section 3.2, Vent Testing.

6.3 Estimate Remediation Cost at Test-Out

If the house fails at test-out, due to appliance combustion or ambient CO level issues, a trained HVAC technician will be needed to correct the problem. If the house fails at test-out due to long spillage time, the remediation measures in Section 7.3 should be considered and a trained HVAC technician or contractor should be consulted to determine cost.

Again, if the remediation cost estimate exceeds the cost of replacing one or both appliances with direct vent appliances or an alternative, appliance replacement should be added to the list of measures to be performed on the home and the remediation step can be omitted if there are no other safety issues identified.

7 Perform Remediation Where Required

Once a cost estimate is complete and remediation has been determined as necessary, the next part of the upgrade process is to identify and implement any remediation required to address the failed combustion safety testing. Remediation is an advanced step that should only be conducted by an HVAC technician with proper training.

The goal of remediation is to ensure that:

1. Combustion gases from the appliances are exhausted to the outside through code-compliant vent systems.
2. Adequate combustion air is provided to the appliances.
3. The installation passes the test-in and test out requirements.

As indicated in earlier sections of this Measure Guideline, remediation can take place after the code compliance inspection, after test-in, after the upgrade, and after test-out.

7.1 Standard Method Remediation

If the volume of air for combustion and ventilation using the Standard Method is inadequate and makeup air has been provided, additional house air volume needs to freely communicate with the appliance(s). Common methods for increasing the volume of air include:

1. Installing louvers in doors that separate the appliances from other spaces in the house. Use the net free area calculation.
2. Providing transfer openings for return air from bedrooms and other areas separated by a door from a central return (see Florida Mechanical Code 2010, Section 601.3).
3. Adding combustion air openings to the outdoors.

As in Section 6.1, a contractor who can perform these modifications should be consulted to determine project cost. If the appliances are to be replaced, the natural draft appliance should be turned off and the house upgrade can proceed as long as an inrelated unsafe condition is not identified.

7.2 Known Air Infiltration Rate Method Remediation

If the volume of air for combustion and ventilation using the Known Air Infiltration Rate Method is inadequate, the ventilation air is insufficient for the Category I or draft hood-equipped appliances. Additional volume needs to freely communicate with the appliance as in Section 7.1.

7.3 Test-in Remediation

If the house fails at test-in due to appliance combustion or ambient CO level issues, a trained HVAC technician should correct the problem before additional work can be performed. If the house fails at test-in due to long spillage time, the remediation measures in Section 7.1 or Section 7.2 should be considered first.

Additional possible remediation measures to be considered at test-in include:

1. Install louvers in doors that separate the appliances from other spaces in the house or replace with full louvered doors.
2. Seal return air ducts passing through the space housing the appliance.
3. Seal supply duct leakage to outdoors to less than 6% of total system flow.
4. Replace high flow intermittent exhaust with low flow continuous exhaust meeting bathroom and kitchen requirements.
5. Provide additional jump ducts in the attic or crawlspace to balance internal operating pressures so the mechanical room changes less than 1 Pa to outside during HVAC operation.
6. Provide supply-only ventilation ducted to the air handler return sized for dryer makeup air and interlocked with the dryer.
7. Provide additional ducted returns direct to the air handler fan cabinet from spaces isolated from central returns. Increase the size of the central return filter grilles to reduce the face velocity to 300–500 ft/minute and reduce operating pressure on the return system.
8. Supply makeup air as required by the code (NFPA 54 Section 9.3.1.5). Off the shelf conditioned makeup air systems are now available for lower flows matching residential needs. Intermittent operation adds little to operating cost.
9. Convert from exhaust-only ventilation to balanced ventilation.
10. Add combustion air openings to the outdoors.
11. Provide an engineered solution, such as a powered vent.

Once a remediation path is chosen, a contractor who can perform these modifications should be consulted and remediation should take place before the upgrade is performed. If remediation is unsuccessful and the appliances are to be replaced, the house upgrade can proceed as long as an unrelated unsafe condition is not detected. Details on some of these remediation options are included in Section 7.5.

7.4 Test-Out Remediation

If the house fails at test-out due to appliance combustion or ambient CO level issues, a trained HVAC technician will be needed to correct the problem. If the house fails at test-out due to long spillage time, the remediation measures in Section 7.3 should be considered. Under no circumstances should the house be left in an unsafe condition after test-out.

7.5 Detail on a Sample of Remediation Options

A summary of the implementation details for several remediation options discussed above is provided after the numbered list below (see detailed list in Section 7.3):

1. Installing louvers in doors that separate the appliances from other spaces in the house
2. Sealing return air ducts passing through the space housing the appliance

3. Supplying makeup air as required by the code (NFPA 54 Section 9.3.1.5)
4. Adding combustion air openings to the outdoors
5. Converting from exhaust-only ventilation to balanced ventilation
6. Providing an engineered solution, such as a powered vent.

7.5.1 Installing Louvers in Doors That Separate the Appliances From Other Spaces in the House

Openings used to connect indoor spaces shall be sized as follows (NFPA 54 Section 9.3.2.3). Note that an open door is not considered an opening.

1. Combining spaces on the same story. Each opening shall have a minimum free area of 1 $in.^2$/1,000 Btu/h of the total input rating of all appliances in the space but not less than 100 in^2. One opening is required at the top and one at the bottom of the enclosure and the minimum dimension of either opening is 3 in.
2. Combining spaces on different stories. The volume of spaces on different stories shall be considered as communicating spaces where such spaces are connected by one or more openings in doors or floors having a total minimum free area of 2 $in.^2$/1,000 Btu/h of the total input rating of all the appliances.

The required size of the opening shall be based on the net free area of louvers or grilles covering the openings. Where the net free area is unknown, use 25% for wood louvers, 75% for metal louvers, and 75% for metal grilles. Louvers and grilles shall be fixed in the open position.

7.5.2 Sealing Return Air Ducts and the Furnace Cabinet

7.5.2.1 Seal Joints

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 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 manufacturer's required airflow without restriction. Furnace returns without the manufacturer's information must provide at least 2 $in.^2$ of total cross sectional area for every 1,000 Btu of output. (See Proctor and Chitwood 2011.)

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 UL181-M, or foil tapes meeting Underwriters Laboratories (UL) 181 A-P and UL 181 B-FX. Sealant foam approved for use as a firestop 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, or unconditioned attic. Line any enclosed support platform or building cavity 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.

7.5.2.2 Visual Inspection of Air Handler

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

7.5.2.3 Smoke Test of Duct and Cabinet Leakage in Appliance Area

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 nontoxic 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 place 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. There must be 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. For further information refer to the NREL Standard Work Specifications Tool (https://sws.nrel.gov/spec/316025).

7.5.3 Supplying Makeup Air as Required by the Code (NFPA 54 Section 9.3.1.5)

Where exhaust fans, clothes dryers, and kitchen ventilation fans interfere with the operation of appliances, makeup air is required. (See Section 7.5.4.)

7.5.4 Adding Combustion Air Openings to the Outdoors

Outdoor combustion air or a combination of indoor and outdoor combustion air is permitted by the code when openings are sized appropriately. The size of openings to the outdoors are based on appliance input and adjusted by the indoor volume communicating with the appliances. See NFPA 54 Sections 9.3.3 and 9.3.4.

7.5.5 Converting From Exhaust-Only Ventilation to Balanced Ventilation

In homes that employ exhaust-only ventilation, a balanced ventilation solution such as an air-to-air heat exchanger or enthalpy exchanger can be used. For purposes of combustion safety, a less costly option is to supply makeup air as in Section 7.5.3.

7.5.6 Providing an Engineered Solution

A professional engineer can perform an assessment of the installation and determine if a powered vent system or other approach can be used for remediation.

8 Materials for Duct Sealing

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

- Tapes for metal ductwork marked 181 A-P
- Mastic that meets 181 A-M
- Non-metallic flexible duct:
- Tape and clamping system
- Mastic that meets UL 181 B-M
- Mechanical fasteners labeled 181 B-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 International Code Council Evaluation Service report as meeting requirements of code, requires no additional sealants.
- Single component sealant foam: use material accepted as firestop in wood frame construction and approved for limited exposed use.

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