Thimbles are used to maintain required clearances and seal unwanted air leaks where vents run through ceilings or sidewalls. Roof jacks are used where vents penetrate the roof and contain a flue gas passageway, an insulating means, flashing, and a cap. Where the vent for a gas appliance is located in or passes through an attic, crawlspace, or other cold area, the vent shall be Type B or Type L and installed with no less than the listed clearance to combustible material.

Combustion Air

Air is needed to burn any fuel, including natural gas and propane. Sealed-combustion appliances draw combustion air from outside, but atmospheric units draw combustion air from the CAZ. When there is insufficient air, combustion is inefficient and dangerous. To supply sufficient combustion air for atmospheric units, the volume of space in which the combustion equipment is located must be 50 ft^3 per 1000 Btu/h of combined input for all combustion appliances in the space. In confined spaces where there is insufficient combustion air, the combustion appliance zone must be vented to outdoors or opened to a larger interior space. Such vents or grilles should have a minimum free area of 2 in^2 per 1000 Btu/h for all combustion equipment in the confined space. When opening the combustion appliance zone to a larger interior space, half of the grille area should be located within a foot of the top of the door or wall and the other half of the grille area should be within a foot of the floor. The minimum net free area of each vent or grille should be no less than 100 in^2.

Install a CO Monitor When a Combustion Appliance is Present

CO monitor should be installed when combustion appliances are present. Inspect heating, water heating, and cooking equipment to find if hazardous conditions exist. The CO monitor should be installed in the hallway near every separate sleeping area. Make sure the monitor is installed per manufacturer's instructions.

CO monitor should meet the requirements of UL-2034 or IAS 6-96. Exposure to a low concentration over several hours can be as dangerous as exposure to high carbon monoxide levels for a few minutes. It is recommended that both low-level and high-level CO monitors be installed.

When assessing a home, keep in mind the symptoms of CO poisoning. Many people with CO poisoning mistake their symptoms for the flu or are misdiagnosed by physicians. Initial symptoms include headache, fatigue, shortness of breath, nausea, and dizziness.

9 ppm is the maximum allowable concentration in a Living Area.

Grilles were added to the top and bottom of this water heater closet to open the confined space to the main body of the house and provide adequate combustion air for the water heater.

Tools & Equipment

- combustion analyzer
- gas leak detector
- digital manometer
- blower door
- lighter (w/ long handle)
- smoke bottle
- mirrors
- soap bubbles
- jumper wires
- high-temperature silicone
- ladder
- tape measure
- flashlights and lamps
- screwdrivers
- nut drivers
- self-tapping screws
- lag bolts or plugs
- tin snips
- crimper snips
- 3/8" drill and 5/16" drill bit
- cleaning equipment
- non-contact voltage detector
- chimney liners
- NFPA 54
- NFPA 31
- NFPA 211
- Weatherization Technical Program standards
- Weatherization field guide

The Hot Climate Initiative is a partnership between DOE and hot climate states to reduce energy costs for low-income persons by improving the energy efficiency of their homes while ensuring their health and safety. Drastic funding cuts in 1995 hit hot climate states hard, forcing substantial cutbacks in weatherization staff and services. Recent funding increases have allowed DOE to reinvigorate the Hot Climate Initiative to help hot-climate states adopt new weatherization practices. In 2011 this document was revised; the Acceptable Draft Readings table was updated in respect to Power Oil Burners based on numbers from the "Oilheat Technician's Manual," National Oilheat Research Alliance (NORA), 2002. p 108.

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U.S. DOE Hot Climate Initiative

COMBUSTION APPLIANCE SAFETY & EFFICIENCY TESTING

This technical brief summarizes the inspection and testing of combustion appliances taught during the whole-house weatherization training as part of the U.S. Department of Energy's Hot Climate Initiative. The materials provided during training contain more detailed information.

Combustion appliances such as furnaces, space heaters, and water heaters present potential health and safety hazards and should be inspected to ensure safe operation. The following inspection and test procedures will identify dangerous fuel leaks, the potential for carbon monoxide (CO) poisoning, and fire hazards.

What to Look for During Safety & Efficiency Inspections

Safe operation of combustion appliances requires a controlled fuel supply, sufficient combustion air, drafting of exhaust gases, and a properly configured vent and chimney system.

Check For Fuel Leaks

Use a calibrated gas leak detector at joints, fittings, and along pipes to determine if fuel is leaking. Natural gas is lighter than air so test above joints, fittings, and pipes. Propane or LPG is heavier than air so test below the connections. Use soap bubbles to confirm a leak since some types of pipe dope (joint sealant) may set off the detector.

Use a gas leak detector to locate any fuel leaks.

Measure Ambient Carbon Monoxide (CO)

Ambient CO levels should be monitored in the living space and the combustion appliance zone to ensure the safety of agency staff and weatherization contractors as well as occupants. **Remember to calibrate the combustion analyzer outside and measure outdoor baseline CO levels before the test to ensure the accuracy of CO readings.** If ambient CO levels exceed 9 parts per million (ppm), the house and combustion appliance zone should be ventilated before further testing and repair of the CO problem.

Unvented Space Heaters

Every weatherized house must have a vented heating system as the primary source of heat. Unvented space heaters shall be removed from the dwelling. In areas with frequent electrical power outages, it may be advisable to install vented space heaters capable of operating without electricity. If the customer refuses to give up the unvented space heater(s) and refuses the installation of a vented heated system, the house shall not be weatherized.

Unvented space heaters are not allowed in mobile homes. Unvented space heaters found in mobile homes shall be replaced with direct-vent models. Pollutants and moisture in exhaust combustion gases are released by unvented space heaters into conditioned space. Moisture in the combustion gases condenses on cold surfaces, sacrificing the mobile home's durability.

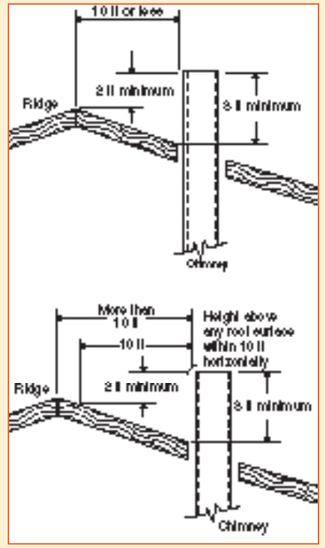
Direct-vent space heaters like this model manufactured by Monitor are good replacements for unvented space heaters.

Inspect the Vent and Chimney

The National Fire Protection Association's *National Fuel Gas Code (NFPA 54), Standard for the Implementation of Oil-Burning Equipment (NFPA 31),* and *Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel-Burning Appliances (NFPA 211)* should be reviewed to ensure that the vent and chimney are properly installed. NFPA 54 includes installation procedures for natural gas- and propane-fired appliances. NFPA 31 includes installation procedures for oil-fired appliances. NFPA 211 includes installation procedures for venting, chimneys, wood-burning stoves, and fireplaces. Check for proper vent type, size, and clearance. Look for sound condition and code-compliant installation.

Look for the obvious! A blocked chimney cannot vent combustion gases out of the house.

Horizontal vent runs must rise at least ¼ inch per foot of run. The vent on this oil-fired furnace violates code and will never draft properly.



Chimneys must be at least 2 feet higher than any portion of the building within 10 feet. B vent height may be less with a UL-listed cap.

- Chimneys and vents should be connected and unblocked.
- Plug any unused holes in the chimney or vent.
- Chimneys should have a sound liner or a new liner must be installed.
- Determine the cause of any corrosion in the vent system. Corrosion can be caused by condensing flue gases or by exterior water leaks. Inadequate or missing chimney flashing may mask signs of acidic condensation within an improperly designed or installed vent system.
- Horizontal runs of vent pipe must rise ¼" per linear foot in the direction of the outlet so that any condensate can run back to the combustion appliance.
- Masonry and metal chimneys should extend at least 3' above the highest point at which they pass through the roof of a building and at least 2' higher than any portion of the building within 10' (B vent height may be less per NFPA with a listed wind-rated cap).
- Make sure the vent has an appropriate vent cap.

Vents must be the appropriate type and size for the combustion appliances they serve. Site-specific circumstances will determine which vent type is appropriate (see table on inside of last page).

- Type B vent is double-wall pipe for gas- or propane-fired combustion appliances. An air gap between the pipes acts as an insulator. The inner vent pipe is aluminum and the outer is galvanized steel.
- Type BW vent is an oval B vent designed for wall furnaces.
- Type L vent is double-wall pipe for gas, propane, and oil-fired combustion appliances. This is much like Type B vent except the inner pipe is stainless steel. L vent is always used with oil-fire equipment while manufacturers may specify L vent for some gas- or propane-fired appliances.
- Due to their high temperatures, woodstoves require hardier vent systems (see table on inside of last page).
- Type PVC Schedule 40 pipe is used for 90+ condensing units.
- Mobile home furnaces and direct-vent space heaters are sealed combustion appliances that exhaust combustion gases and draw combustion air through the same double-wall vent system. Remember that mobile home furnaces must be specifically labeled for use in mobile homes.

Vents and vent connectors should be at least the same diameter as the exhaust port of the combustion appliance. Size the vent and vent connector using NFPA 54 or NFPA 31 based on the number and type of appliances, vent type, vent height, connector rise or lateral run, and the type of chimney.

Continued on inside of last page

The horizontal run cannot be more than 75% of the chimney height. If the horizontal run is more than 10', the diameter must be increased by one size (e.g. 3" to 4"). Because of their restriction to draft, 90° elbows are equivalent to 10' of horizontal run.

COMBUSTION APPLIANCE	MINIMUM ALLOWABLE VENT TYPE*	
	Conditioned Space	Unconditioned Space
Gas-Fired Forced-Air Furnace (natural gas or propane)	Single-Wall Galvanized, or B Vent	B Vent
Gas-Fired Vented Space Heater (natural gas or propane)		
Gas-Fired Water Heater (natural gas or propane)		
Oil-Fired Furnace, Boiler, or Water Heater	Single-Wall 24- or 26-gauge Steel, or L Vent	L Vent
Mobile Home Furnace	Special	Special
Direct-Vent Space Heater		
Condensing Forced-Air Furnace (90+ AFUE)		
Floor Furnace	N/A (entire vent system usually in unconditioned space)	Gas: B Vent
		Oil: L Vent
Gas-Fired Wall Furnace	Single-Wall Galvanized (although clearance usually dictates BW Vent)	BW Vent
Woodstove	Single-Wall 24-Gauge Black Steel, or Shielded Single-Wall (e.g., Super Six or Duravent)	Double-Wall Stainless with Insulation Between Walls (e.g., GSW or All-Fuel), Triple-Wall

*** There are flexible single- and double-wall venting systems that can be used in place of rigid vents. Install per manufacturer's instructions.**

Clearances are allowable distances between heat-producing appliances, chimneys, or vent systems and combustible surfaces. These vary for different combustion appliances and venting systems, and are listed in the tables below.

VENT CONNECTOR TYPE	CLEARANCES			
	Combustion Appliance Type	Without Protection	With Heat Shield	
			Wall	Ceiling
Single-Wall Galvanized	Vented gas space heaters Atmospheric gas furnaces and water heaters Fan-assisted-draft gas furnaces (80+ AFUE)	6"	2"	3"
	Oil furnaces, vented space heaters, boilers, and water heaters	18"	6"	9"
24 Gauge Steel (Black or Stainless)	Wood stoves	18"	6"	9"
B Vent (including BW)	Atmospheric gas furnaces and water heaters, Fan-assisted-draft gas furnaces (80+ AFUE)	Install per manufacturer's instructions (usually 1")		
L Vent	Oil furnaces, boilers, or water heaters	Install per manufacturer's instructions (usually 3")		

For atmospheric chimneys, combustion gases draft because they are more buoyant than air. The strength of the draft is affected by the chimney height, cross sectional area of the chimney, temperature difference between ambient air and combustion products, and wind. See ***Test Worst-Case Draft***.

CHIMNEY TYPE	Minimum Clearance from Combustible Surfaces
Interior chimney masonry with fireclay liner	2"
Exterior masonry chimney with fireclay liner	1"
All-fuel metal vent: insulated double-wall or triple-wall pipe	Install per manufacturer's instructions (usually 2" or less)

Test Cook Stove for CO:

1. Range-Top Burners: Hold probe of combustion analyzer 6" to 12" above each burner. The reading should max out and then stabilize after about two minutes. Each burner should read less than 25 ppm as measured.
2. Oven:
   a. Remove pots and pans.
   b. Check for aluminum foil in oven blocking combustion air holes. If found, remove before testing.
   c. Place probe from testing device well into exhaust vent of oven. This is usually a 1 x 5 inch hole near the back of the range top. This will give an undiluted sample of combustion gases.
   d. Set oven to bake at 500°F
   e. Measure for a minimum of 10 minutes and record CO level.
   f. While the ANSI standard for cook stove CO is 800 ppm air-free, a more appropriate action level for weatherization is 100 ppm as measured. The 800 ppm air-free is an outdated 1929 standard.

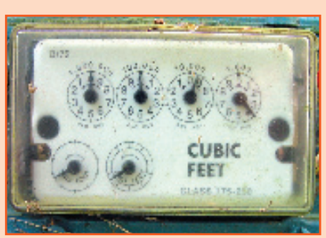
Dirt or rust prevents an even flame on this cook stove burner and causes CO to be produced. The gas openings were cleaned with a pipe cleaner to eliminate CO and allow an even, clean-burning flame.

Water Heaters:

1. Inspect the vent system for correct size, materials, and installation as described above.
2. If applicable, inspect the chimney into which the vent system is connected as described above.
3. Check CO levels as described in ***Measure Flue Gases for CO and Efficiency.***
4. If the water heater is located in a different area than the heating system, perform a worst-case draft test of the additional CAZ as described above.

Clock the Gas Meter

Clock the gas meter using the "Carl's Calibration" card provided during training to detect under-firing or over-firing. Clock only one appliance at a time. If the actual fuel input varies from the rated input on the furnace nameplate by more than ± 10% (± 5% for 90+ condensing units), refer the unit to a HVAC technician for inspection and repair to adjust gas pressure to acceptable levels (3.5 inches of water column for natural gas and 11 inches of water column for propane).



Most gas meters have 5 or 6 dials. Clock the dial that spins the fastest, which is the one labeled ½ or 1 cubic foot.

Seconds for one revolution of the dial	METER DIAL Consumption per Revolution		
	1/2 Cu. Ft.	1 Cu. Ft.	2 Cu. Ft.
	Thousand Btu/hr @ 1,000 Btu/Cu.Ft.		
15	120	240	480
20	90	180	360
25	72	144	288
30	60	120	240
35	51	103	206
40	45	90	180
45	40	80	160
50	36	72	144
55	33	65	131
60	30	60	120
70	26	51	103
80	22	45	90
90	20	40	80
120	15	30	60
150	12	24	48
180	10	20	40

HOW TO COMPLETE SAFETY & EFFICIENCY INSPECTIONS

Inspect and Clean the Heat Exchanger:

1. Clean the heat exchanger with a brush and vacuum cleaner to remove soot and debris.
2. Re-inspect the heat exchanger using a flashlight and a mirror to determine whether cracks or holes are present.
3. If cracks or holes are found, replace the heat exchanger if a new one can be found, or refer the unit for replacement. If the unit is more than 10 years old, replace the entire unit instead of just the cracked heat exchanger.

Measure Flue Gases for CO and Efficiency:

1. Start the heating unit. Allow it to reach "steady state," a condition that exists when the stack temperature stops rising more than 2° in one minute.
2. Insert the probe into the heat exchanger ports (see figures on next page) of the furnace, taking a complete set of readings in each port. For a water heater, insert the combustion analyzer probe down into the water heater before the draft diverter and take readings on both sides of the baffle.
3. Check the table below to determine if the heating unit is within acceptable ranges. Note: Unvented space heaters may remain only if they are secondary heat sources that conform to ANSI Z.21.11.2.
4. If CO exceeds acceptable levels:
   a. Verify that the vent system is allowing sufficient draft as described in ***Test Worst-Case Draft.***
   b. Verify that the gas pressure is within an acceptable range by measuring the gass pressure or clocking the gas meter (natural gas only, see ***Clock the Gas Meter***).
   c. Adjust the primary and/or secondary air on the gas burners as described below to reduce CO to acceptable levels.
5. If step 4 does not reduce CO to acceptable levels, refer the heating system for replacement as a health and safety measure.
6. Measure the efficiency in each combustion port.

To measure CO in this floor furnace, the probe (not shown) is placed in each of the combustion ports. The draft probe is inserted in the vent as shown.

APPLIANCE	Suggested CO Action Level	ANSI Standard for CO
Gas furnace, boiler, or water heater	100 ppm, as measured (200 ppm, air free)	400 ppm, air-free
Unvented gas space heater	200 ppm, air-free	200 ppm, air-free
Oil-fired furnace, boiler, or water heater	100 ppm, as measured	200 ppm, as measured
Gas cook stove: Range-top burner	25 ppm, as measured	800 ppm, air-free *(1929 standard)*
Gas cook stove: Oven	100 ppm, as measured	800 ppm, air-free *(1929 standard)*

Clean Gas Burners:

1. Clean gas burners of dirt and rust.
2. Adjust primary and/or secondary air and the gas pressure so that the unit is within the acceptable CO and efficiency levels.
3. Other tune-up and repair items, such as fuel pressure (see ***Clock the Gas Meter***) and draft adjustments may have to be performed prior to completing air adjustments.

Test the Safety Controls:

1. Test the Gas Valve (if the unit has a standing pilot): Blow out the pilot light. Listen for a click to indicate that the gas valve solenoid has closed. It should close within two and a half minutes. Verify this with a combustible gas leak detector. If it does not, the gas valve is faulty and should be replaced.
2. Test the High-Limit Switch:
   a. Turn the power off. Remove the blower belt or disconnect one of the electrical leads to the blower motor. Tape lead to prevent shock or short circuit.
   b. Insert a thermometer immediately above the heat exchanger on the distribution side.
   c. Turn power on.
   d. Give a call for heat by turning up the thermostat (or by disconnecting one leg of the thermostat and placing a jumper wire from Tl to T2 at the gas valve if it is a very hot day or if the thermostat is broken). Make sure the high-limit setting on the limit control is set to a maximum of 200ºF.
   e. Listen for the combustion being shut down as the heat exchanger area heats up beyond the limit control setting, signaling the limit control to close the gas valve.
   f. If this does not occur at the temperature setting, the limit control is faulty and must be replaced.
   g. Turn power off.
   h. Reconnect the thermostat and/or blower motor. Turn the power on.
   i. Cycle the unit to ensure correct operation of the furnace.

Test Worst-Case Draft:

A worst-case draft test should be performed before and after weatherization to ensure that combustion products are exhausted from the living space. If weatherization work takes more than one day, a worst-case draft test should be performed at the end of each workday to ensure the house is left in a safe condition. During the test, the combustion appliance zone is depressurized "naturally" (not with a blower door) to determine if the chimney/vent can exhaust combustion products in conditions that most impede draft. If multiple combustion appliances exist, start with the lowest BTU appliance and work up.

1. Measure and record the outdoor temperature. Deactivate combustion appliances and exhaust fans. Check and clean the dryer lint filter and vent. Replace or clean furnace filter if needed.
2. Close all windows and exterior doors. Open all interior doors. Measure the pressure difference of the combustion appliance zone (CAZ) with respect to the outdoors using a manometer. This is the baseline pressure that should be subtracted from all other CAZ readings.
3. Turn on all exhaust fans such as bathroom or kitchen fans and the clothes dryer. Do NOT turn on the whole-house fan. Measure the pressure difference of the CAZ with respect to outdoors.
4. Close all interior doors except those to rooms with exhaust fans and again measure the pressure difference of the CAZ with respect to outdoors.

HEATING UNIT TYPE & VENTING SYSTEM TYPE	Acceptable Draft Reading for Worst Case Draft Test at Listed Outdoor Temperatures (ºF)				
	<20	21-40	41-60	61-80	>80
Gas Furnace or Water Heater with a Natural Draft Chimney	-5 Pa -0.020" wc	-4 Pa -0.016" wc	-3 Pa -0.012" wc	-2 Pa -0.008" wc	-1 Pa -0.004" wc
	Acceptable Draft Readings for Worst Case Draft Test Overfire and at Breech (at any outdoor temperature)				
Power Oil Burners - Overfire Draft	-0.020" wc or -5 Pa				
Power Oil Burners - Vent Connector or Breech	-0.040 to -0.060" wc or -10 to -5 Pa				

WARNING: Ambient CO levels should be monitored in the combustion appliance zone during draft testing, especially if depressurization of the combustion zone exceeds –5 Pascals during house depressurization testing. If ambient CO levels in the combustion zone exceeds 20 parts per million (ppm), the draft test should cease for the technician's safety. The combustion zone should be ventilated before testing and repair of CO problems resumes.

5. Close the door to the furnace room. Measure the pressure difference of the CAZ with respect to outdoors.
6. If a furnace is present, turn the air handler on. Measure the pressure difference of the CAZ with respect to outdoors.
7. Open and close interior doors (including door to CAZ) to induce the most negative CAZ pressure. Check interior doors using a smoke puffer. If smoke enters the room from the main body of the house, open the interior door. If air from the room blows smoke back into the main body of the house, close the interior door.
8. If the draft in the combustion appliance vent is less negative than the limit indicated in the table above (or positive), the vented combustion appliance is susceptible to extended periods of induced spillage and/or back drafting when exhaust devices are in operation.
9. One or more of the following activities may increase inadequate draft or reduce excessive depressurization to acceptable levels:
   a. Repair chimney obstructions, disconnections, or leaks;
   b. Properly size vent, connector, and liner;
   c. Install a metal chimney liner and/or a wind-rated chimney cap;
   d. Seal leaks in the return ducts in the CAZ;
   e. Balance supply and return air by adding new returns, or by adding passive returns (air openings to the main body of the house);
   f. Reduce capacity of large exhaust fans;
   g. Provide make-up air for dryers and exhaust fans; and/or;
   h. Provide combustion-air inlet to CAZ.
10. Ensure that repairs allow adequate draft by recreating worst-case CAZ conditions and retesting.
11. Return dwelling, exhaust fans, and combustion appliances to normal settings.