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 I, 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 at least 30 ft³ 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 in² 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 1 in².

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 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.

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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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.

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, saturating the mobile home’s durability.

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
- Lag bolts or plugs
- 3/8” drill bit
- 1/8” drill bit
- Cleaning equipment
- Non-contact voltage detector
- Chimney liners
- NFPA 54
- NFPA 31
- NFPA 211
- Weatherization Technical Program standards
- Weatherization field guide

Use a gas leak detector to check any fuel leaks.
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.

- 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 at least 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 harder 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. Select 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.

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

<table>
<thead>
<tr>
<th>MINIMUM ALLOWABLE VENT TYPE*</th>
<th>Conditioned Space</th>
<th>Unconditioned Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas-Fired Forced-Air Furnace (natural gas or propane)</td>
<td>Single-Wall Galvanized, or B Vent</td>
<td>B Vent</td>
</tr>
<tr>
<td>Gas-Fired Vented Space Heater (natural gas or propane)</td>
<td>Gas Furnace, or Furnace</td>
<td>L Vent</td>
</tr>
<tr>
<td>Gas-Fired Water Heater (natural gas or propane)</td>
<td>Oil Furnace, or Boiler</td>
<td>Special</td>
</tr>
<tr>
<td>Oil-Fired Furnace, Boiler, or Water Heater</td>
<td>Single-Wall 24- or 26-gauge Steel, or L Vent</td>
<td>Special</td>
</tr>
<tr>
<td>Mobile Home Furnace</td>
<td>Direct-Vent Space Heater</td>
<td>Special</td>
</tr>
<tr>
<td>Condensing Forced-Air Furnace (90+ AFUE)</td>
<td>Condensing Forced-Air Furnace</td>
<td>Condensing Space Heater</td>
</tr>
</tbody>
</table>

* 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 table below.

### VENT CONNECTOR TYPE

| CLEARANCES |
|-----------------|-----------------|-----------------|
| CHIMNEY TYPE | Minimum Clearance from Combustible Surfaces |
| Single-Wall Galvanized | Vented gas space heaters | Atmospheric gas furnaces and air heaters | Fan-assisted-draft gas furnaces (80+ AFUE) | 6” | 2” | 3” |
| 24 Gauge Steel (Black or Stainless) | Oil furnaces, vented space heaters, boilers, and water heaters | Fan-assisted-draft gas furnaces (80+ AFUE) | 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.
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-Cut Draft.
   b. Verify that the gas pressure is within an acceptable range by measuring the gas 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.

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 T1 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 209°F.
   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 Drafts:

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.
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.
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. 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.
10. Insert a thermometer immediately above the heat
    exchanger on the distribution side.
11. Turn power on.
12. Give a call for heat by turning up the thermostat
    (or by disconnecting one leg of the thermostat and
    placing a jumper wire from T1 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 209°F.
13. 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.
14. If this does not occur at the temperature setting, the
    limit control is faulty and must be replaced.
15. Turn power off.
16. Reconnect the thermostat and/or blower motor. Turn
    the power on.
17. Cycle the unit to ensure correct operation of the
    furnace.

### HEATING UNIT TYPE & VENTING SYSTEM TYPE

| Acceptable Draft Reading for Worst Case Draft Test at Listed Outdoor Temperatures (°F) |
|---|---|---|---|---|
| <20 | 21-40 | 41-60 | 61-80 | >80 |
| Gas Furnace or Water Heater with a Natural Draft Chimney | -5 Pa | -4 Pa | -3 Pa | -2 Pa | -1 Pa |
| Power Oil Burners - Overfire Draft | -0.020” wc | -0.016” wc | -0.012” wc | -0.008” wc | -0.004” wc |
| Power Oil Burners - Vent Connector or Breech | -0.040 to -0.060” wc | -0.010 to -0.050” wc | -0.010 to -0.050” wc | -0.010 to -0.050” wc |

**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 exceed 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.

- 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.