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 combined space in which the combustion equipment is located must be 5 ft³ per 1000 Btu/h of combined output 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 for all combustion appliances in the 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 in².

Install a CO Monitor When a Combustion Appliance is Present

CO monitors 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.

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. Direct technical 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 states adopt new weatherization practices.

Direct technical questions to:

- Anthony Cox, New River Center for Energy Research and Training, (540) 381-9446 x303
- John Langford, J&J Weatherization, (434) 847-5487
- Alex Moore, SMS Results, (703) 938-0021
- R.W. Davis (technical reviewer), Energy Conservation Services Group, (740) 664-5108
Inspect the Vent and Chimney

The National Fire Protection Association’s National Fuel Gas Code (NFPA 54), Standard for the Installation 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 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-firing 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. 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.

<table>
<thead>
<tr>
<th>CHIMNEY TYPE</th>
<th>Minimum Clearance from Combustible Surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior chimney masonry with fireclay liner</td>
<td>2&quot;</td>
</tr>
<tr>
<td>Exterior masonry chimney with fireclay liner</td>
<td>1&quot;</td>
</tr>
<tr>
<td>All-fuel metal vent insulated double-wall or triple-wall pipe</td>
<td>Install per manufacturer’s instructions (usually 2&quot; or less)</td>
</tr>
</tbody>
</table>

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.

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 Table Worst-Case Draft.
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).

Dirt or rust presents 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.

Clock the Gas Meter

<table>
<thead>
<tr>
<th>SIZE OF THE METER DIAL</th>
<th>1/2 Cu. Ft.</th>
<th>1 Cu. Ft.</th>
<th>2 Cu. Ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thousand Btu/hr @ 1,000 Btu/Cu.Ft.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>120</td>
<td>240</td>
<td>480</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
<td>180</td>
<td>360</td>
</tr>
<tr>
<td>25</td>
<td>72</td>
<td>144</td>
<td>288</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>120</td>
<td>240</td>
</tr>
<tr>
<td>35</td>
<td>51</td>
<td>103</td>
<td>206</td>
</tr>
<tr>
<td>40</td>
<td>45</td>
<td>90</td>
<td>180</td>
</tr>
<tr>
<td>45</td>
<td>40</td>
<td>80</td>
<td>160</td>
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<tr>
<td>50</td>
<td>36</td>
<td>72</td>
<td>144</td>
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<tr>
<td>55</td>
<td>33</td>
<td>65</td>
<td>131</td>
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<tr>
<td>60</td>
<td>30</td>
<td>60</td>
<td>120</td>
</tr>
<tr>
<td>65</td>
<td>26</td>
<td>51</td>
<td>103</td>
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<td>70</td>
<td>22</td>
<td>45</td>
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<td>75</td>
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<td>15</td>
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<td>85</td>
<td>12</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>20</td>
<td>40</td>
</tr>
</tbody>
</table>

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.

HOW TO COMPLETE SAFETY & EFFICIENCY INSPECTIONS

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 unaided 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.

3. Inspect and Clean the Heat Exchanger:
   a. Clean the heat exchanger with a brush and vacuum cleaner to remove soot and debris.
   b. Verify that the gas pressure is within an acceptable range by measuring the gas pressure or clocking the gas meter.
   c. Adjust the primary and/or secondary air on the gas burners as described below to reduce CO to acceptable levels.
   d. If the unit is more than 10 years old, replace the entire unit instead of just the cracked heat exchanger.

4. Measure Flue Gases for CO and Efficiency:
   a. Start the heating unit. Allow it to reach “steady state,” a condition that exists when the stack temperature stops rising more than 2º in one minute.
   b. 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.
   c. Inspect the vent system for correct size, materials, and installation as described above.
   d. Set oven to bake at 500°F
   e. Measure for a minimum of 10 minutes and record CO level.
   f. If cracks or holes are found, replace the heat exchanger if a new one can be found, or refer the unit for replacement.
   g. Re-inspect the heat exchanger using a flashlight and a mirror to determine whether cracks or holes are present.

5. Measure CO levels as described in Test Worst-Case Draft.

6. Water Heaters:
   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 unaided 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.

7. Water Heaters:
   a. Inspect the vent system for correct size, materials, and installation as described above.
   b. Inspect the vent system for correct size, materials, and installation as described above.
   c. Inspect and Clean the Heat Exchanger:
   d. Check the table below to determine if the heating unit is within acceptable ranges.
   e. If CO exceeds acceptable levels:
      i. Clock the Gas Meter
      ii. Verify that the vent system is allowing sufficient draft as described in Test Worst-Case Draft
      iii. Clean gas burners of dirt and rust.
      iv. Adjust primary and/or secondary air on the gas burners as described below to reduce CO to acceptable levels.
      v. If step 4 does not reduce CO to acceptable levels, refer the heating system for replacement as a health and safety measure.
   f. Measure the efficiency in each combustion port.

<table>
<thead>
<tr>
<th>APPLIANCE</th>
<th>Suggested CO Action Level</th>
<th>ANSI Standard for CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas furnace, boiler, or water heater</td>
<td>100 ppm, as measured</td>
<td>400 ppm, air-free</td>
</tr>
<tr>
<td>Untvented gas space heater</td>
<td>200 ppm, air-free</td>
<td>200 ppm, air-free</td>
</tr>
<tr>
<td>Oil-fired furnace, boiler, or water heater</td>
<td>100 ppm, as measured</td>
<td>200 ppm, as measured</td>
</tr>
<tr>
<td>Gas cook stove: Range-top burner</td>
<td>25 ppm, as measured</td>
<td>800 ppm, air-free</td>
</tr>
<tr>
<td>Gas cook stove: Oven</td>
<td>100 ppm, as measured</td>
<td>800 ppm, air-free</td>
</tr>
</tbody>
</table>

8. Clean Gas Burners:
   a. Clean gas burners of dirt and rust.
   b. Adjust primary and/or secondary air and the gas pressure so that the unit is within the acceptable CO and efficiency levels.
   c. 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 area heats up beyond the limit control set to a maximum of 200°F.
   - c. Turn the power on.
   - d. Give a call for heat by turning up the thermostat if it is a very hot day or if the thermostat is broken).
   - e. Listen for the combustion being shut down as the limit control is faulty and must be replaced.
   - f. If this does not occur at the temperature setting, signaling the limit control to close the gas valve.
   - g. Turn power off.
   - h. Reconnect the thermostat and/or blower motor. Turn the power on.

### 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.

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 all exhaust fans and again 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. 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.

### HEATING UNIT TYPE & VENTING SYSTEM TYPE

<table>
<thead>
<tr>
<th>Acceptable Draft Reading for Worst Case Draft Test at Listed Outdoor Temperatures (F)</th>
<th>&lt;20</th>
<th>21-40</th>
<th>41-60</th>
<th>61-80</th>
<th>&gt;80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Furnace or Water Heater with an Atmospheric Chimney</td>
<td>-5 Pa</td>
<td>-4 Pa</td>
<td>-3 Pa</td>
<td>-2 Pa</td>
<td>-1 Pa</td>
</tr>
<tr>
<td>-0.020&quot; wc</td>
<td>-0.016&quot; wc</td>
<td>-0.012&quot; wc</td>
<td>-0.008&quot; wc</td>
<td>-0.004&quot; wc</td>
<td></td>
</tr>
<tr>
<td>Oil Burner</td>
<td>-15 Pa</td>
<td>-13 Pa</td>
<td>-11 Pa</td>
<td>-9 Pa</td>
<td>-7 Pa</td>
</tr>
<tr>
<td>-0.06&quot; wc</td>
<td>-0.053&quot; wc</td>
<td>-0.045&quot; wc</td>
<td>-0.038&quot; wc</td>
<td>-0.030&quot; wc</td>
<td></td>
</tr>
</tbody>
</table>

### WARNING:

Ambient CO levels should be monitored in the combustion appliance zone during draft testing, especially if depressurization of the combustion zone exceeds -5 Pa when the combustion zone exceeds 20 Pa. The draft test should cease for the technician’s safety. The combustion zone should be ventilated before testing and repair of CO problems resumes.

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