**Table 8-5: Carbon Monoxide Causes and Solutions**

| Cause | Analysis & Solution |
|---|---|
| Flame smothered by combustion gases. | Chimney backdrafting from CAZ depressurization or chimney blockage. |
| Burner or pilot flame impinges. | Align burner or pilot burner. Reduce gas pressure if excessive. |
| Inadequate combustion air with too rich fuel-air mixture. | $O_2$ is <6%. Gas input is excessive or combustion air is lacking. Reduce gas or add combustion air. |
| Blower interferes with flame. | Inspect heat exchanger. Replace furnace or heat exchanger. |
| Primary air shutter closed. | Open primary air shutter. |
| Dirt and debris on burner. | Clean burners. |
| Excessive combustion air cooling flame. | $O_2$ is >10%. Increase gas pressure. |

## 8.5 Heating System Replacement

This section discusses replacing combustion furnaces and boil-ers. We'll also discuss gas heating-replacement and oil-heating-replacement specifications.

### 8.5.1 Combustion Furnace Replacement

*SWS Detail: 5.0108.4 Furnaces; 5.0108 Equipment Installation 5.8801 Equipment Removal; 5.0104 Duct Installation; 5.0104 Duct Installation; 5.0105 Duct Repair; 5.0106 Duct Sealing; 5.0504.1 Natural Gas/Propane Fuel Piping*

This section discusses air handlers of combustion furnaces and also heat pumps. Successful air-handler replacement requires selecting the right heat (and cooling) input, blower model, and

blower speed. The installation must include repairs to ducts and other remaining components, and testing to verify that the new air handler operates correctly.

### Preparation

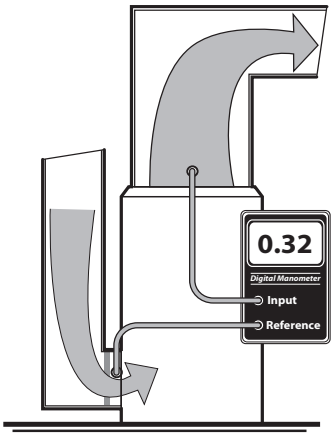
- ✓ Recover refrigeration in the existing heating-cooling unit according to EPA regulations.
- ✓ Disconnect and remove the furnace or heat pump, attached air-conditioning equipment, and other materials that won't be reused.
- ✓ Transport these materials off the client's property to a recycling facility.
- ✓ Verify that all accessible ducts were sealed as part of the furnace's installation, including the air handler, the plenums, and the branch ducts.

### Equipment Selection

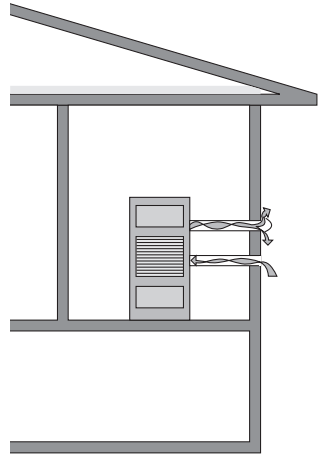
- ✓ Evaluate the building to determine the correct size of the furnace, using ACCA Manual J or equivalent method. Select the smallest BTUH output furnace that your preferred manufacturer offers and that exceeds your heat loss calculation.
- ✓ Select the air handler using ACCA Manual S or equivalent method along with manufacturers' air-handler specifications. Consider blower airflow requirements for air conditioning if there is existing central air conditioning.
- ✓ Select the most energy efficient blower available. Prefer electrically commutated motors (ECM) when possible.
- ✓ Select the supply and return registers using ACCA Manual T or equivalent method.

## Air-Handler Installation

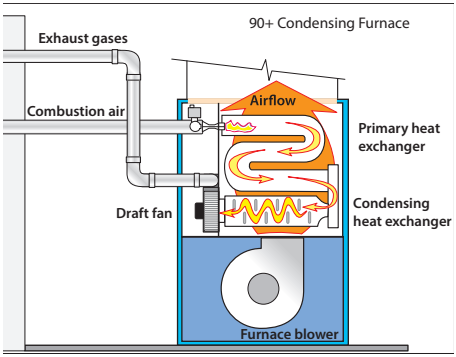
- ✓ Install MERV 6 or higher filter inside or outside of the new furnace.
- ✓ The filter must be easy to replace.
- ✓ The filter retainer must hold the filter firmly in place.
- ✓ The filter must provide complete coverage of blower intake or return grille. The filter compartment must not permit air to bypass the filter.
- ✓ If flue-gas temperature or supply air temperature are unusually high, check static pressure and fuel input.
- ✓ Attach the manufacturer's literature including, operating manual and service manual, to the furnace.



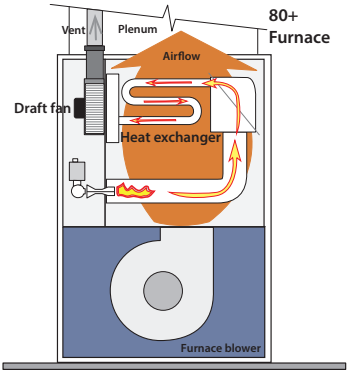

**Static pressure and temperature rise:** Measure static pressure and temperature rise across the new furnace to verify that the duct system isn't restricted. The correct airflow, specified by the manufacturer, is necessary for high efficiency.



**Sealed combustion heaters:** Sealed-combustion furnaces prevent the air pollution and house depressurization caused by some open-combustion furnaces.




**90+ Gas furnace:** A 90+ furnace has a condensing heat exchanger and a stronger draft fan for pulling combustion gases through its more restrictive heat exchanger and establishing a strong positive draft.




**80+ Gas furnace:** An 80+ furnace has a restrictive heat exchanger and draft fan, but has no draft diverter and no standing pilot light.

### Supporting Air Handlers

Support the new air handlers using these specifications.

- Support horizontal air handlers from below with a non-combustible, water-proof, and non-wicking material. Or support the horizontal air handler with angle iron and threaded rod from above.
- Support upflow air handlers with corner support legs, bricks, or pads from below when necessary to hold it above a damp basement floor.
- Support downflow air handlers with a strong, airtight supply plenum. Insulate this supply plenum on the exterior of the plenum.

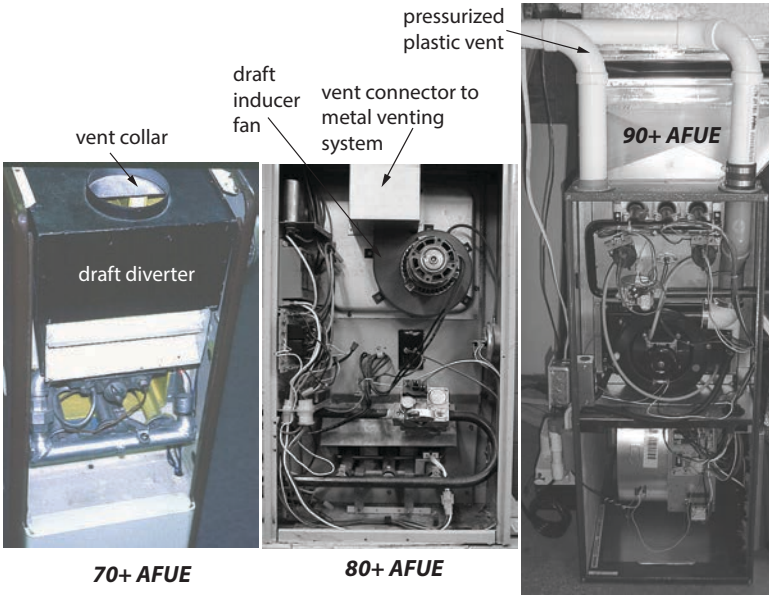
## 8.5.2 Gas-Fired Heating Installation

*SWS Detail: 5.0108 Equipment Installation; 5.0203 Equipment Installation 5.0108.4 Furnaces; 5.0203.1 Boilers; 5.8801 Equipment Removal; 5.0504.1 Natural Gas/Propane Fuel Piping*

The goals of gas-appliance replacement are to save energy and improve heating safety. The heating replacement project should produce a gas-fired heating system in virtually new condition, even though existing components like the gas lines, chimney, pipes, or wiring may remain.

Include maintenance or repair of existing components as part of the installation. Analyze design defects in the original system, and correct the defects during the heating system's replacement.

- ✓ If possible, install a condensing sealed-combustion (direct vent) furnace or boiler with a 90+ AFUE.
- ✓ Install non-condensing furnaces and boilers with a minimum AFUE of 80%, if the 90% replacement unit isn't cost-effective or practical.
- ✓ Install new gas-fired unit with adequate clearances to allow maintenance.
- ✓ Follow manufacturer's venting instructions along with the National Fuel Gas Code (NFPA 54) to install a proper venting system. *See "Inspecting Venting Systems" on page 332.*
- ✓ Check clearances of the heating unit and its vent connector to nearby combustibles, according to NFPA 54. *See page 332.*
- ✓ Measure the new unit's gas input, and adjust the gas input if necessary.




**Gas furnace evolution:** Energy auditors should be able to identify the 3 types of gas and propane furnaces. Only the 90+ AFUE furnace has a pressurized vent. The two earlier models vent into traditional natural-draft chimneys.

## Testing New Gas-Fired Heating Systems

- ✓ Do a combustion test, and adjust fuel-air mixture to minimize $O_2$. However don't allow CO beyond 200 ppm as measured or 400 ppm air-free with this adjustment. *See pages 280 and 317.*
- ✓ Verify that the gas water heater vents properly after installation of a sealed-combustion or horizontally vented furnace or boiler. Install a chimney liner if necessary to provide right-sized venting for the water heater.

## 8.5.3 Combustion Boiler Replacement

*SWS Details: 5.0203.1 Boilers; 5.0202 Distribution; 5.0288.1 Boiler Room Water Drainage; 5.0204.1 Fuel-Fired Boilers; 5.8801 Equipment Removal; 5.0504.1 Natural Gas/Propane Fuel Piping*

Technicians replace boilers as an energy-conservation measure or for health and safety reasons.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving features. Dividing homes into zones, with separate thermostats, can significantly improve energy efficiency compared to operating a single zone.

Follow these specifications when recommending a replacement boiler.

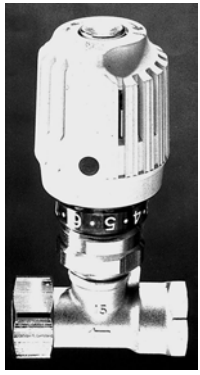
### Boiler Design

A boiler's seasonal efficiency is more sensitive to correct sizing than is a furnace's efficiency.

- ✓ Consider weatherization work that reduced the heating load serviced by the previous boiler when sizing the new boiler.
- ✓ Determine the correct size of the boiler. Use ACCA Manual J or Manual N.
- ✓ Use the current version of ANSI/ACCA Manual S or Manual CS or equivalent procedures to select the boiler.
- ✓ Along with calculations from these manuals, consider the total installed radiation surface area connected to the boiler and also the radiator sizes in individual rooms.
- ✓ Select heating equipment of the lowest capacity required to meet the design heating load, and provide sufficient vol-

ume for components of the existing distribution system that remains in place.

- ✓ Size new radiators according to room heat loss and design water temperature.
- ✓ Select a boiler that is ENERGY STAR® certified or equivalent.
- ✓ Install unit in a dry location and within conditioned space when possible.
- ✓ Provide ease of access for routine maintenance/service on all system components requiring maintenance or service.



**Radiator temperature control:** RTCs work well for controlling room temperature, especially in overheated rooms.

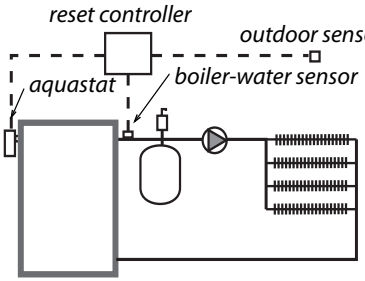
## Pump and Piping

- ✓ Verify a functioning pressure-relief valve, expansion tank, air-excluding device, back-flow preventer, and an automatic fill valve must be part of the new hydronic system.
- ✓ Verify that all supply piping is insulated with foam or fiberglass pipe insulation.
- ✓ Suggest that the pump be installed near the downstream side of the expansion tank to prevent the suction side of the pump from depressurizing the piping, which can pull air into the piping system.

- ✓ Replace the expansion tank, unless it's the proper size for the new system. Adjust the expansion tank for the correct pressure during boiler installation. *See page 384.*
- ✓ Extend new piping and radiators to conditioned areas, like additions and finished basements, which are currently heated by space heaters.

## Controls

- ✓ Maintaining a low-limit boiler-water temperature is wasteful. Boilers should be controlled for a cold start, unless the boiler is used for domestic water heating.
- ✓ For large boilers, install reset controllers that adjust supply water temperature according to outdoor temperature and prevent the boiler from firing when the outdoor temperature is above a setpoint where heat isn't needed.




**Reset controller:** This control adjusts circulating-water temperature depending on the outdoor temperature.

- ✓ Verify that return-water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation within the boiler, unless the boiler is designed for condensation. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies, as necessary, to prevent condensation within a non-condensing boiler.
- ✓ Specify radiator temperature controls (RTCs) for areas with a history of overheating.

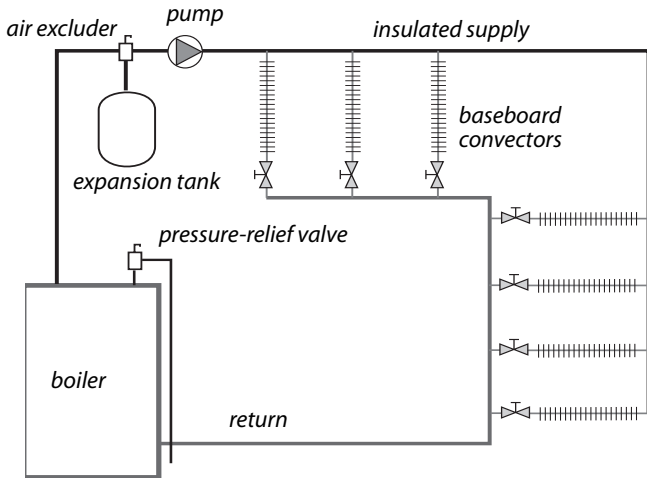
## Combustion Testing

- ✓ Inspect the chimney and upgrade it if necessary.

✓ Verify that flue-gas oxygen and temperature are within the ranges specified in these two tables.

a. *"Combustion Standards for Gas Furnaces and Boilers" on page 300*

b. *"Minimum Oil Burner Combustion Standards" on page 323*




**Simple reverse-return hot-water system:** The reverse-return method of piping is the simplest way of balancing flow among the heat emitters.

## Steam Boilers

Steam-boiler performance is heavily dependent on the performance of the existing steam distribution system. The boiler installer should know how the distribution system performed when it was connected to the old boiler.

The new boiler's water line should be at the same height as the old boiler's water line, or the installers should know how to compensate for the difference in water-line levels.

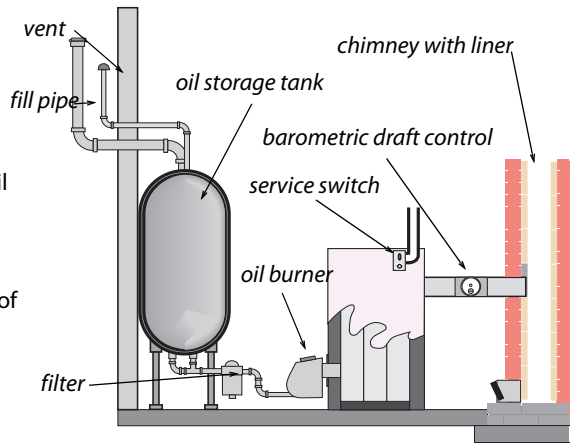
## 8.5.4 Oil-Fired Heating Installation

*SWS Detail: 5.0504.2 Oil Piping; 5.0108 Equipment Installation; 5.0203 Equipment Installation 5.0108.4 Furnaces; 5.0203.1 Boilers; 5.8801 Equipment Removal*

Oil-heating replacement should provide an oil-fired heating system in virtually new condition, even though components like the oil tank, chimney, piping, and wiring may remain in place.

Any maintenance or repair for these remaining components should be part of the replacement job. Analyze design defects of the original system, and correct them during the heating-system replacement.

- ✓ New oil-fired furnaces and boilers should have a minimum AFUE of 83%.
- ✓ Install new oil-fired furnaces and boilers with adequate clearances to facilitate maintenance.
- ✓ Inspect the existing chimney and the vent connector. Replace the vent connector with Type L double-wall vent pipe if necessary.
- ✓ Install a stainless steel chimney liner if necessary. *See "Special Venting Considerations for Gas" on page 342.*




**Oil heating system:** Components of an oil heating system may need replacement, repair, or cleaning during replacement of the furnace or boiler.

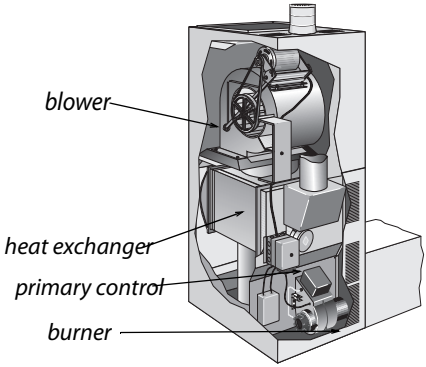
- ✓ Verify that the clearances between the vent connector and nearby combustibles are adequate.
- ✓ Install a new fuel filter, and purge the fuel lines as part of the new installation.

## Controls

- ✓ Verify that a working emergency shut-off is installed in the living space.
- ✓ Look for a control that interrupts power to the burner in the event of a fire.
- ✓ Measure the transformer voltage to verify that it complies with the manufacturer's specifications.
- ✓ Measure the control circuit amperage, and adjust the thermostat's heat anticipator to match the amperage. Or, follow the thermostat manufacturer's instructions for adjusting cycle length.

## Testing New Oil-Fired Heating Systems

- ✓ Verify that the oil pressure matches the manufacturer's specifications, but isn't less than 100 psi.
- ✓ If the flue-gas temperature is too high, adjust oil pressure per manufacturers instructions or replace nozzle as necessary to produce the correct input and flue-gas temperature.




**Oil-fired downflow furnaces:** Their design hasn't changed much in recent years except for the flame-retention burner.

- ✓ Verify that the spray angle and spray pattern fit the size and shape of the combustion chamber.
- ✓ Adjust oxygen, flue-gas temperature, and smoke number to match manufacturer's specifications or specifications given here. Smoke number should be zero on all modern oil-fired equipment.

## 8.5.5 Evaluating Oil Tanks

*SWS Detail: 5.0504.2 Oil Piping*

Inspect the oil tank, and remove dirt and moisture at bottom of the tank. Verify that the oil tank and oil lines comply with NFPA 31.

Oil tanks are now almost always installed above ground. But many old oil tanks are still buried. Inspect above-ground tanks to find leaks.

Below-ground tanks and above-ground tanks can both be evaluated by tests for water in the fuel system.

1. Start by inspecting the oil filter for corrosion. Corrosion in the oil filter indicates a high probability of water and corrosion in the tank.

2. Next use water-finding paste, applied to the end of a probe, to detect water at the bottom of the oil tank. For indoor tanks, you'll need a flexible probe because of the ceiling-height limitations.

### Inspecting Above-Ground Oil Tanks

Indoor oil leaks are usually accompanied by petroleum smells. Inspect the oil tank as well as all the oil piping between the oil tank and the oil-fired furnace.

- ✓ Look for different colors on the tank from condensation, corrosion, or fuel leaks.
- ✓ Look at the bottom of the oil tank and see if oil is dripping from a leak.
- ✓ Look for patches from previous leaks.
- ✓ If the oil tank is new, don't mistake previous oil-tank leaks for leaks in the new tank.
- ✓ Use the water test described previously.

If you smell oil but you can't see the leak, consider the following tests.

- ✓ Use the water test described previously.
- ✓ For hidden leaks, consider ultrasound leak detection by a oil-tank specialist.

### Advice for Below-Ground Oil Tanks

Leaky below-ground oil tanks are a financial problem and a major environmental problem. Local, state, or federal authorities may require homeowners to remove the tank, abandon it in place, or have it leak-tested by one of the following methods.

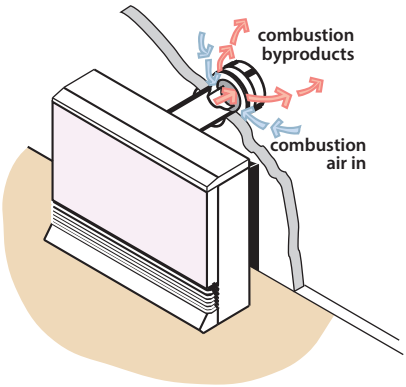
- ✓ Use the water testing described previously.

✓ A tank specialist collects multiple soil samples from around the tank and analyzes them for petroleum contamination by an approved method.

## 8.6 Combustion Space Heater Replacement

*SWS Detail: 5.0301 Room Conditioning; 5.0301.3 Wall Furnace; 5.05 Combustion Safety; 5.0501 Combustion Appliance Zones; 5.0502 Combustion Air; 5.8801 Equipment Removal; 5.0504 Fuel Delivery*

Space heaters are inherently more efficient than central heaters, because they have no ducts or distribution pipes.




**Sealed-combustion space heater:** Sealed-combustion space heaters draw combustion air in, using a draft fan.


**Space heater controls:** Many modern energy-efficient space heaters have programmable thermostats as a standard feature.

Weatherization agencies replace space heaters as an energy-conservation measure or for health and safety reasons. Choose a sealed-combustion space heater. Inspect existing space heaters for health and safety problems.

✓ If power outages are common, select a space heater that operates without electricity.

- ✓ Follow manufacturer's venting instructions carefully. Don't vent sealed-combustion or induced-draft space heaters into naturally drafting chimneys.
- ✓ Verify that flue-gas oxygen and temperature are within the ranges specified by the manufacturer.
- ✓ If the space heater sits on a carpeted floor, install a fire-rated floor protector.
- ✓ Install the space heater away from traffic, draperies, and furniture.
- ✓ Provide the space heater with a correctly grounded duplex receptacle for its electrical service.

### 8.6.1 Space Heater Operation

Communicate the following operating instructions to the occupants.

- ✓ Don't store any objects near the space heater that would restrict airflow around it.
- ✓ Don't use the space heater to dry clothes or for any purpose other than heating the home.
- ✓ Don't allow anyone to lean or sit on the space heater.
- ✓ Don't spray aerosols near the space heater. Many aerosols are flammable or they can corrode the space heater's heat exchanger.

### 8.6.2 Unvented Space Heaters

*SWS Detail: 5.8801 Equipment Removal*

Unvented space heaters include ventless gas fireplaces and gas logs installed in fireplaces previously designed for wood-burning or coal-burning. These unvented space heaters create indoor air pollution because they deliver all their combustion byprod-

ucts to the indoors. Unvented space heaters aren't safe. Replace them with vented space heaters or electric space heaters.

DOE forbids unvented space heaters as primary heating units in weatherized homes. However, unvented space heaters may be used as secondary heaters, under these four requirements.

1. The heater must have an input rating less than 40,000 BTUH.
2. If located in a bedroom, the heater must have an input rating of less than 10,000 BTUH.
3. The heater must be equipped with an oxygen-depletion sensor.
4. The room containing the heater must have adequate combustion air.
5. Home must have adequate ventilation:

## 8.7 Gas Burner Safety & Efficiency Service

*SWS Detail: 5.8801 Equipment Removal*

Gas burners should be inspected and maintained during a service call. These following specifications apply to gas furnaces, boilers, water heaters, and space heaters.

### 8.7.1 Combustion Efficiency Test for Furnaces

Perform the following procedures at steady-state to verify a fur-nace's correct operation.

- Perform a combustion test using a electronic flue-gas analyzer. Recommended flue-gas temperature depends on the

type of furnace and is listed in the table titled, *"Combustion Standards for Gas Furnaces and Boilers" on page 300*.

- Measure temperature rise (supply minus return temperatures). Temperature rise should be within the manufacturer's specifications for a furnace or boiler: between 30° and 70°.
- If $O_2$ is high, or the estimated output from the table is low, increase gas pressure until you measure 6% $O_2$ if possible, as long as you don't create CO in the process.
- Increase gas pressure if needed to increase temperature rise and flue-gas temperature.

If you know the airflow through the furnace from measurements described in *"Ducted Air Distribution" on page 347*, you can use the table, *"Carbon Monoxide Limits" on page 581*, to check whether output is approximately what the manufacturer intended. Dividing this output by measured input as described above gives you another check on the steady-state efficiency.

## 8.7.2 Inspecting Gas Combustion Equipment

Perform the following inspection procedures on all gas-fired furnaces, boilers, water heaters, and space heaters, as necessary.

- ✓ Look for soot, melted wire insulation, and rust in the burner and manifold inside and outside the burner compartment. These signs indicate flame roll-out, combustion gas spillage, CO, and incomplete combustion.
- ✓ Inspect the burners for dust, debris, misalignment, flame-impingement, and other flame-interference problems. Clean, vacuum, and adjust as needed.
- ✓ Inspect the heat exchanger for cracks, holes, or leaks.
- ✓ Verify that furnaces and boilers have dedicated circuits with safety shutoffs near the appliance. Verify that all 120-volt wiring connections are enclosed in covered electrical boxes.

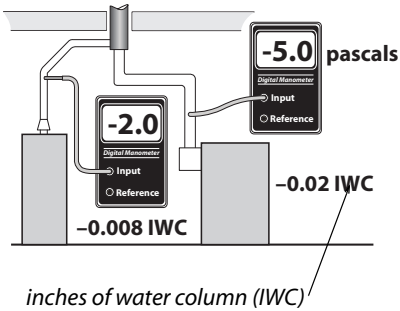
- ✓ Verify that pilot is burning (if equipped) and that main burner ignition is satisfactory.
- ✓ Check venting system for proper diameter and pitch. *S*
- ✓ Check venting system for obstructions, blockages, or leaks.
- ✓ Observe flame characteristics. Flames should be blue and well shaped. If flames are white or yellow, the burner may suffer from faulty combustion.

## 8.7.3 Testing and Adjustment

*SWS Detail: 5.05 Combustion Safety; 5.0503 Appliance Venting; 5.0501 Combustion Appliance Zones; 5.0502 Combustion Air*

The goal of these measures is to reduce carbon monoxide (CO), stabilize flame, and verify the operation of safety controls.

- ✓ Do an electronic combustion analysis and note the oxygen, CO, and flue-gas temperature.
- ✓ Test for spillage or measure draft. Take action to improve the draft if it is inadequate because of improper venting, obstructed chimney, leaky chimney, or depressurization.




**Measuring draft:** Measure chimney draft *downstream* of the draft diverter.

- ✓ If you measure CO and the measured oxygen level is low, open a window while observing CO level on the meter to

see if CO is reduced by increasing the available combus-tion air through the open window.

- ✓ Adjust gas input if combustion testing indicates over-firing or under-firing.
- ✓ For programmable thermostats, read the manufacturer's instructions about how to control cycle length. These instructions may be printed inside the thermostat.

### Burner Cleaning

Clean and adjust the burner if any of these conditions exists.

- CO is greater than 100 ppm as measured or 200 ppm air-free measurement for space heaters and water heaters and 200 ppm as measured or 400 air-free for furnaces or boilers.
- Visual indicators of soot or flame roll-out exist.
- Burners are visibly dirty.
- Measured draft is inadequate.
- The appliance hasn't been serviced for two years or more.

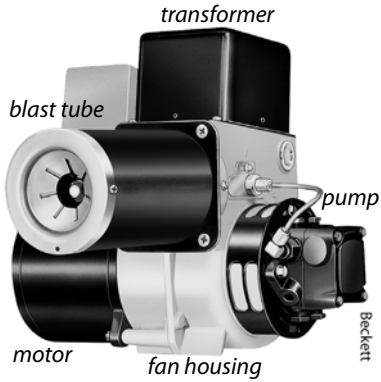
### Maintenance and Cleaning

Gas-burner and gas-venting maintenance should include the following measures.

- ✓ Remove causes of CO and soot, such as over-firing, closed primary air intake, flame impingement, and lack of combustion air.
- ✓ Remove dirt, rust, and other debris that may be interfering with the burners. Clean the heat exchanger if there are signs of soot around the burner compartment.
- ✓ Seal leaks in vent connectors and chimneys.

## 8.8 Oil Burner Safety and Efficiency Service

Oil burners require annual maintenance to maintain acceptable safety and combustion efficiency. Use combustion analysis to evaluate the oil burner and to guide maintenance and adjustment. These procedures apply to oil-fired furnaces, boilers, and water heaters. Use other test equipment as discussed to measure other essential operating parameters and to make adjustments as necessary.




**Oil Burners:** Oil burners are power burners that atomize the oil by pumping it through a nozzle. A blower forces combustion air into the oil mist. Electrodes powered by a transformer light the mixture.

### 8.8.1 Oil Burner Testing and Adjustment

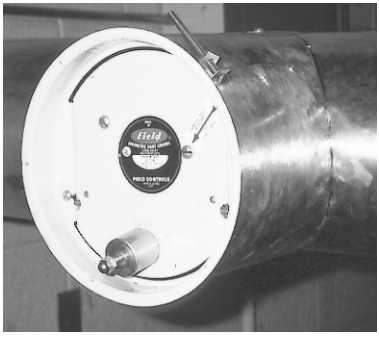
Unless the oil-fired heating unit is very dirty or disabled, technicians should do combustion testing and adjust the burner for safe and efficient operation.

#### Combustion Testing and Adjustment

Combustion testing is essential to understanding the current oil burner performance and potential for improvement.

- ✓ Sample the undiluted flue gases with a smoke tester, after reading the smoke tester instructions. Compare the smoke smudge left by the gases on the filter paper with the manufacturer's smoke-spot scale to find the smoke number.

- ✓ If the smoke number is higher than 3, take steps to reduce smoke before sampling the gases with a combustion analyzer to prevent the smoke from fouling the analyzer.
- ✓ Sample undiluted flue gases between the barometric draft control and the appliance. Analyze the flue gas for $O_2$, flue-gas temperature, CO, and steady-state efficiency (SSE).
- ✓ Measure the overfire draft over the fire inside the firebox through a plug in the heating unit.
- ✓ A flue gas temperature more than 450° F is a sign that a clean heating unit is oversized. Exceptions: steam boilers and boilers with tankless coils. If the nozzle is oversized, replace the burner nozzle after selecting the correct nozzle size, spray angle, and spray pattern.
- ✓ Adjust the barometric damper for a negative overfire draft of–0.020 IWC or –5 pascals at a test plug in the heating unit.
- ✓ Adjust the air shutter to achieve the oxygen and smoke values, specified by the manufacturer.
- ✓ Adjust oxygen, flue-gas temperature, CO, and smoke number to match manufacturer's specifications or specifications given here. Smoke number should be near zero on all modern oil-fired equipment.




**Barometric draft control:** This control provides a stable overfire draft and controlled flow of combustion gases through the heat exchanger.

**Table 8-6: Minimum Oil Burner Combustion Standards**

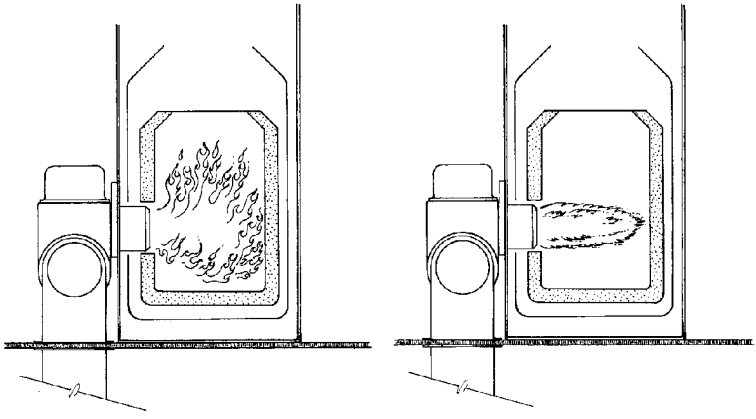
| Oil Combustion Performance Indicator | Non Flame Retention | Flame Retention |
|---|---|---|
| Oxygen (% $O_2$) | 4–9% | 4–7% |
| Stack temperature (°F) | 350°–600° | 325°–500° |
| Carbon monoxide (CO) parts per million (ppm as measured) | ≤200 ppm | ≤ 200 ppm |
| Steady-state efficiency (SSE) (%) | ≥ 75% | ≥ 80% |
| Smoke number (1–9) | ≤ 2 | ≤ 1 |
| Excess air (%) | ≤ 100% | ≤ 25% |
| Oil pressure pounds per square inch (psi) | ≥ 100 psi | ≥ 100–150 psi (pmi)* |
| Natural-draft venting: Overfire draft (negative) | –.020 IWC or –5 Pa. | > –.020 IWC or > –5 Pa. |
| Positive-pressure burner with natural-draft chimney and barometric control: Over-fire draft (positive) | n/a | or 0.020 to 0.120 IWC 5 to 30 Pa. (pmi)* |
| Positive-pressure burner with horizontal vent and without a barometric control: Over-fire draft (positive) | n/a | or 0.20 to 0.60 IWC 50 to 150 Pa. (pmi)* |

* pmi = per manufacturer's specifications

## Other Efficiency Testing and Adjustment

- ✓ Adjust the gap between electrodes and their angle for proper alignment.
- ✓ Measure the control-circuit amperage. Adjust the thermostat's heat anticipator to match the amperage, or read the thermostat manufacturer's instructions for adjusting cycle length.

- ✓ Measure the oil-pump pressure, and adjust it to manufacturer's specifications if necessary.
- ✓ Measure the transformer voltage, and adjust it to manufacturer's specifications if necessary.
- ✓ Adjust the airflow or the water flow to reduce high flue-gas temperature if possible, but don't reduce flue-gas temperature below 350°F.



**Older oil burner** **Flame-retention oil burner**

**Flame-retention burner:** The flame of a flame-retention burner is hotter and more compact than the older burner.

## 8.8.2 Oil Burner Inspection and Maintenance

Use visual inspection and combustion testing to evaluate oil burner operation. An oil burner that passes visual inspection and complies with the specifications on *page 323* may need no maintenance. Persistent unsatisfactory test results may indicate the need to replace the burner or the entire oil-fired heating unit.

### Safety Inspection, Testing, and Adjustment

- ✓ Inspect burner and appliance for signs of soot, overheating, fire hazards, corrosion, or wiring problems.

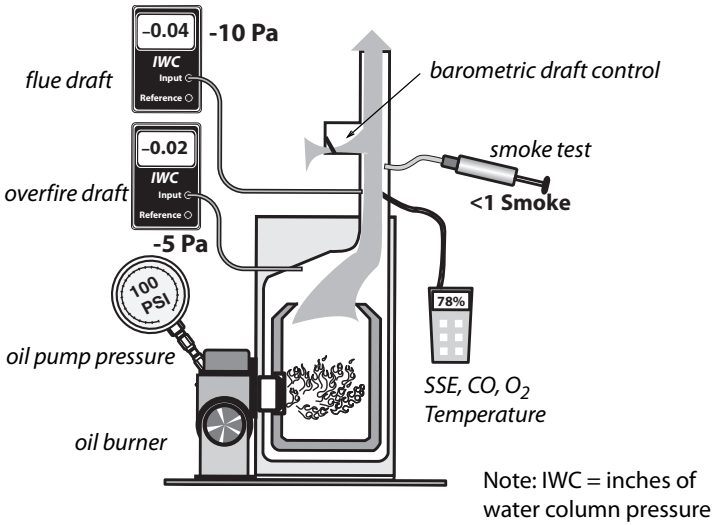
- ✓ Inspect heat exchanger and combustion chamber for cracks, corrosion, or soot buildup.
- ✓ If the unit smells excessively of oil, test for oil leaks and repair the leaks.
- ✓ Time the flame sensor control or stack control to verify that the burner shuts off, within either 45 seconds or a time specified by the manufacturer, when the cad cell is blocked from seeing the flame.
- ✓ Measure the high limit shut-off temperature and adjust or replace the high limit control if the shut-off temperature is more than 200° F for furnaces, or 220° F for hot-water boilers.

### Oil Burner Maintenance

After evaluating the oil burner's operation, specify some or all of these maintenance tasks as necessary, to optimize safety and efficiency.

- ✓ Clean the burner's blower wheel.
- ✓ Clean dust, dirt, and grease from the burner assembly.
- ✓ Replace oil filter(s) and nozzle.
- ✓ Clean or replace air filter.
- ✓ Remove soot from combustion chamber.
- ✓ Remove soot from heat exchange surfaces.
- ✓ Adjust gap between electrodes to manufacturer's specs.
- ✓ Check if the nozzle and the fire ring of the flame-retention burner is appropriate for the size of the combustion chamber.
- ✓ Repair the ceramic combustion chamber, or replace it if necessary.
- ✓ Verify correct flame sensor operation.

After these maintenance procedures, the technician carries out the diagnostic tests described previously to evaluate improvement made by the maintenance procedures and to determine whether more adjustment or maintenance is required.




**Measuring oil-burner performance:** Measuring oil-burning performance requires, a manometer, flue-gas analyzer, smoke tester, and pressure gauge.

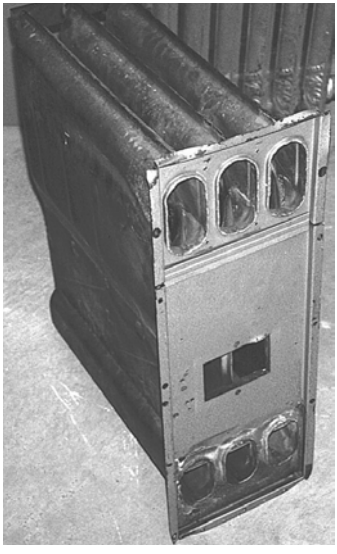
## 8.9 Inspecting Furnace Heat Exchangers

*SWS Detail: 5.05 Combustion Safety; 5.0501 Combustion Appliance Zones; 5.0502 Combustion Air; 5.8801 Equipment Removal*

Leaks in heat exchangers are a common problem, causing the flue gases to mix with house air. Ask clients about respiratory problems, flue-like symptoms, and smells in the house when the heat is on. Also, check around supply registers for signs of soot, especially with oil heating. All furnace heat exchangers should be inspected as part of weatherization. Consider using one or more of these six options for evaluating heat exchangers.

1. Look for rust at exhaust ports and vent connectors.
2. Look for flame-impingement on the heat exchanger during firing and flame-damaged areas near the burner flame.
3. Observe flame movement, change in chimney draft, or change in CO measurement when blower is activated and deactivated.
4. Measure the flue-gas oxygen concentration before the blower starts and then again just after the blower starts. There should be no more than a 1% change in the oxygen concentration.
5. Examine the heat exchanger by shining a bright light on one side and looking for light on the other side using a mirror to look into tight locations.
6. Employ chemical detection techniques, according to the manufacturer's instructions.

*See "NFPA Codes" on page 276.*



**Furnace heat exchangers:** Although no heat exchanger is completely airtight, it shouldn't leak enough to display the warning signs described here.

## 8.10 Wood Stoves

Wood heating is a popular and effective auxiliary heating source for homes. However, wood stoves and fireplaces can cause indoor air pollution and fire hazards. Inspect wood stoves to evaluate potential hazards.

### 8.10.1 Wood Stove Clearances

Stoves that are listed by a testing agency like Underwriters Laboratory have installation instructions stating their clearance from combustibles. Unlisted stoves must adhere to clearances specified in NFPA 211.

### 8.10.2 Stove Clearances

Look for metal tags on the wood stove that list minimum clearances. Listed wood stoves may be installed to as little as 6 inches away from combustibles, if they incorporate heat shields and combustion design that directs heat away from the stove's back and sides.

Unlisted stoves must be at least 36 inches away from combustibles. Ventilated or insulated wall protectors may decrease unlisted clearance from one-third to two thirds, according to NFPA 211. Always follow the stove manufacturer's or heat-shield manufacturer's installation instructions.

#### Floor Construction and Clearances

The floor of a listed wood stove must comply with the specifications on the listing (metal tag). Modern listed stoves usually sit on a 1-inch thick non-combustible floor protector that extends 18 inches beyond the stove in front.

The floor requirements for underneath a unlisted wood stove depends on the clearance between the stove and the floor, which depends on the length of its legs. Unlisted wood stoves must have floor protection underneath them unless they rest on a

floor of non-combustible construction. An example of a non-combustible floor is one composed of only masonry material sitting on sand or gravel.

An approved floor protector is either one or two courses of hollow masonry material (4 inches thick) with a non-combustible quarter-inch surface of steel or other non-combustible material on top of the masonry. This floor for a non-listed wood stove must extend no less than 18 inches beyond the stove in all directions.

### Vent-Connector and Chimney Clearance

Interior masonry chimneys require a 2-inch clearance from combustibles and exterior masonry chimneys require a 1-inch clearance from combustibles. All-fuel metal chimneys (insulated double-wall or triple wall) usually require a 2- inch clearance from combustibles.

Double-wall stove-pipe vent connectors require a 9-inch clearance from combustibles or a clearance listed on the product. Single wall vent connectors must be at least 18 inches from combustibles. Wall protectors may reduce this clearance up to two-thirds.

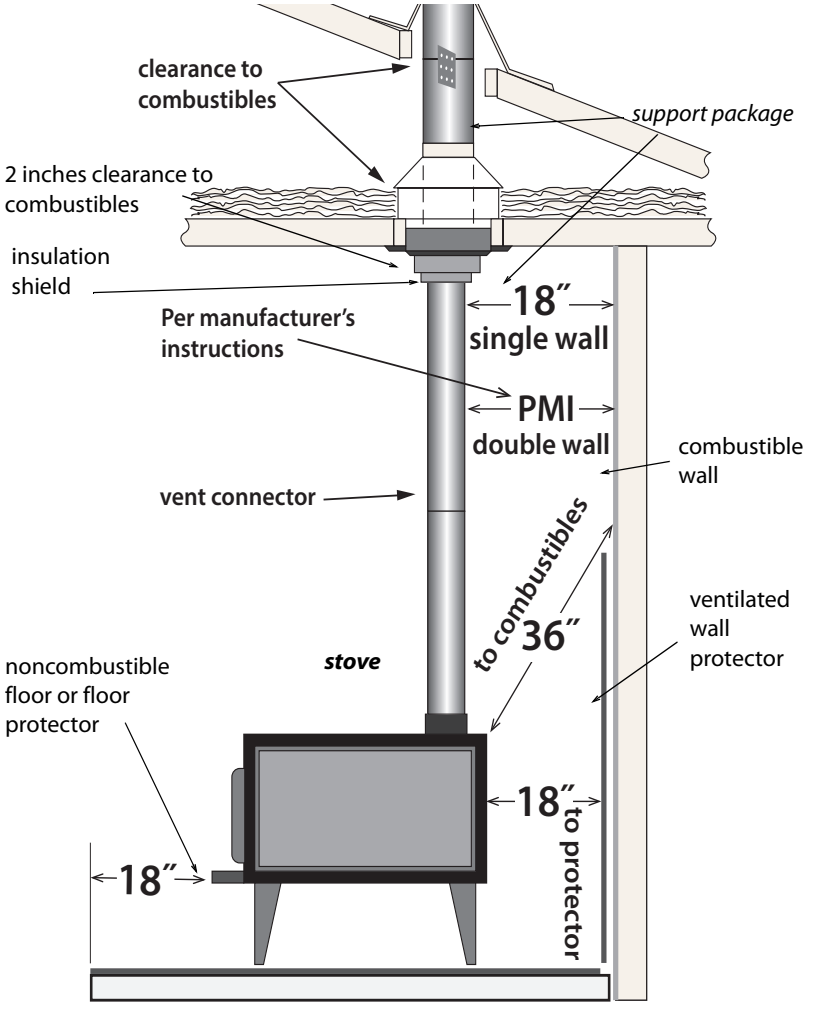
See also *"Wood Stove Clearances" on page 328* and *"Stove Clearances" on page 328*.

## 8.10.3 Wood Stove Inspection

All components of wood stove venting systems should be approved for use with wood stoves. Chimney sections penetrating floor, ceiling, or roof should have approved thimbles, support packages, and ventilated shields to protect nearby combustible materials from high temperatures. Perform or specify the following inspection tasks.

- ✓ Inspect stove, vent connector, and chimney for correct clearances from combustible materials as listed on stoves and vent assemblies or as specified in NFPA 211.

- ✓ Each wood stove must have its own dedicated flue pipe. Two wood stoves may not share a single flue.
- ✓ If the home is tight (<0.35 ACH), the wood stove should be equipped with a dedicated outdoor combustion-air duct.
- ✓ Inspect vent connector and chimney for leaks. Leaks should be sealed with a high temperature sealant designed for sealing wood stove vents.
- ✓ Galvanized-steel pipe must not be used to vent wood stoves.
- ✓ Inspect chimney and vent connector for creosote build-up, and suggest chimney cleaning if creosote build-up exists.
- ✓ Inspect the house for soot on seldom-cleaned horizontal surfaces. If soot is present, inspect the wood stove door gasket. Seal stove air leaks or chimney air leaks with stove cement. Improve draft by extending the chimney to reduce indoor smoke emissions.
- ✓ Inspect stack damper and/or combustion air intake damper.
- ✓ Check catalytic converter for repair or replacement if the wood stove has one.
- ✓ Assure that heat exchange surfaces and flue passages within the wood stove are free of accumulations of soot or debris.
- ✓ Wood stoves installed in manufactured homes must be approved for use in manufactured homes.




**Wood-stove installation:** Wood-stove venting and clearances are vitally important for wood-burning safety. Read manufacturer's instructions for the stove and its venting components.

## 8.11 Inspecting Venting Systems

*SWS Detail: 5.0503 Appliance Venting; 5.0503.1 Fuel-Fired Appliance Venting; 5.0501 Combustion Appliance Zones*

Combustion gases are vented through vertical chimneys or other types of approved horizontal or vertical vent piping. Identifying the type of existing venting material, verifying the correct size of vent piping, and making sure the venting conforms to the applicable codes are important tasks in inspecting and repairing venting systems. Too large a vent often leads to condensation and corrosion. Too small a vent can result in spillage. The wrong vent materials can corrode or deteriorate from heat.

*See "NFPA Codes" on page 276.*

### 8.11.1 Vent Connectors

A vent connector connects the appliance's venting outlet collar with the chimney. Approved vent connectors for gas-fired units are made from the following materials.

- Type-B vent, consisting of a galvanized steel outer pipe and aluminum inner pipe for gas-fired units.
- Type-L vent connector with a stainless-steel inner pipe and a galvanized-steel outer pipe for oil-fired units.
- Double-wall stove-pipe vent connector with a stainless-steel inner pipe and a black-steel outer pipe for solid-fuel units.
- Galvanized steel pipe for gas or oil-fired units only: *See table.*

**Table 8-7: Single-Wall Galvanized Vent Connector Thickness**

| Diameter of Vent Connector (inches) | Inches (gauge) |
|---|---|
| 5 and smaller | 0.022 (26 gauge) |
| 6 to 10 | 0.028 (24 gauge) |
| 11 to 16 | 0.034 (22 gauge) |
| Larger than 16 | 0.064 (16 gauge) |

From *International Mechanical Code 2009*

Double-wall vent connectors are the best option, especially for appliances with some non-vertical vent piping. A double-wall vent connector maintains flue gas temperature and prevents condensation. Gas appliances with draft hoods, installed in attics or crawl spaces must use a Type-B vent connector. Use Type-L double-wall vent pipe for oil vent connectors in attics and crawl spaces.

## Vent-Connector Requirements

Verify that vent connectors comply with these specifications.

- Vent connectors must be as large as the vent collar on the appliances they vent.
- Single wall vent-pipe sections must be fastened together with 3 screws or rivets.
- Vent connectors must be sealed tightly where they enter masonry chimneys.
- Vent connectors must be free of rust, corrosion, and holes.
- Maintain minimum clearances between vent connectors and combustibles.

**Table 8-8: Clearances to Combustibles for Vent Connectors**

| Vent Connector Type | Clearance |
|---|---|
| Single wall galvanized steel vent pipe | 6" (gas), 18" (oil) |
| Type-B double wall vent pipe (gas) | 1" (gas) |
| Type L double wall vent pipe | 3" or as listed (oil) |
| Single-wall stove pipe | 18" (wood) |
| Double-wall stove pipe | 9" or as listed (wood) |

- The chimney combining two draft-hood vent connectors must have a cross-sectional area equal to the area of the larger vent connector plus half the area of the smaller vent connector. This common vent must be no larger than 7 times the area of the smallest vent connector.

**Table 8-9: Areas of Round Vents**

| Vent diameter | 4" | 5" | 6" | 7" | 8" |
|---|---|---|---|---|---|
| Vent area (square inches) | 12.6 | 19.6 | 28.3 | 38.5 | 50.2 |

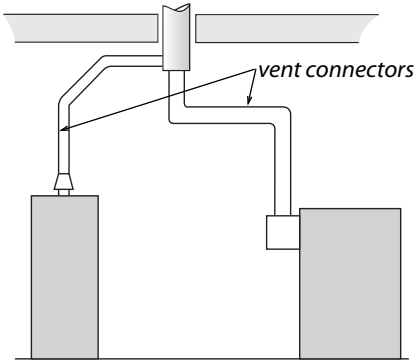
- The horizontal length of vent connectors shouldn't be more than 75% of the chimney's vertical height or have more than 18 inches horizontal run per inch of vent diameter.
- Vent connectors must have upward slope to their connection with the chimney. NFPA 54 requires a slope of at least $^1/_4$-inch of rise per foot of horizontal run so that combustion gases rise through the vent. The slope also prevents condensation from collecting in the vent and corroding it.

**Table 8-10: Connector Diameter vs. Maximum Horizontal Length**

| Diam (in) | 3" | 4" | 5" | 6" | 7" | 8" | 9" | 10" | 12" | 14" |
|---|---|---|---|---|---|---|---|---|---|---|
| Length (ft) | 4.5' | 6' | 7.5' | 9' | 10.5' | 12' | 13.5' | 15' | 18' | 21' |

From *International Fuel Gas Code 2000*

- When two vent connectors connect to a single chimney, the vent connector servicing the smaller appliance must enter the chimney above the vent for the larger appliance.




**Two vent connectors joining chimney:** The water heater's vent connector enters the chimney above the furnace because the water heater has a smaller input.

## 8.12 Chimneys

*SWS Detail: 5.0503 Appliance Venting; 5.0503.1 Fuel-Fired Appliance Venting*

There are two common types of vertical chimneys for venting combustion fuels that satisfy NFPA and ICC codes. First there are masonry chimneys lined with fire-clay tile, and second there are manufactured metal chimneys, including all-fuel metal chimneys, Type-B vent chimneys for gas appliances, and Type L chimneys for oil appliances.

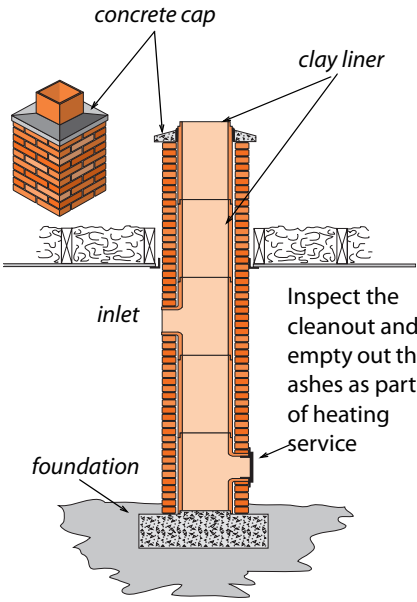
### 8.12.1 Masonry Chimneys

*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Verify the following general specifications for building, inspecting, and repairing masonry chimneys.

- A masonry foundation should support every masonry chimney.

- Existing masonry chimneys should be lined with a fire clay flue liner. There should be a $^1/_2$-inch to 1-inch air gap between the clay liner and the chimney's masonry to insulate the liner. The liner shouldn't bond structurally to the outer masonry because the liner needs to expand and contract independently of the chimney's masonry structure. The clay liner can be sealed to the chimney cap with a flexible high-temperature sealant.



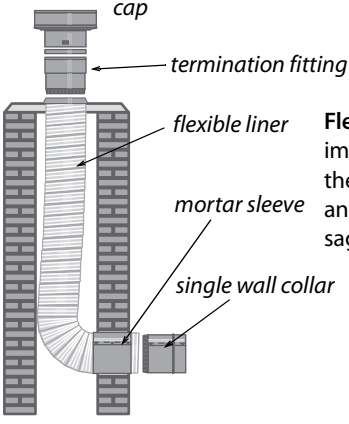

**Masonry chimneys:** Remain a very common vent for all fuels.

- Masonry chimneys should have a cleanout 12 inches or more below the lowest inlet. Clean mortar and brick dust out of the bottom of the chimney through the clean-out door, so that this debris won't eventually interfere with venting.
- Seal the chimney's penetrations through floors and ceilings with sheet metal and high-temperature sealant as a fire-stop and air barrier.
- Re-build deteriorated or unlined masonry chimneys as specified above or reline them as part of a heating-system replacement or a venting-safety upgrade. Or, install a new

metal chimney instead of repairing the existing masonry chimney.

### Metal Liners for Masonry Chimneys

Install or replace liners in unlined masonry chimneys or chimneys with deteriorated liners as part of heating system replacement. Orphaned water heaters may also need a chimney liner because the existing chimney may be too large. Use a correctly sized Type-B vent, a flexible or rigid stainless-steel liner, or a flexible aluminum liner.




**Flexible metal chimney liners:** The most important installation issues are sizing the liner correctly along with fastening and supporting the ends to prevent sagging.

Flexible liners require careful installation to avoid a low spot at the bottom, where the liner turns a right angle to pass through the wall of the chimney. Comply with the manufacturer's instructions, which usually require stretching the liner and fastening it securely at both ends, to prevent the liner from sagging and creating a low spot.

Flexible liners are easily damaged by falling masonry debris inside a deteriorating chimney. Use B-vent, L-vent, or single-wall stainless steel pipe instead of a flexible liner when the chimney is significantly deteriorated.

To minimize condensation, insulate the flexible liner — especially when installed in exterior chimneys. Consider fiberglass-

insulation jackets or perlite, if the manufacturer's instructions allow. Wood-stove chimney liners must be stainless steel and insulated.

Sizing flexible chimney liners correctly is very important. Oversizing is common and can lead to condensation and corrosion. The manufacturers of the liners include vent-sizing tables in their specifications. Liners should display a label from a testing lab like Underwriters Laboratories (UL).

**Masonry chimneys as structural hazards:** A building owner may want to consider reinforcing a deteriorated chimney by repointing masonry joints or parging the surface with reinforced plaster. Other options include demolishing the chimney or filling it with concrete to prevent it from damaging the building by collapsing during an earthquake.

**Video: Natural drafting chimneys—** Discussion about the various type of appliances that use atmospheric chimneys.

## Solutions for Failed Chimneys

Sometimes a chimney is too deteriorated to be re-lined or repaired. In this case, abandon the old chimney, and install one of the following.

- A double-wall horizontal sidewall vent, equipped with a barometric draft control and a power venter mounted on the exterior wall. Maintain a 4-foot clearance between the ground and the vent's termination if you live where it snows.
- A new heating unit, equipped with a power burner or draft inducer, that is designed for horizontal or vertical venting.
- A new manufactured metal venting system.

**Table 8-11: Clearances to Combustibles for Common Chimneys**

| Chimney Type | Clearance |
|---|---|
| Interior chimney masonry w/ fireclay liner | 2" |
| Exterior masonry chimney w/ fireclay liner | 1" |
| All-fuel metal vent: insulated double-wall or triple-wall pipe | 2" |
| Type B double-wall vent (gas only) | 1" |
| Type L double-wall vent (oil) | 3" |
| Manufactured chimneys and vents list their clearances. | |

## 8.12.2 Manufactured Chimneys

*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Manufactured metal chimneys have engineered parts that fit together in a prescribed way. Parts include: metal pipe, weight-supporting hardware, insulation shields, roof jacks, and chimney caps. One manufacturer's chimney may not be compatible with another's connective fittings.

All-fuel chimneys (also called Class A chimneys) are used primarily for the solid fuels: wood and coal. All-fuel metal chimneys come in two types: insulated double-wall metal pipe and triple-wall metal pipe. Comply with the manufacturer's specifications when you install these chimneys.

**All-fuel metal chimney:** These chimney systems include transition fittings, support brackets, roof jacks, and chimney caps. The pipe is double-wall insulated or triple-wall construction.

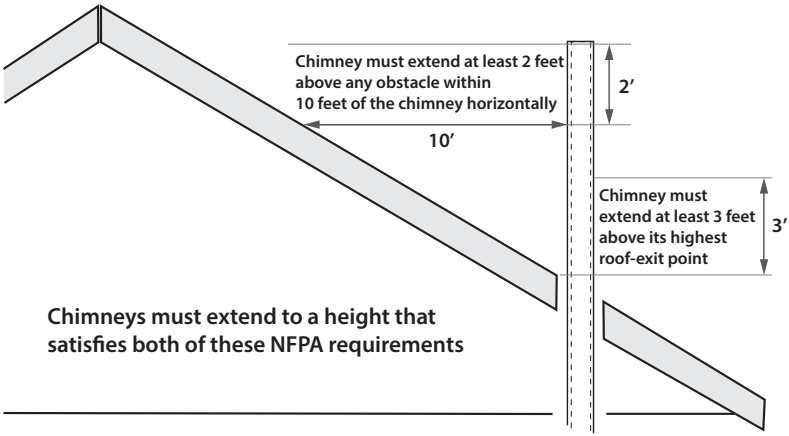
Type-B vent double-wall pipe is permitted as a chimney for gas appliances. Type BW pipe is manufactured for gas space heaters in an oval shape to fit inside wall cavities.

Type L double-wall pipe is used for oil chimneys.

## 8.12.3 Chimney Terminations

*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Masonry chimneys and all-fuel metal chimneys should terminate at least three feet above the roof penetration and two feet above any obstacle within ten feet of the chimney outlet.




**Chimney terminations:** Should have vent caps and be given adequate clearance height from nearby building parts. These requirements are for both masonry chimneys and manufactured all-fuel chimneys.

B-vent chimneys can terminate as close as one foot above flat roofs and above pitched roofs up to a $^{6}/_{12}$ roof pitch. As the pitch rises, the minimum required termination height, as measured from the high part of the roof slope, rises as shown in this table.

**Table 8-12: Roof Slope and B-Vent Chimney Height (ft)**

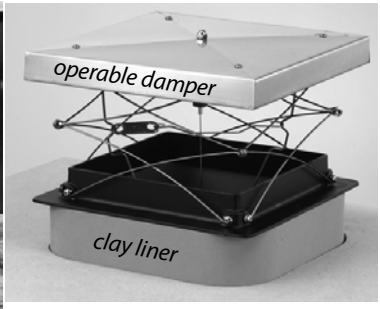
| flat-6/12 | 6/12-7/12 | 7/12-8/12 | 8/12-9/12 | 9/12-10/12 | 10/12-11/12 | 11/12-12/12 | 12/12-14/12 | 14/12-16/12 | 16/12-18/12 |
|---|---|---|---|---|---|---|---|---|---|
| 1' | 1' 3" | 1' 6" | 2' | 2' 6" | 3' 3" | 4' | 5′ | 6' | 7' |

From *National Fuel Gas Code 2009*

## 8.12.4 Air Leakage through Masonry Chimneys

The existing fireplace damper or "airtight" doors seldom provide a good air seal. Help the clients decide whether they will use the fireplace in the future or whether to take it out of service. Consider these solutions for chimneys with ineffective or missing dampers.

- Install an inflatable chimney seal along with a notice of its installation to alert anyone wanting to start a fire to remove the seal first.
- Install an operable chimney-top damper and leave instructions on how to open and close it. Also notify users of which position is open and which is closed.
- Air seal the chimney top from the roof with a watertight, airtight seal. Also seal the chimney from the living space with foam board and drywall. If you install a permanent chimney seal such as this, post a notice at the fireplace saying that it is permanently disabled.

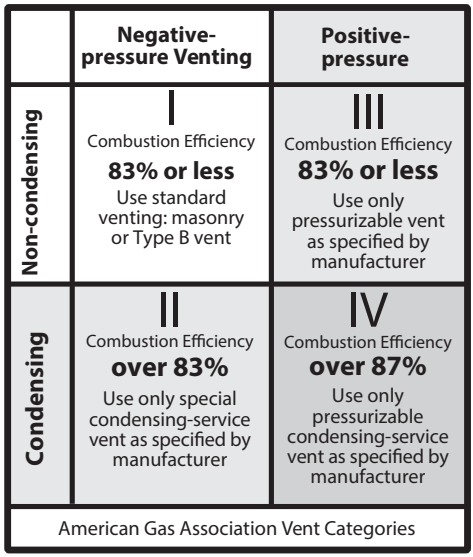


**Reducing air leakage through masonry chimneys:** You can seal a chimney off permanently, install an inflatable seal inside, or install a chimney-top damper from the outside to reduce air leakage through the chimney.

## 8.13 Special Venting Considerations for Gas

The American Gas Association (AGA) publishes a classification system for venting systems attached to natural-gas and propane appliances. This classification system assigns Roman numerals to four categories of venting based on whether there is positive or negative pressure in the vent and whether condensation is likely to occur in the vent.

**AGA venting categories:** The AGA classifies venting by whether there is positive or negative pressure in the vent and whether condensation is likely.




A majority of gas appliances found in homes and multifamily buildings are Category I, which have negative pressure in their vertical chimneys. We expect no condensation in the vent connector or chimney.

Condensing furnaces are usually Category IV, have positive pressure in their vent, and condensation occurring in both the appliance and vent. Category III vents are rare, however a few fan-assisted furnaces and boilers vent their flue gases through airtight non-condensing vents. Category II vents are very rare and beyond the scope of this discussion.

## 8.13.1 Venting Fan-Assisted Furnaces and Boilers

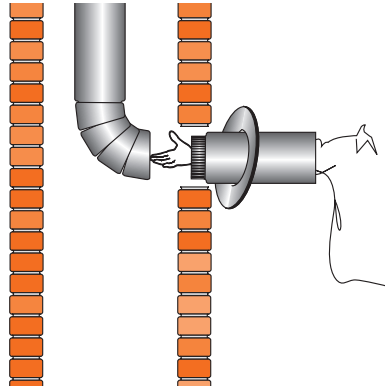
*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Newer gas-fired fan-assisted central furnaces and boilers eliminate dilution air and may have slightly cooler flue gases compared to their predecessors. The chimney may experience more condensation than in the past. Inspect the existing chimney to verify that it's in good condition when considering replacing an

old natural-draft unit. Reline the chimney when you see any of these conditions.

- When the existing masonry chimney is unlined.
- When the old clay or metal chimney liner is deteriorated.
- When the new furnace has a smaller input (BTUH) than the old one, the liner should be sized to the new furnace and the existing water heater.

**B-vent chimney liner:** Double wall Type-B vent is the most commonly available chimney liner and is recommended over flexible liners. Rigid stainless-steel single wall liners are also a permanent solution to deteriorated chimneys.



## Liner Materials for 80+ Furnaces

For gas-fired 80+ AFUE furnaces, a chimney liner should consist of one of these four materials.

1. A type-B vent
2. A rigid or flexible stainless steel liner (preferably insulated)
3. A poured masonry liner
4. An insulated flexible aluminum liner

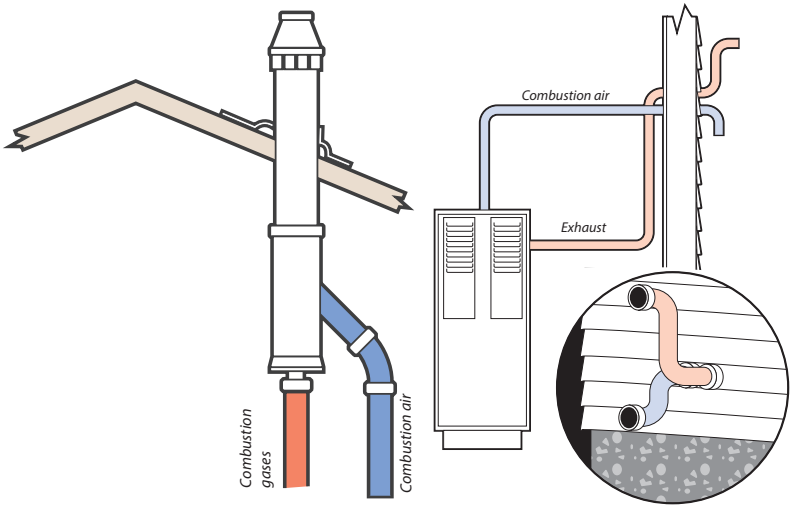
Chimney relining is expensive. Therefore consider a power-vented sealed-combustion unit when an existing chimney is inadequate for a new fan-assisted appliance.

## 8.13.2 Venting Sealed-Combustion Furnaces and Boilers

*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Some space heaters, furnaces, and boilers use factory-built metal chimneys with single stainless steel liners that vent horizontally under positive pressure.

Condensing furnaces usually employ horizontal or vertical plastic-pipe chimneys.




**Two types of sealed-combustion vents:** On the left is a concentric vent exiting through a roof. On the right is a plastic-pipe vent and combustion-air opens through the wall.

## 8.13.3 Sidewall Power Venting

*SWS Detail: 5.0503.1 Fuel-Fired Appliance Venting*

Stainless-steel vents powered by fans in gas and oil appliances exit through walls and don't require vertical chimneys.

**Table 8-13: Characteristics of Gas Furnaces and Boilers**

| Annual Fuel Utilization Efficiency (AFUE) | Operating characteristics |
|---|---|
| 70+ | Category I, draft diverter, no draft fan, standing pilot, non-condensing, indoor combustion and dilution air. |
| 80+ | Category I, no draft diverter, fan-assisted draft, electronic ignition, indoor combustion air, no dilution air. |
| 80+ | Category III, horizontal fan-pressurized non-condensing vent, indoor combustion air, no dilution air. |
| 90+ | Category IV, no draft diverter, fan-assisted draft, low-temperature plastic venting, positive draft, electronic ignition, condensing heat exchanger, outdoor combustion air is strongly recommended. |