Carbon Monoxide Problems from New Furnaces

by Thomas H. Greiner

Several case studies from the Iowa State University Extension show that carbon monoxide hazards exist even with new gas appliances. Proper installation and analysis are key to avoiding or solving these problems.

While checking for CO in the outdoor air from a furnace outlet (visible under the window in the far left of this photo), Dr. Saqib Mukhtar was unable to approach any closer without exceeding maximum allowed personal exposure concentrations.

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Carbon monoxide (CO) can creep into living spaces and cause a variety of health problems, sometimes even death. While old or poorly maintained gas furnaces and other older appliances are often the sources of CO, new heating appliances also cause CO problems. Many of these failures arise from improper installation. As a housing engineer with Iowa State University Extension, I encounter many CO-related problems.

What Can Go Wrong

I was once called to a home where the family dog was nearly blind, and one of the occupants had experienced severe headaches and dizziness. The furnace was a high-efficiency, direct-vent, sealed-combustion propane unit with top mounted burners. In two years the furnace had filled with soot and three of the five heat exchanger chambers had cracked above the top-mounted burners, while all five of the large, open rivets holding the top of the exchanger together had fallen out. This had allowed air to blow into the flame chamber, which had disrupted the flame and forced it to the top of the exchanger, causing the three cells to crack. The installation of this new unit had other problems too, including too many bends in the discharge and air intake pipes, and a reduction in pipe size from 3 inches to 2 inches.

Once the source of CO is located, it is important to discover how it enters the house. In the above case, the furnace was producing extremely high concentrations of CO, which was being vented outdoors below the windows on the west side of the house. Concentrations of CO in the outdoor air near the discharge vent exceeded 4,500 parts per million (ppm), the limit of my combustion analyzer. Under certain weather and wind conditions, the CO would find its way into the loose turn-of-the-century structure.

The owners of this house were dissatisfied with the service provided by the original installer and contacted a different dealer. The second dealer informed the owners that their new furnace had been recalled to correct the rivet problem in the heat exchanger. Although there was a repair kit for the rivets, the heat exchanger had to be replaced because it was completely sooted up. The second dealer contacted the manufacturer, who furnished a new heat exchanger. This dealer also corrected the venting by installing larger vent pipes. In addition, the propane supplier replaced the exterior gas regulator because of their concern over its operation.

Another case involved a new home with an induced-draft furnace on a 4-inch vent. The furnace installer had neglected to fasten and seal the bottom plate of the furnace under the circulating blower. The furnace was made for either a bottom return or a sidewall return, with bold, capitalized warnings that the plate must be screwed down to prevent possible carbon monoxide problems.

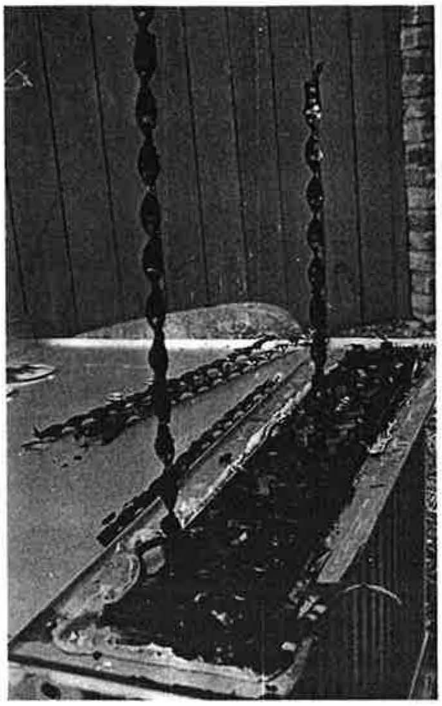
The family began having respiratory problems as soon as they moved into their new home. A heating contractor installed an electronic air filter and told them to operate the furnace blower continuously. But the return was sucking air from the basement around the unfastened bottom plate. This depressurized the basement to over 9 Pascals (Pa), causing a complete flow reversal in the common furnace and water heater vent.

The family suffered from several respiratory and health problems, caused, perhaps, by nitrogen dioxide from the water heater and dust off the basement floor. Medical specialists did not attribute these problems to poor indoor air quality, even after the family told them of the constant exposure for more than two and a half years!

There were several other clues that the ductwork was defective. The upstairs was difficult to heat and cool and, after the electronic air filter was installed, the air conditioner coil had plugged with dirt in less than one year. Why? Because dirty air from the basement floor was being drawn directly into the furnace.

The heating contractor recommended increasing the house ventilation rate by installing a new heat recovery ventilator. However, the contractor had not discovered the open bottom on the furnace, which I found during pressure testing.

At another four-year old home, the owners complained that the pilot on their water heater continually went out. The furnace was a direct-vent, sealed-combustion furnace and the water heater was a natural-draft unit with separate vent pipe. The heating contractor was unable to correct the problem and told the homeowner the house was "too tight."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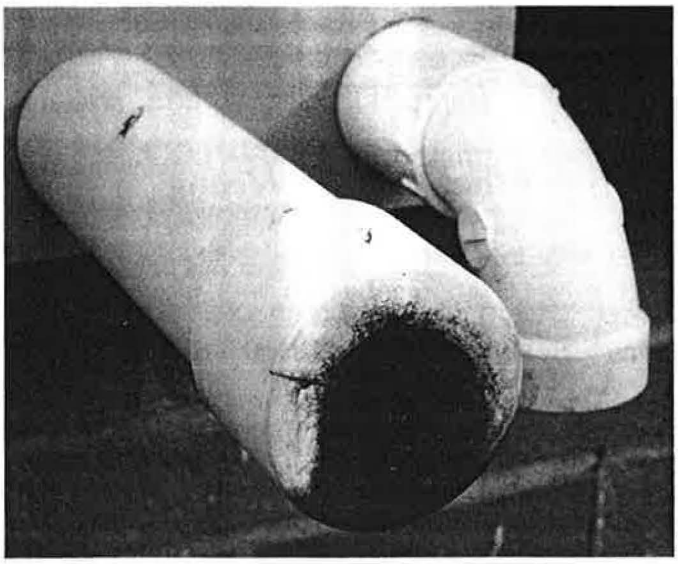
A secondary heat exchanger from a high efficiency condensing furnace plugged with black soot.

Further investigation revealed that the return ductwork in the basement was extremely leaky. When the furnace blower operated, the basement was depressurized to 8 Pa and the water heater backdrafted. The owner noted that the vent pipe above the water heater would get ice cold on chilly nights. After being shown what caused the problem, the heating contractor air sealed the returns in the basement, added an extra upstairs return, and opened the two basement supplies. After duct sealing, basement depressurization was 3 Pa and the water heater vented adequately.

A fourth case concerned a homeowner who returned after a vacation to find soot throughout his house. Almost on reflex, a contractor replaced the furnace with a direct-vent, sealed-combustion unit, leaving the water heater vented into the former common vent. The homeowner later complained that the water heater sometimes spilled. He contacted numerous persons who attempted to correct the problem. One of the contractors decided to install a temperature-sensitive, anti-spill switch, which is designed to shut off the water heater when hot gases spill from the draft diverter. Unfortunately, during downdrafting, the incoming cold air diluted the hot combustion gases and the spill switch never functioned. (These switches are effective in shutting the units down when the vent is totally blocked, and some manufacturers are now changing the name to "blocked vent switch.")

The real source of the problem was eventually found to be a 14-inch roof-mounted attic fan. It operated automatically (using a temperature sensor) and would sometimes run for weeks at a time to reduce attic heat in summer. When the fan operated, the basement was depressurized to 15 Pa (see "Drawbacks of Powered Attic Ventilators," *HE* Nov/Dec '95, p. 5). This was an older one-and-a-half story house that had many leaks connecting the basement to the attic. In addition, the homeowner had recently put new steel siding on the house, and the installers had blocked over the end gable vents and the soffit vents, replacing them with much smaller and less effective venting.

Shutting off the fan in the attic decreased depressurization to 3 Pa. While the problem was originally thought to lie with the old furnace, in the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Soot is visible on this outdoor furnace outlet where concentrations exceeded 4,500 ppm (the maximum reading on our test instruments).

end, simply shutting off this fan solved the problem.

Why Things Go Wrong

Two failures are basic to all combustion appliance CO problems: (1) incomplete fuel combustion, and (2) a vent system that does not adequately remove the exhaust. These two failures are often interrelated. For example, during a flue reversal, all the products of combustion spill into the room housing the appliance. The appliance then "breathes its own fumes." As oxygen in the room is consumed, incomplete combustion occurs and CO is produced.

Vent Failures

Combustion products usually go up the vent, but certain conditions may cause them to spill at the draft diverter or out the burner ports. Buoyant forces that cause combustion products to vent result from temperature differences. The buoyant forces are small and easily overpowered by other, more powerful forces. The buoyant (lifting) force, approximately 5 Pa, is only about ⅙ oz in a 4-inch-diameter round flue pipe. Wind forces, exhaust fans, and the furnace blower are all more powerful and can reverse the flow in the vents. Combustion appliances also compete for air. For example, when a fireplace and a furnace are both operating they both need outside air. If the house is tight, they will compete with each other for the air they need.

Technicians often hold a match near the draft hood to check for proper draft, and this method is suggested in some manufacturers' literature. However, holding a match is not a good way to check, because the match is a hot source, and the smoke will tend to rise even if it is not being pulled up into the draft hood. Instead, technicians should use a smoke stick of neutral density, such as those used to check for infiltration during house leakage tests.

Vent failures are often sporadic, intermittent, and difficult to reproduce. Because pressure differences are small, it takes only a small change to cause warm gases to vent incorrectly. Often, a downdraft will occur when the house is closed. Simply opening the front door once can change the pressures, allowing warm air to go up the vent again. Auditors checking for CO problems should always attempt to monitor venting under the worst case scenario.

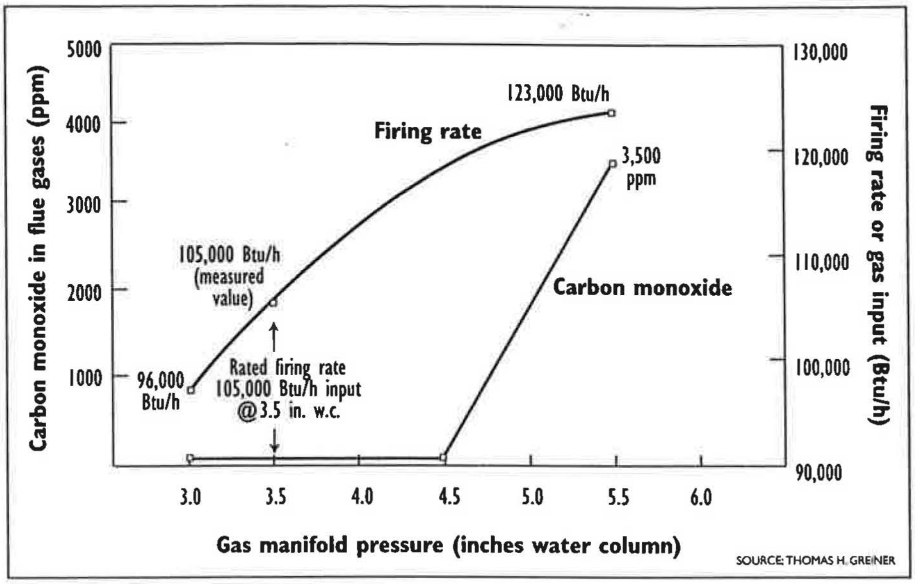

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Figure 1. The results of an overfiring test and the resultant CO production from a furnace. The overfiring was measured by clocking the meter (which gives input in Btu/h) and by measuring the gas manifold pressure. The nominal firing rate was 105,000 Btu/h at 3.5 inches gas manifold pressure. At this firing rate, CO production was under 20 ppm. As the gas manifold pressure was increased, the firing rate increased. At 4.5 inches manifold pressure, CO production began to shoot up, and at 5.5 inches manifold pressure, the CO production was over 3,500 ppm and the firing rate was 123,000 Btu/h. This is only a single example; different burners will react differently.

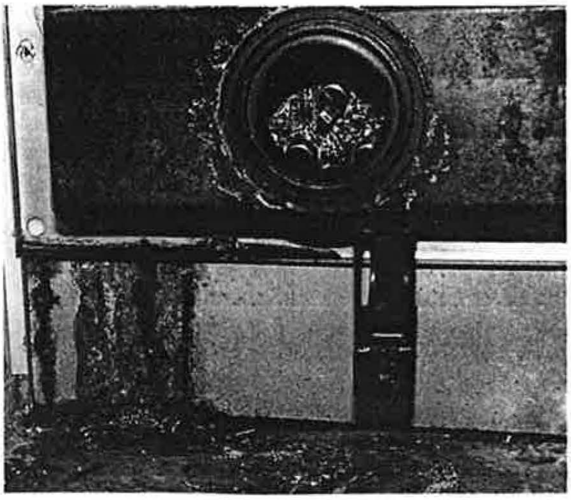
Overfiring

Overfiring, or overgassing, is another common source of CO. A properly adjusted gas furnace or water heater produces hardly any CO. When too much gas is supplied to the burner, sufficient oxygen does not flow into the burner, and CO is produced.

I find overfiring to be a more common cause of CO problems in a home than cracked heat exchangers. Overfiring often occurs in conjunction with intermittent vent failure and is therefore difficult to diagnose unless proper procedures and equipment are used.

Overfired units typically still burn with a blue flame. Too often, without proper test instruments, the heating contractor will assume that the unit is burning clean. During several carbon monoxide conferences held here in Iowa, we purposely overfired furnaces and then asked heating contractors to predict the potential for CO by using flame color. They were not able to distinguish the problem until they were told and shown that the furnace was misadjusted.

The differences between a properly adjusted furnace and an overfired furnace are extreme. An overfired furnace can produce more than 4,500 ppm CO in the flue (see Figure 1). A simple reduction of gas pressure, which takes



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Looking into the exhaust end of a secondary heat exchanger. Note the black soot and flaking rust where water from combustion has leaked out.

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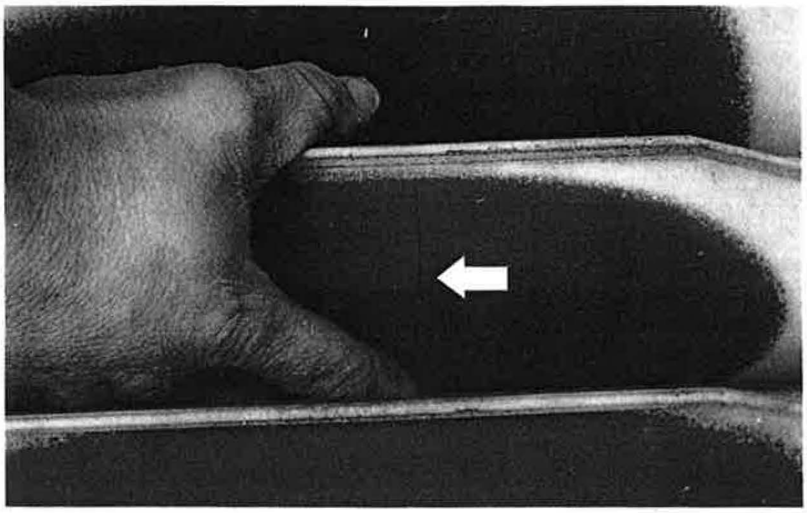
two minutes to perform, can bring CO levels back to below 20 ppm.

How do excess gas pressures occur? Sometimes, the gas regulator can fail, or, in some cases, the installing contractor does not perform the initial gas pressure adjustment. In yet other cases the heating contractor or homeowner, desiring more heat, may increase the gas flow by changing the gas pressure adjustment. Overfiring may also be caused by improper orifices, which can result when units are changed from propane to natural gas or from natural gas to propane. The correct orifice is vital to proper gas flow.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A small crack can mean big trouble, especially when it is located on a heat exchanger as shown here.

Manufacturers typically desire no overfiring beyond a tolerance of +2%. Yet I find units 20%–30% overfired. Because overfiring cannot be diagnosed by flame color, it is vital that all contractors perform the following steps:

- Check the rate of gas flow to the burner, and check for overfiring by clocking the meter (that is, use the test dial on the gas meter to verify that the appliance is using the proper amount of gas).
- Check manifold gas pressure using an accurate manometer.
- Ensure that gas orifices are correct.
- Measure carbon monoxide concentrations in the combustion products. (Instruments to measure CO in the flue products are readily available, and are vitally necessary for carbon monoxide investigations. The same instrument can also be used to measure ambient air CO concentrations.)

Heat Exchanger Failures

The heat exchanger keeps the furnace exhaust from mixing with the house air. Holes or cracks in the exchanger can cause serious problems. Holes can allow the exhaust to enter the duct system and be distributed throughout the house. Holes and cracks can also allow air from the blower to enter the burner chamber and disrupt burner operation, increasing the amount of CO produced. Air flow through large holes or cracks can cause combustion product spillage from the burner ports—a very dangerous situation. Condensing furnaces also have a secondary heat exchanger, which removes heat from the flue gases, causing them to condense.

Some of the causes of premature heat exchanger failure are:

- *Incorrect temperature rise.* The temperature can be either too high or too low—caused by incorrect blower speed selection, restricted ductwork, insufficient ductwork, dirty filters, or lack of filters. The correct range for temperature rise is on the information plate of each furnace.
- *Taking air from inside the house.* Contaminants inside the house are hard on high-efficiency units as they create acids in condensation, which contributes to corrosion. Use sealed combustion and don't use contaminants (such as aerosol sprays) in the house. A very common problem with older units located near laundry machines has been corrosion due to chlorine fumes.
- *Incorrect gas flow rate.* Many units are overfired, running rich and hot. Overfired units do not have sufficient air for complete combustion. Cracking of the heat exchanger, sooting, and CO can result from overfiring.
- *Oversizing.* This causes rapid on/off cycling without sufficient time to heat the furnace exchanger or the vent. Condensation forms and does not get evaporated out. The "wet time" is excessive.


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This new furnace has an open bottom section covered with a plate, which the installers failed to attach properly. The unsecured plate warped and allowed air to leak into the furnace from the basement, instead of being pulled through the electronic air filter and return duct on the right side of the furnace.

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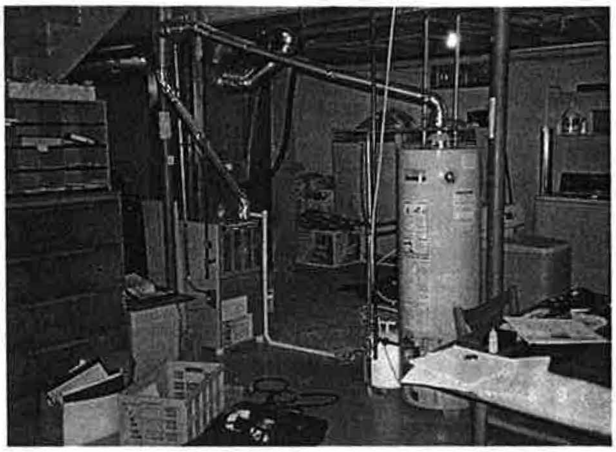
Older "High Efficiency" Furnaces

Many of the first high-efficiency units installed in the 1980s were poorly designed, and the metal in the exchangers was not adequate to stand up to the condensing gases. These units have been failing. For instance, in January 1996 I inspected an 86% efficient condensing furnace. The combustion discharge at the base had rusted completely through. The burner was producing several thousand ppm CO because air flow was insufficient. Unfortunately, the combustion air fan pulled extra room air across the safety switch, and the safety switch did not shut down the unit. The problem was found by combustion gas analysis, and the furnace was replaced.

Preventing CO Poisoning

Carbon monoxide is produced whenever a fuel does not burn completely.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Here an induced draft furnace and natural draft waterheater are vented into a common flue. While this is a frequent configuration, it has potential hazards, including the possibility of backdrafting from the water heater's draft diverter.

CO poisoning will cause severe and permanent medical problems and death; medical researchers report that 14%–40% of seriously poisoned patients have delayed neurologic symptoms that may be disabling. CO is the leading cause of poisoning deaths in the United States.

Too often people think that CO poisoning cannot happen to them, because they live in a drafty older house or have a new furnace. This is not true. As these cases reveal, CO poisoning can occur in older, loose houses or newer, tight houses and can be caused by new furnaces as well as old ones.

Carbon monoxide poisoning is preventable. Annual maintenance of heating appliances by a qualified service technician and installation of reliable CO detectors can reduce the needless costs, pain, and suffering CO poisoning causes.

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