About Carbon Monoxide

The Case of the CO Leak: Solving the Mysteries of Carbon Monoxide Exposures

By Thomas Greiner

Carbon monoxide causes more deaths from poisoning annually than any other substance, but diagnosing its source eludes all but the best-trained contractors. Thomas H. Greiner dissects the various ways CO exposures happen, and how they are commonly misdiagnosed.

A colorless, odorless, flavorless, nonirritating gas, carbon monoxide (CO) causes more poisoning deaths today than any other substance. In my work as a professional engineer with Iowa State University Extension, I've investigated more than 65 indoor air quality cases in the last three years, many of them related to CO production and venting problems. Inadequate installation and maintenance of heating appliances and improper venting can cause serious health problems, mental deterioration, and death to residents exposed to the gas.

Preventing indoor CO problems isn't impossible. Proper installation and regular maintenance of equipment by trained and qualified heating contractors reduces the probability of CO emissions and venting failures. However, diagnosing indoor CO problems can be difficult because of their intermittent nature. Heating equipment in a structure operates as part of a system, and is subject to influence from depressurization caused by other devices within a building, and by weather conditions affecting the building structure.

The dearth of contractors trained to consider the complex nature of CO diagnostics is one factor leading to the frequency of indoor CO problems.

Preventive Measures

Yearly service by a qualified heating contractor is vital to reducing the risks posed by carbon monoxide. Unfortunately, not all heating contractors are qualified. Of 104 Iowa contractors responding to a 1995 survey, 25 didn't have equipment to measure CO and 61 had not had the appropriate training.

Contractors are quickly obtaining the training necessary to investigate CO alarms. But until there is a broad enough pool of contractors who understand preventive maintenance and venting, homeowners run the risk of CO exposure.

Many homeowners report CO detectors going off, but find their contractor unable to diagnose the cause. In recent investigations of 29 homes, I found multiple occurrences of misdiagnosed problems. In 10 of these houses, contractors said they fixed a problem, but hadn't. An additional six professionals reported no carbon monoxide problem and told the homeowners the problem was the CO detector, even though a CO problem was evident when I tested the house. Three contractors indicated there was a problem but failed to locate it and one professional said the problem was caused by a freak occurrence in the weather and would not happen again.

The truth is, faulty CO detectors are uncommon. More likely, the CO source eluded the contractor. Using the CO detector as the alarm mechanism, and a qualified contractor to find the problem and provide a solution, poisoning by CO can be kept to a minimum.

Identification of CO causes is no simple matter. The causes are as varied as unvented appliances, use of gas cookers for heating, portable space heaters such as kerosene heaters, hibachi and charcoal cookers, cracked heat exchangers, depressurization of the combustion appliance zone causing backdrafting of the furnace flue, or a vehicle running in an attached garage. Any of these might set off a CO detector, but conditions may have changed by the time the contractor arrives at the house to locate the problem. For example, backdrafting of the furnace flue might set off an alarm, but if a window is opened, the pressure in the combustion zone (area where combustion appliances reside) will change. This could reverse the backdrafting and change the reading on the CO detector. Downdrafting of appliances or vehicles in attached garages are usually intermittent and easy to overlook during investigations. The following examples show some of the many ways a CO problem can arise, and how contractors can make correct and incorrect diagnoses.

Exposure from a Plugged Chimney: Case One

On one of the first cool days of fall, a young mother, alone with her two children, noticed that her chemical dot CO detector had changed color. None of the family felt sick, so she called the local fire department for advice. They immediately offered to investigate. When they turned on the furnace, they found 139 parts per million (ppm) of carbon monoxide in the basement. OSHA and the EPA suggest that between 9 and 50 ppm for no more than eight hours no more than once a year constitutes a safe level of exposure.

A heating contractor was called, who diagnosed and corrected the immediate problem--a chimney plugged with dead birds. He removed the dead birds and replaced the old chimney with a new metal vent.

The family then purchased a listed carbon monoxide detector but a week after they thought the problem was fixed, the detector indicated 39 ppm and they called me. When I checked their home and heating system, I discovered several serious problems with the furnace and the vent system. The old furnace was badly out of adjustment, in poor repair, and producing extremely high levels of carbon monoxide, over 3,300 ppm in the flue gases. By placing the metal vent pipe in contact with wood (a code violation and a fire hazard), the contractor had created another problem. The vent had a long, horizontal run which did not draw well. The 39 ppm reading was caused by the slight spillage of extremely high concentrations of carbon monoxide. These concentrations were so high that I observed birds sitting on the chimney top falling into the open chimney, poisoned by the CO exiting the flue.

Increasing the primary air supply to the furnace burner reduced the CO production from 3,300 ppm to 9 ppm. Still, because of the age of the unit and the vent problems that still existed, the owner replaced the furnace.

This case raises real concerns. The furnace had not worked correctly the previous winter, and the owners had called the heating contractor numerous times to relight the pilot. If the family hadn't purchased a detector, they wouldn't have known about the CO problem. Further, if the family assumed the heating contractor had corrected the CO problem and not purchased another detector, they would have continued to be exposed to carbon monoxide. (Although the inexpensive chemical dot detector furnished the family sufficient warning, the dots are NOT recommended. Without an audible alarm they can't offer sufficient protection, especially during the night.)

The heating contractor could have performed several tests that would have alerted him to the furnace and vent problems. In this case, visual inspection would have revealed an improper flame pattern, a closed primary air shutter, burned wires, soot production, rust on the back of the furnace cover, and lack of a roof vent cap (a vent cap would have prevented birds from falling into the vent). Measuring gas flow would have revealed that the gas flow was excessive, which increases the odds the furnace will produce CO. Combustion monitoring equipment would have indicated the large amounts of carbon monoxide.

An unrelated but dangerous problem was found in the downstairs rental apartment, which was served by the main furnace and did not have a separate thermostat. When the downstairs occupants were cold, they would operate the kitchen range with the oven door open, producing 990 ppm of CO. The owner was advised to have the range cleaned and adjusted, to install a vented range hood, and to ensure that the oven was not used for heating the room.

More Furnace and Vent Malfunctions: Case Two

In 1981, a farm family had had a bad experience with carbon monoxide. During a nighttime blizzard, the entire family was exposed to CO from unburned fuel caused by a malfunctioning furnace burner. The family sat in the car all night, too sick to drive and unable to see through the snowstorm.

Remembering the incident years later, the children gave their mother a battery-operated CO detector for Christmas. The alarm was silent until the following fall, when it went off after the woman turned the furnace on and ran it for a short time. The woman opened the windows, turned off the furnace, and called her heating contractor. He told her the furnace was not malfunctioning and said the detector was faulty or too sensitive. She exchanged the detector.

Six weeks later, at 6:30 am, the new CO detector went off. The woman called the liquefied petroleum (LP) gas supplier, her heating contractor, the sheriff, the fire department, and the first responders at the hospital. None had equipment to test for carbon monoxide. The gas supplier found nothing wrong and the heating contractor left a note saying, "I found the furnace to be OK for Carbon Monoxide--the filter looks OK also for the winter--furnace inside on the top looks like new yet. If any questions call me. Thanks."

Again the woman exchanged the detector and got another. The store owner told her there had been a lot of defective detectors. He assured her this one was less sensitive and would not alarm.

In January, the woman read a brochure about an Iowa State University workshop on carbon monoxide where I was speaking. She contacted me to tell me she was interested in carbon monoxide due to her experience 14 years ago. She was concerned that no one in her local community had equipment to measure for CO, and hoped I would encourage them to obtain equipment. She went on to tell me her stories about "bad" detectors and "false" alarms.

Obviously something was remiss in her house. She still had the same furnace that had leaked combustion products 14 years before; she had two different detectors that had alarmed; she was experiencing headaches; and the CO investigators did not appear to have the equipment they needed to find the problem.

The following day I went to her home to investigate. I found elevated CO concentrations with the kitchen at 6 ppm and the basement at 22 ppm. The furnace was producing over 3,800 ppm in the flue gases, with a weak draft and some spillage at the draft diverter. The weak draft was not surprising, as the vent ran horizontally for approximately 15 ft in an unheated crawlspace before turning and exiting through the north roof. A few minutes of furnace operation raised the basement concentrations to 35 ppm.

I advised the occupant to leave the home until the furnace problems were corrected. She phoned her contractor, whose only diagnostic questions were "Is the detector alarming?" and "Is the furnace heating?" When told the detector was not alarming and the furnace was heating, the contractor informed the owner that there was no serious problem.

The occupant contacted another heating contractor, who immediately came to the house. After inspecting the furnace, he agreed it needed either immediate repair or replacement. The LP supplier was also contacted. We found defective gas regulators both on the LP tank and outside the house that caused excessive manifold gas pressures at the burners. Based on the age and condition of the furnace and the vent system, the contractor advised replacement with a new, direct-vent sealed-combustion furnace and advised the occupant not to stay in the house until he could replace the furnace.

The woman moved out, and I monitored CO concentrations for the following two cold January days. This case is a good example of the intermittent nature of vent failure. The draft was weak when I was there. The furnace was producing high concentrations of carbon monoxide and had caused multiple detector alarms. It spilled sufficiently to raise the basement concentration to 35 ppm. Yet during the following two days, the highest CO reading in the basement by the furnace was only 4 ppm.

The Air-Flow Balancing Act: Case Three

Although heating contractors couldn't solve those first two cases, the problems were obvious--rusty and sooty furnaces. In this case, the problem was not obvious from casual observation of the two furnaces and the venting systems. The furnaces were relatively new and appeared to be in good condition. There was no soot or rust and the flames were blue. Without proper equipment to measure for carbon monoxide, air flows, and pressure differences, the initial investigators had been unable to diagnose problems caused by house depressurization from exhaust air flows.

The family had bought the house from a retired couple in June, 1993. In October, all five family members were hospitalized, with dangerous carboxyhemoglobin levels of 13%-30%. They were treated with oxygen and released. A heating contractor determined that the problem was an improperly installed thermally-actuated flue damper on the water heater. The 4-inch damper was installed over a 3-inch vent pipe, which blocked the damper operation.

After the poisoning, the family purchased four battery-operated CO detectors, which sounded intermittently, even after the damper was removed. The detectors required frequent fresh air rejuvenation and replacement of the sensing cells. A CO chemical card also turned black. The heating contractor, the utility company, and the building inspector failed to detect any carbon monoxide with gas indicator tubes. A member of the family was poisoned again, with carboxyhemoglobin levels in excess of 33%.

The heating contractor informed the homeowner that the poisonings had resulted from a blocked water heater damper, a gas fireplace that had been left on overnight and had backdrafted, and fresh air intakes that had frozen shut. The contractor said he solved all three independent problems.

The heating contractor extended the main 7-inch vertical vent an additional 5 ft above the flat roof and added an elbow above the roof to the existing 9-inch vertical combustion air intake. To bring ventilation air into the house, he also replaced the 1/8-inch screen on the combustion air intakes with a larger screen after frosting occurred (code requires 1/4-inch mesh). He advised the homeowner to install glass doors on the gas fireplace, keep the doors closed, and only operate the fireplace during waking hours. The contractor installed an additional 6-inch outside air intake, connected it to the return duct at both furnaces, and advised the homeowner to operate the furnace blower continuously.

All this was done, but the alarms continued to sound intermittently. The contractor had no more solutions to offer. He advised the homeowner to monitor the CO levels herself, using gas detection tubes that he gave her. The homeowner, by now frustrated and scared, believed that he was not taking her concerns seriously. She asked Iowa State University for assistance, and after a telephone consultation, was given the names of several contractors for further evaluation.

Multiple problems were identified. The water heater vent was blocked; the gas fireplace backdrafted and caused backdrafting of the water heater and furnaces; the venting was undersized; the house depressurized when various combinations of exhaust appliances operated; the vertical combustion air intake was often covered with snow and ice; and the combustion units were producing carbon monoxide. Two additional possibilities that were not investigated were depressurization of the house caused by winds over the attic ridge ventilator, and combustion products being reintroduced into the house through the combustion air intake located on the flat roof next to the vent termination. The combustion and outside air provided was not sufficient for all the exhaust appliances, even with additional openings that had been installed.

Section 607 of the Uniform Mechanical Code states, "Operation of exhaust fans, kitchen ventilation systems, clothes dryers or fireplaces shall be considered in determining combustion air requirements to avoid unsatisfactory operation of installed gas appliances." This rule wasn't applied. 1,685 cubic feet per minute (CFM) of exhaust appliances existed in the house (see "Physical Characteristics, Case Three"). Only 334 CFM of outside air, plus 148 CFM estimated natural infiltration had been provided. (Estimations were arrived at by using blower door tests and established procedures.) The operation of the gas appliances showed that this was insufficient, resulting in the primary problem.

To provide sufficient combustion and makeup air would require either large openings to the outdoors or powered intake fans operating in conjunction with exhaust and heating appliances. My experience shows that even when combustion air openings are added and meet code, they do not always function adequately. Adding powered intake fans, with safety interlocks, also did not seem a good solution--those systems are complex and expensive to install. In addition, powered intake fans would blow cold outdoor air into the house and increase gas and electrical use.

The previous owners, a retired couple, probably hadn't experienced severe problems because they had a different life-style. The present occupants used many of the exhaust appliances concurrently and often: range hood, bathroom fans, clothes dryer, and gas fireplace. The retired couple hadn't used all four bathrooms at the same time and rarely used the fireplace. Their risk increased when they had guests and used all exhaust appliances.

Heating contractors failed to reduce CO production levels from the heating appliances. Carbon monoxide levels rose to over 35 ppm after only seven minutes of backdrafting combustion products from the furnaces and water heater into the utility room, even with utility room door open to the lower level. The test was discontinued. The production was probably caused by a dirty burner, poorly adjusted burners, inadequate primary air, or overgassing.

The homeowner was advised to replace both furnaces with high efficiency sealed combustion units and upgrade the water heater by adding induced draft. She was advised to stop using the gas log, or replace it with a direct-vent, sealed-combustion gas fireplace insert. She replaced both furnaces and the water heater. The family has experienced no further problems with carbon monoxide and enjoys increased comfort and lower heating costs.

By installing new high efficiency, direct-vent furnaces, the homeowner eliminated problems with insufficient combustion air and house depressurization. The furnaces' sealed and dedicated pipes obtain needed combustion air directly from outdoors, regardless of the depressurization in the house. As package units, new furnaces are relatively simple to install; don't cause drafts from combustion air being drawn into the house; and decrease gas, electrical and heating costs.

Other Sources of CO Poisoning

Charcoal grills often go unrecognized as a source of carbon monoxide. In Iowa, a couple were recently killed by a charcoal grill stored for the night under their fifth-wheel camper. The cover accidentally slipped off the grill, and they were both found dead the next morning. In recreating the accident, I found that it took less than two minutes for carbon monoxide to enter the camper. In approximately one hour, concentrations in the bedroom of the camper rose to over 500 ppm, high enough to kill the occupants.

Some sources, such as blocked chimneys, are obvious but still get overlooked. Downdrafting is not always obvious and occurs intermittently. Depressurization from exhaust fans, wind, or other sources is often overlooked, too. New heating appliances are designed to operate in today's tight houses and should be installed when CO problems from older heating appliances occur.

These cases emphasize the need to have the heating system inspected annually by a qualified heating contractor--and to have sensitive, listed CO detectors installed as additional insurance.

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