CO Leaks

CAUSES & CURES

These three cases illustrate the dangers of carbon monoxide spills and the difficulty of properly diagnosing the causes

by Thomas Greiner

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.

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 can be varied: 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.

The water heater and furnace are common-vented in the back corner of this basement. In this case, common-venting caused severe CO problems when a bird's nest on the top of the house blocked the chimney. CO spilled into the basement from both appliances. (If the appliances had been vented separately, only one would have spilled CO.)

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. Although there is no indoor air quality criteria for CO in homes, the EPA limit for outdoor air is often used. The EPA requires that CO levels not exceed 9 ppm for longer than 8 hours more than once a year.

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.

This direct-vent sealed-combustion high-efficiency furnace is installed correctly. Note the plastic discharge pipe and sealed plastic air intake pipe. Being completely sealed, they can work independently of any air pressures within the home.

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 had assumed that the heating contractor corrected the CO problem and had not purchased a second detector, they would have unknowingly 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 at 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,

The top of this water heater shows evidence of flue gas spillage — the rust, paint discoloration, and debris are all clues to a backdrafting problem. A CO detector would give more immediate warning of the same problem.

Some backdrafting problems leave obvious markers, such as the rust and corrosion inside this furnace burner compartment.

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 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 amiss in her house. She still had the same furnace that had leaked combustion products 14 years before; she had purchased two different detectors that had both 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 feet 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 woman to leave home until the furnace problems were corrected. She phoned her contractor, whose only diagnostic questions were "Is the detector alarming?" and "Is the

A simple CO detector alerted the owners of this house to a serious carbon monoxide problem, which a technician blamed on a chimney stuffed with dead birds. The author was called in after a second alert, and found that the furnace was producing tremendous amounts of CO, which spilled into the basement even without the obstruction in the chimney. The CO killed birds landing on the chimney; the dead birds then fell into the vent, worsening the spillage into the basement.

This chimney, in contrast, is equipped with a proper cap on the gas vent, which will prevent bird entry. However, as the earlier case demonstrates, the roots of carbon monoxide problems are often complex, and heating contractors need to look beyond simple solutions.

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.

She then 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. What I found on this second visit provides a good example of the intermittent nature of vent failure. On my original visit, I had found that the draft was weak and the furnace was producing high concentrations of carbon monoxide, raising the basement levels to 35 ppm. Yet during the following two days, while the furnace was running, the highest CO reading I measured in the basement near the furnace was only 4 ppm.

The Air-Flow Balancing Act: Case Three

Although heating contractors couldn't solve those first two cases, the symptoms were obvious — rusty and sooty furnaces. In this third case, the problem was not evident 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 ten-year-old 5,600 square-foot house from a retired couple in June, 1993. The house was well built and had been well maintained. In October, all five family members were hospitalized with dangerous carboxyhemoglobin levels ranging from 13% to 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 feet 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. The total exhaust from all exhaust appliances in the house was 1621 cfm (see table, next page). Only 334 cfm of outside air, plus 148 cfm estimated natural infiltration, had been provided. (Estimates 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 lifestyle. 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 the 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

A contractor investigating a CO problem attempted to alleviate a furnace backdrafting condition by providing an additional combustion air intake (note the black plastic tubing at left.) While this measure helped to equalize pressure in the house, it was not sufficient to counteract all the exhaust fans in the house and correct the problem.

Case Three: Exhaust Air vs. Intake Air (cfm)

Exhaust Measurements	
Kitchen exhaust	500
South bathroom #1	44
South bathroom #2	44
Northeast bathroom #1	82
Northeast bathroom #2	66
Entry bath	52
Basement bath #1	29
Basement bath #2	50
Clothes dryer	104
Subtotal, mechanical	**971**
Fireplace, gas	535
Water heater	25
68,000 btu furnace	40
90,000 btu furnace	50
Subtotal, gas appliance vents	**650**
Total Exhaust	**1621**

Outside Air Provided	
9-inch fresh air to utility	110
6-inch furnace combustion air	138
4-inch fireplace combustion air	86
Total Outside Air	**334**
Natural Infiltration	**148**

As this table shows, total exhaust potential far outweighed the outside air provided to the house in Case Three. When several exhaust fans operated at once, which was common with the family of five, the house was depressurized and backdrafting of the combustion appliances occurred. Natural infiltration, while sometimes helpful, is not a reliable way to provide makeup air because it is controlled by wind and weather conditions.

The rust and soot on the outside of this furnace cover is echoed by the mess on the inside. The rust is usually a result of moisture that forms when trapped gases condense inside the furnace as a result of backdrafting.

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. New furnaces are relatively simple to install, don't cause drafts from combustion air being drawn into the house, and decrease 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 small charcoal grill, which they had cooked on and then stored for the night in the storage compartment of their camper. As the coals burned out, 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, UL- or AGA-listed CO detectors installed as additional insurance.

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