

# Carbon Monoxide from Ovens: A Serious IAQ Problem

by George Tsongas

*It might not be the turkey that puts you to sleep after Thanksgiving dinner.*

**T**raditionally, few people have considered gas ovens to be a major source of carbon monoxide (CO), even though all their exhaust products are often vented directly into the indoor air of a residence. Yet unvented space heaters with a similar output of combustion gases have been banned in many states because of indoor air quality (IAQ) dangers inherent in their use.

CO poisoning in homes is generally the most serious of the wide variety of IAQ problems, in that people can die quickly from it, whereas most other such problems can be considered chronic. Weatherization personnel must perform a variety of combustion safety tests to determine if CO is being produced by any of the combustion appliances in a residence. If they find dangerously high levels, the crew should know how to fix the problem.

## CO and Its Effects

Carbon monoxide is a colorless, odorless, nonirritating, but highly toxic, gas. It is flammable and slightly lighter than air. It is produced whenever there is incomplete combustion of hydrocarbon fuels—that is, when there is insufficient air to burn the fuel completely. The highest concentrations of CO typically occur at start-up of the appliance. This is especially true of ovens, because little or no air can flow through the oven until the air inside it heats and rises out of the exhaust vent.

High levels of CO cause headaches, nausea, shortness of breath, dizziness, confusion, brain damage, and, in severe cases, death. CO strangles the victim by



GEORGETSONGAS

During field tests of ovens in 60 apartments, researchers found that 51% of the readings of CO level in the kitchen air were over the recommended exposure limit of 9 ppm for an eight-hour period.

reducing the amount of oxygen that can get to cells and impairing the body's usage of oxygen even if it reaches the cellular level. Victims should be removed from the exposure, though symptoms often persist well after removal from the source. That is because the so-called half life of CO in blood—the time for the peak concentration to decline to half its original value—is about four hours.

Often the symptoms are similar to those of flu. People who may have been exposed to CO should go to the hospital

for a simple blood test. Another option is to check carboxyhemoglobin levels in the blood using a breath CO detector. A relatively inexpensive (\$95) attachment is now available for Bacharach MONOXOR II carbon monoxide monitors, which are widely used for combustion safety testing.

Symptoms are related to the exposure level and time of exposure. The U.S. Environmental Protection Agency (EPA) recommends that a person should not breathe CO concentrations of 9 parts per million (ppm) or higher for any eight-

hour period; 35 ppm or higher for any one-hour period; or 200 ppm or higher at any one time. Moreover, a person should not be exposed to any one of these three conditions more than once per year. The World Health Organization and Health Canada recommend a maximum exposure of 25 ppm for a one-hour period. ASHRAE Standard 62-1989 recommends an exposure limit of no more than 9 ppm in a living space, and Japan has an indoor standard that limits exposure to 10 ppm for any duration (see "Suicide in Sendai," *HE* May/June '95, p. 40).

## Field Test Findings

Excessive carbon monoxide production from combustion appliances and CO poisoning are much more common than has previously been recognized. Among 25 homes with gas ovens tested in an ongoing survey by Montana Power Company's Low-Income Weatherization Program in Kalispell, Montana, CO concentration in the kitchen was found to be greater than 9 ppm in the cooking area in every case.

At Portland State University (PSU), my group measured IAQ in 23 low-income homes. One-third had ovens that caused levels in the cooking area to exceed the eight-hour 9 ppm standard after 20 minutes. However, 10 of the 23 cases showed CO levels increasing with time. (CO levels from the oven operation were monitored at 3, 10, and 20 minutes after turning on the oven.) That indicated the need to go back and continue testing over a longer time period. Most of the apartments or homes were fairly small and apparently leaky, demonstrating that leaky dwellings, as well as tight ones, are vulnerable.

In the few cases where CO released from stoves has been monitored, the stoves probably were not left on long enough to reach the maximum CO levels in the kitchen air. We conducted a follow-up study in Portland to determine just how long it takes to reach steady-state conditions (maximum indoor CO levels). Sixty ovens were monitored in two relatively leaky apartment buildings with the oven set on broil and the oven door closed. Half of the readings were over 9 ppm, and 15% were over the one-hour 35 ppm standard level.

The minimum time for an oven to reach maximum CO levels in the surrounding air was 20 minutes, but the average was 45 minutes to 60 minutes. Reaching equilibrium in that short a time implies that the apartments were very

leaky, as was the case. Had they been much more airtight, it could have taken many hours to reach steady-state conditions, though the steady-state level would be higher than that in the leakier units. Tight homes also tend to have higher indoor CO levels from long-term oven operation.

The study also found that CO levels in

the exhaust ports can indicate potential IAQ problems. In the field tests, about 40% of the ovens had CO production levels in excess of 50 ppm in their undiluted exhaust port at the time of the maximum CO reading in the kitchen air; the highest reading was over 2,000 ppm, and the average was 100 ppm. Ovens should be tuned if the steady-state CO levels in their undi-

## Recommended Oven CO Test Protocol

- All gas and propane ovens should be tested for combustion safety, since they can be a major source of carbon monoxide (CO).
- Test the oven in its as-found condition (do not clean or adjust) before starting any weatherization.
- Use an electronic CO meter with a range of 0 ppm–2,000 ppm and a resolution of 1 ppm, such as the Bacharach MONOXOR II. Older nonelectronic meters or diffusion tubes are not suitable.
- Zero the CO meter. This is typically done outdoors in a rural or unpolluted area. Do not zero for individual houses. Calibrate the meter with 10 ppm and 500 ppm calibration gas about every six months (check zero at this time).
- Turn the kitchen exhaust hood on, if one exists, to avoid exposing test personnel to potential CO.
- Insert the CO meter probe tip well into the oven exhaust vent (typically an opening about 1 in high by 5 in wide centered in the back dial section on the top of the stove). The intent is to monitor the exhaust gases inside the oven exhaust before they are outside the oven and diluted with air.
- Turn the meter on and then turn the oven on bake at 350°F with the oven door closed.
- Watch the CO meter reading rise and record the peak or maximum reading. It should typically reach a peak within about 5 to 10 minutes and then begin to drop back down again to a steady value after a much longer time.
- If the peak value is less than 100 ppm, the oven is not producing elevated levels of CO and need not be tuned or adjusted. Weatherization can continue.
- If the peak value is greater than 100 ppm, turn the oven off. It is producing elevated levels of CO that could cause adverse health effects. It needs to be cleaned, tuned, or otherwise adjusted prior to or in conjunction with any air tightening of the dwelling.
- If aluminum foil is lining the oven bottom, it needs to be removed or perforated along its edges so the secondary air holes in the oven bottom are not blocked. Such blockage is a major cause of high CO levels.
- If the CO levels are still above 100 ppm after removing or fixing the foil, or if no foil is present, clean or tune the oven.
- After the oven has completely cooled (at least 30 minutes with the oven off and the oven door open), turn the oven back on. Recheck the peak CO level in the oven exhaust gases.
- Continue to adjust and recheck the peak exhaust CO level until it is below 100 ppm; only then continue with weatherization. Almost all ovens can be satisfactorily tuned in the field.
- If, after repeated tuning attempts, the CO levels are still elevated, call the oven manufacturer. A few models cannot be satisfactorily tuned.
- If the occupants complain of headaches, nausea, flulike symptoms, or worse, or if a home CO detector alarm has gone off recently, measure the occupants' CO blood levels with a breathalyzer or recommend that the occupants get a blood test immediately at a hospital. Turn off all combustion appliances.
- In extreme cases, it may be advisable to measure the maximum steady CO level in the kitchen air. After oven start-up it typically takes at least an hour to reach that level in loose dwellings and may take upwards of 8 to 10 hours in very tight homes.
- Consider giving any client whose dwelling has any type of CO combustion appliance, or at least those whose oven was not satisfactory, a home CO detector. Types with an LED readout are preferable (see "Conservation Clips: CO Detectors Not Created Equal" p.63).

Two important caveats:

- (1) This protocol does not apply to convection ovens, which have been known to blow hot air full of CO into the auditor's face.
- (2) A separate protocol needs to be developed for testing stove burners. In both cases, the indoor CO level should be tested.

luted exhaust gases is above about 25 ppm. Higher exhaust concentrations can produce indoor air readings above 9 ppm, with consequent adverse health effects.

Other field tests have corroborated the studies in Montana and Oregon. One low-income home I tested in Philadelphia had a CO level of 330 ppm in the kitchen air after only five minutes of oven operation! Similar problems were found with hundreds of homes in a study directed by Bruce Davis as part of low-income weatherization efforts in Arkansas. In almost every case the excess CO levels in the oven exhaust ports were reduced to below about 25 ppm after the oven was cleaned or adjusted.

It is particularly important to recognize that gas ovens are used as either the main or a supplemental space heating source in numerous U.S. homes, especially low-income homes. Two medical studies have indicated that 40%–50% of all urban low-income dwellings are heated with their ranges. It would seem reasonable that a similarly large fraction of nonurban low-income dwellings are heated in the same way. Given that about half of the ranges in the United States are gas or propane fired, and that about 20% of the U.S. population is classified as low-income, the potential problem is enormous.

The evidence suggests as much. In a recent study of the factors setting off CO detector alarms after their use was mandated in Chicago, stoves (either stove burners or ovens) were deemed responsible in 78% of the cases. At one Kentucky hospital, when patients coming into the emergency room with flulike symptoms were given blood tests, about 25% were found to have CO poisoning. These limited test results indicate that combustion appliance operation is often unacceptable. Monitoring for safety should be the first priority for weatherization crews.

## CO Monitoring

Sufficiently sensitive monitoring equipment has been available at relatively moderate cost to measure CO levels only in the last few years. This equipment measures levels both in the undiluted flues and exhaust ports of combustion appliances and in the indoor air. Low-income weatherization agencies have recognized the need to use the newer equipment and have purchased it. However, most utilities and heating contractors have no CO monitoring equipment, sufficiently sensitive or not.

## CO Test Protocol

Fortunately, testing for CO production from stove burners or ovens is relatively easy. Monitoring requires a continuous readout CO meter that is accurate to within a few ppm. The most extensively used CO meter (typically for furnace and water heater testing) is the Bacharach MONOXOR II, which is widely sold for about \$600–\$700. It has an electrochemical sensor with a readout range of 0–2,000 ppm, making it quite accurate in the low range. Some older pump-type or diffusion tube-type monitors are not appropriate because they cannot detect low levels of CO.

Before monitoring the effects of an oven, always check to see whether there is aluminum foil on the bottom. This foil often blocks the secondary air holes along the edges and results in excess CO production. I have personally covered the bottom of an oven with foil and produced over 750 ppm in the kitchen air!

One approach to monitoring the effect of an oven is to turn it on and measure the CO level in the kitchen air after a few minutes. But that method is now discredited because it can take hours for indoor CO levels to reach their peak.

Another approach to monitoring is to turn the oven on to the bake setting (at say 350°F), and close the oven door as soon as possible. Then measure the kitchen CO levels at a height of 5 ft at regular intervals of 15 to 30 minutes until the levels are constant at their peak values and record the time elapsed since the

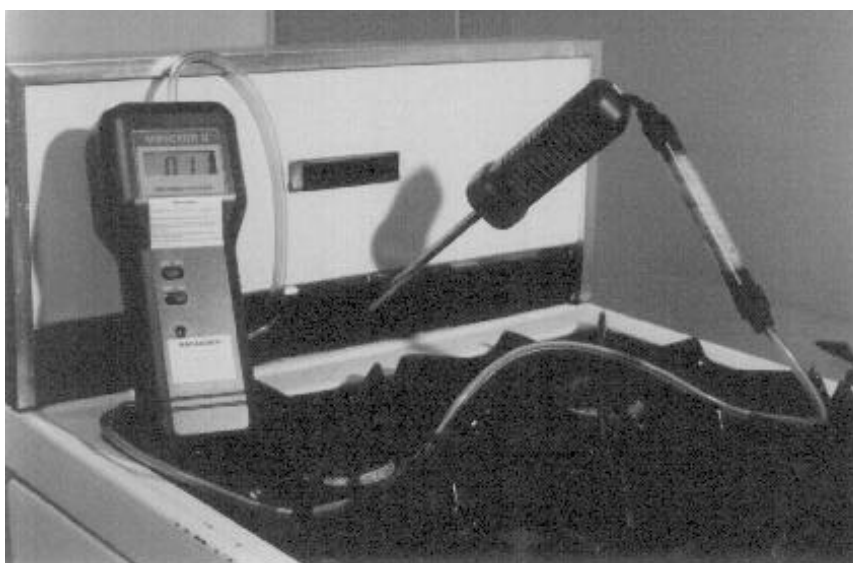
oven was turned on. If the CO level is above 9 ppm, a potential health problem exists, and the oven must be tuned prior to any weatherization.

A faster approach is to monitor the CO level continuously in the undiluted exhaust port or vent of the oven (see “Recommended Oven CO Test Protocol”). The CO level there should peak in the first 5 to 10 minutes or so after oven start-up. If that peak level is above 100 ppm, the oven should be tuned prior to any weatherization. After tuning, recheck the peak level; it should be below 100 ppm. It may also be wise to check the steady-state or maximum kitchen CO levels for those cases where the exhaust port peak CO level is well above 100 ppm.

Even tuned ovens can go out of tune, so dwelling owners or occupants should install smoke alarm-type carbon monoxide detectors. They typically cost about \$40–\$50. An excellent one is the Nighthawk 2000, which has a digital readout and is sensitive from 0 to 999 ppm. It is strongly recommended that detectors be installed in all dwellings that have combustion appliances, including homes with attached garages.

## Oven Repair

There is very little information readily available on how to adjust, clean, or otherwise tune an oven that is producing excessive levels of CO. However, experience in Arkansas with more than 300 ovens and in a PSU research project indicates that the following items should be checked:



Sensitive monitoring equipment, such as this CO meter, has become more widely available and affordable in recent years.

- Primary air adjustment—check the shutter opening. This is very important.
- Fuel orifice size. The size will be different for liquified petroleum (LP) and natural gas.
- Oven supply pressure. It is usually best to maintain the value stamped on the plate—usually 3.5–4.5 in of water (870–1,100 Pa) for natural gas and 9–11 in (2,200–2,700 Pa) for LP. Also check rated heat input on the plate and ensure that the orifice and pressure combination provides that input.
- Secondary air path. Secondary air holes should be cleaned or cleared; pay special attention to the presence of aluminum foil lining the bottom of the oven and covering the secondary air holes.
- Burner and pilot. These should be cleaned.

The good news is that most ovens can easily be repaired so that they emit little or no CO in the exhaust port, typically below 100 ppm peak or 25 ppm steady state. Ovens are basically simple devices, and repair tools cost little. A Dwyer, Ritchie, Bacharach, or other brand U-tube manometer to measure the gas pressure should cost between \$10 and \$40. A

small brass wire brush, flair wrenches, and an asbestos glove are used for tuning as well.


## Kitchen Exhaust Fans

Ventilating combustion products directly out of the kitchen eliminates the opportunity for them to affect occupants. This would get rid of CO and also oxides of nitrogen that are always present. These pollutants are a special concern in tight houses.

Kitchen fans are generally noisy, in part because they have relatively high flow rates. If they are too noisy, people will be reluctant to use them. Thus in selecting an exhaust fan to install in an existing home, look for one that is relatively quiet. It may require a fan with a somewhat lower capacity, but that is probably a good tradeoff. It's better to have a lower-power fan that is used than a high-power one that isn't. One fairly quiet option for retrofitting a fan into an existing home is remote installation: an axial fan that is rated for greasy air can be installed in an attic.

Finally, it is important to educate clients about the need to use their kitchen

exhaust fan (if one exists) whenever the range is operating. Often people think that the only reason to use it is to get rid of cooking odors. Using fans can help reduce indoor pollutant concentrations by removing the pollutants at their source.

Whether or not an exhaust fan exists, safety tests should be performed in any home with combustion appliances, particularly before any weatherization efforts are undertaken. These simple tests have the potential to eliminate a serious safety problem. 

## Further Reading

Heckerling, P., et. al. "Predictors of Occult Carbon Monoxide Poisoning in Patients with Headache and Dizziness." *Annals of Internal Medicine* 107 (1987): 174–176.

Sterling, T.D., and Kobayashi, D. "The Use of Gas Ranges for Cooking and Heating in Urban Dwellings." *Journal of the Air Pollution Control Association* 31 (1981): 162–165.

*George Tsongas is a professor of mechanical engineering at Portland State University in Oregon and a private consulting engineer.*