AIVC 12,367

Carbon Monoxide

by Richard Kadulski

Tabloid paper headlines would scream "The Invisible Killer in your home!"

About fifteen years ago, we became aware of radon as a health hazard. Then, its presence and allowable concentrations were little understood. Now we are becoming aware of the more significant presence of carbon monoxide (CO), a much more toxic substance. CO is a colourless, odourless deadly gas with no "safe" concentration. Because you can't see, taste, or smell CO, it can kill you before you know it is there.

The production of CO is entirely within our control, because of the combustion appliances we use. Properly installed and maintained appliances will reduce CO production. Trouble starts when combustion appliances are installed improperly.

Everyone is at risk for CO poisoning. However, individuals with greater oxygen requirements such as unborn babies, infants, children, senior citizens, and people with coronary or respiratory problems are at greater risk.

The danger of CO is its attraction to haemoglobin in the blood as the CO replaces the oxygen body cells need to function. Haemoglobin-carrying CO is not able to release oxygen to the tissues, which start to asphyxiate. When CO is present in the air, it quickly accumulates in the blood. Its affinity with red blood cells is up to 270 times greater than the affinity of oxygen and haemoglobin.

Breathing air containing carbon monoxide at 100 ppm (parts per million) for two hours has been shown to increase blood carboxyhemoglobin concentrations up to 16.0%, a concentration that can cause the symptoms of CO poisoning. CO is released slowly. After three to four hours of breathing fresh air only half the CO is eliminated from the blood.

Carbon monoxide in the body causes flu like symptoms, such as headaches, fatigue, nausea, dizzy spells, confusion, and irritability. Because CO reduces oxygen delivery to the brain, persons with higher levels of CO in their blood do not think clearly, and might not recognize the warning signs. As levels increase, vomiting, loss of consciousness, and eventually brain damage and death can result.

The true incidence of exposure to carbon monoxide is unknown and may be greatly underestimated, as it can be easily misdiagnosed by medical personnel as the flu or even food poisoning. Accidental CO exposure in a home can be difficult to reproduce and document. Yet exposure to CO caused by intermittent spillage from vented appliances has serious consequences.

Carbon monoxide poisoning is not directly an issue for builders. However, systems incorporated into buildings, building design and construction details can contribute to increased CO levels.

Carbon monoxide is a by-product of incomplete combustion whenever fuel does not have sufficient oxygen. In properly installed and maintained appliances, gas burns clean and produces little carbon monoxide. However, anything that disrupts the burning process or results in a shortage of oxygen can increase CO production. Wood, coal, and charcoal fires always produce carbon monoxide, as do gasoline engines. Common home appliances such as gas or oil furnaces, gas clothes dryers, gas ranges, gas water heaters or space heaters, fireplaces, charcoal grills, and wood burning stoves and tobacco produce CO. Fumes from automobiles and gas-powered lawn mowers contain CO that can enter a home through connecting walls or doorways if an engine is left running in an attached garage.

What causes carbon monoxide not to vent to the outside?

Incorrectly installed venting systems and chimneys, chimneys plugged by bird nests, tree leaves, or ice build-up, deteriorating chimneys, chimneys too short to vent correctly, appliances with no venting system, and house air flow patterns and downdrafting can all cause vent failure.

A chimney relies on the buoyancy of warm air to carry combustion gases out of the house. Unfortunately, buoyant forces are weak and can easily be overcome by kitchen and bathroom exhaust fans, clothes dryers, and air leaks in the house. Winds around the outside of the building or a chimney that is too short can create a downdraft. Although downdrafting usually disappears as the flue warms up, it can last for several hours.

The air handling blower on a furnace is much more powerful than the natural draft of the chimney, so poorly installed or leaky ductwork on the air return side can downdraft the chimney. In one documented case, an Iowa family was hospitalized

Thomas H. Greiner, Associate Professor at Iowa State University is one of North America's leading experts on carbon monoxide. He has written a number of easy to read papers on the issue. They are posted on the Iowa State University web site. These papers were valuable in preparing this story. They can be accessed at:

www.ae.iastate.edu/human_housing.htm

or

www.exnet.iastate.edu/Pages/communications/CO

Actively discourage house designs with attached garages. . . it is difficult to achieve gas tight enclosures between the house and garage.

How much should you pay for a CO sensor? Good CO detectors cost about $90. to $100. If you are offered one for much less, then it's quality is suspect.

with CO poisoning because they had removed the cover on the return side of the furnace, and that was enough to depressurize the furnace room.

CO build-up inside homes is not an issue just for new, draft free construction. Drafty, leaky older houses also are subject to CO problems.

Besides the obvious problems with leaky houses (they are hard to heat and cool, drafty, and uncomfortable) there can also be venting problems. The stack effect in a leaky house which has a large portion of its leakage located high on the house, (e.g., in the ceiling or on the second floor) creates a suction that draws replacement air into the house through the basement and lower levels. The negative pressure at the lowest level can pull air down the chimneys and vents, causing combustion gas spillage into the home.

Even installed make-up air ducts may not be adequate. Fan-powered combustion air kits which operate whenever the appliance burner is on to force air into the furnace room for combustion air and for venting are more reliable than passive combustion air pipes.

Carbon Monoxide Concentrations

CO Concentration *(ppm)*	Effects
0-2	normal ambient concentrations
9	max allowable concentration over 8 hour period (ASHRAE)
15-20	impaired performance (2-3% concentration in bloodstream)
20	typical concentration in flue gases of properly operating furnace
25	Workers Compensation Board (BC) max allowable average workplace exposure over 8 hours
50	max allowable average workplace exposure over 8 hours (USA- OSHA)
110	measured concentration in skating rink
200	maximum workplace exposure (US - NIOSH) alarm must sound within 35 minutes
800	dizziness, nausea & convulsions within 45 minutes; death within 2-3 hours
3,200	concentration inside charcoal grill
35,000	tailpipe exhaust from warm gasoline engine without catalytic converter
70,000	tailpipe exhaust from cold engine during first minute of cold weather start

Detection and remedial action are a new investigative area. Tools are still being refined, and technicians are only beginning to appreciate the subtleties involved. This was highlighted in an Iowa Study.

Indoor air quality studies in 65 Iowa homes found 29 with excessive concentrations of CO produced by the furnace or water heater. The response of professionals contacted by homeowners for help was inadequate; ten professionals claimed to have fixed the problem - but had not; six reported no CO problem and told the homeowners the problem was the CO detector when in fact there was a CO problem; three indicated there was a problem but could not find it; one said the problem was caused by freak weather, and would not likely recur - but it was a CO problem that would likely recur. Only two professionals correctly diagnosed and corrected the problem.

How can carbon monoxide poisoning be prevented?

1. Prevent carbon monoxide from being produced by proper design, installation, and maintenance of combustion appliances. In our new, more airtight houses, providing combustion air and avoiding excessive depressurization is critical.

2. Vent combustion products outdoors. Dilution with outside air is not an efficient method of removing pollutants. Providing more outside air while CO is still being produced does not solve the problem and is dangerous. Even with high volumes of dilution air, the air quality is degraded when pollutants are dumped into a space. Removing toxic materials at the source is safer and more effective.

To remove any small amount of CO that might be produced, and all other products of combustion, the heating appliances should always be vented to the outdoors. The new, direct-vent sealed combustion appliances give positive venting of all combustion products to the outdoors while increasing efficiency and lowering heating costs.

3. Install carbon monoxide detectors.

Garages and CO Concentrations

Actively discourage house designs with attached garages. Evidence is beginning to show that it is extremely difficult to achieve gas tight enclosures between the house and garage.

When a car engine is started from cold, the fuel mixture is rich (causing more CO), and the catalytic converter is ineffective. Even well-tuned engines will produce more than 80,000 ppm for the first minute or two of operation. The CO concentration will typically drop to 1,000 ppm or less after 5 to 15 minutes of operation.

A 5.5 horsepower gasoline-powered pressure washer was run in a double garage with both doors open, the window open, and a vent open. In 12 minutes CO concentrations in the garage rose to 658 parts per million (ppm).

The rate of emissions from a typical gasoline engine is so large (30,000 to 100,000 ppm) that providing sufficient ventilation is very difficult. It is NOT recommended to use equipment and tools powered by gasoline engines inside buildings.

That is why it is important not to run a vehicle inside the garage any longer than the time needed to move it out of the garage. In commercial garages and underground parking areas, large capacity exhaust fans (with CO detectors) operate continuously to lower concentrations.

Measurements in one residential garage, where a car was warmed up for only two minutes with the overhead door open, the CO concentrations in the garage rose to 500 ppm. Ten hours after the car had been backed out of the garage, there was still a measurable concentration of CO in the garage.

Residential CO detectors are not designed or approved to operate in garage conditions, so they should not be used there.

Suggestions have been made that a garage exhaust could be used to remove CO. An exhaust fan from the garage to outdoors will lower the pressure in the garage. However, the fan can also depressurize the house so vented appliances (furnaces, water heaters, and boilers) can spill their exhaust gases into the house. If a separate exhaust fan is installed in the garage, it must be checked for proper operation after installation. Even with a garage fan operating, a gasoline engine in a garage is not safe.

Detecting CO in the field

Flame colour is not an accurate measure of CO concentrations. What is normally accepted as a safe blue flame may still be producing excessive concentrations of carbon monoxide. Measurement of CO in the flue gases is the only reliable method to determine if complete combustion is occurring.

Preventive Measures.

- Install CO detectors
- Yearly service of heating appliances by a qualified service technician
- Immediate action to protect all building occupants when a detector alarms.
- Correction of problems after a carbon monoxide detector alarms.

> *A little known fact is that the life span of all gas sensors is limited. Smoke detectors should be replaced every 7 years or so, while CO detectors have a life span of about 4 to 5 years. The test indicator light on most detectors only tests the function of the alarm signal, and the power supply, but not the sensor itself.*

Gas Detectors: How Do They Work?

Smoke detectors use a photoelectric sensor, which detects smoke by the reflection of light back to the cell, creating a current, and starting the siren. A second, more common type uses an ionizing detector. A tiny amount of radioactive material emits alpha particles into a chamber between two charged metal plates. Smoke in the chamber breaks an electric current, thus setting off the alarm.

The first commercial sensors for carbon monoxide were developed in Japan, using a metal oxide semi-conductor (also called MOS sensors). In these, the gas sensing detectors are two coiled-wire heating elements separated by an insulating material. When the right gas is present, a reaction takes place, causing free electrons to be released, thus changing the electrical conductivity, which sets off the alarm. They require power, so they are not effective during power outages, the most vulnerable time for CO generation (when combustion appliances are most likely to be used for heating). MOS sensors are not specific to CO, and can give false alarms as products such as hair spray, air "fresheners" and paint fumes can also set them off.

A further development was a technology that relies on colour chemistry to detect CO. These biometric or colorimetric sensors are more effective, but the technology was licensed exclusively to First Alert.

The latest technology, and the one that seems most stable is based on electrochemical detection. In this type any CO present reacts with oxygen in the air, affecting the current than flows through the detectors' circuit. The detector can differentiate between short term high and long term low concentrations of CO, and give warnings accordingly.

The major concern with sensor technologies is their reliability, as there can be a drift in the accuracy of the sensors. The accuracy of research grade MOS type CO sensors can change by 7% in one week, while commercial units have been tested to drift as much as 31%. Reports have shown that some detectors could fail to alarm at CO concentrations as high as 1000 ppm.

Tests of 96 detectors done by the Gas Research Institute (GRI) in the US, found that the electrochemical detectors gave the best performance overall.

Detector Standards

The standard for CO detectors has been updated three times since 1992. Unfortunately, many CO detectors sold in Canada in the past year are obsolete technology that in effect has been dumped into Canada, because the US standards have been tightened up quicker than the Canadian standard.

UL 2034 was the standard for many years, but concerns have been raised whether or not alarms meeting this standard provide acceptable performance. In the UL test, units are tested once only, from a manufacturer supplied sample (rather than a randomly selected unit). The UL standard does not require follow up testing of the samples to verify accuracy over time. GRI testing found that half the sensors tested failed to meet the UL requirements after 4 months of use.

A more robust standard is the *IAS 6-96* standard. The requirements are that detectors not activate at low concentrations, but must alarm at high concentrations. The low threshold is a CO concentration that would result in a 5% carboxyhemoglobin concentration in human blood, or 100 ppm for 35 minutes, 65 ppm for 65 minutes, 50 ppm for 60 minutes separated by 6 hours clean air, or 30 ppm for 30 days.

In Canada, the Canadian Standards Association is about to release its new standard, which will be known as *CGA 6.19-98*. This standard, which mirrors the IAS requirements, should be in effect by October of this year. When selecting a CO detector, look for the IAS or CGA standard label.