Carbon Monoxide Poisoning

By Randolph J. Harris

Carbon monoxide poisoning is believed to be the most common cause of poisoning in both homes and industry. Carbon monoxide (CO) is a colorless, odorless, toxic gas. Every year, thousands of victims die due to CO intoxication and even more survivors of CO incidents suffer from central nervous system damage. Most fire deaths are actually caused by CO inhalation.

You might remember from high school science class, that oxygen normally combines with the hemoglobin in the blood to form oxyhemoglobin, so that the oxygen can be transported to the cells of the body. Carbon monoxide combines with the hemoglobin to form carboxyhemoglobin (COHG). Carboxyhemoglobin is about 240 times more stable than oxyhemoglobin. Once combined, the hemoglobin will not easily give up the CO and therefore cannot carry oxygen. When there is insufficient hemoglobin left to carry oxygen, the victim dies from internal suffocation.

Normally, an average person's blood will contain just under 1% COHG from normal bodily functions. Smokers can have 5-10% COHG. Effects from COHG are not usually noticeable below concentrations of 10%. At concentrations of approximately 20% a headache can develop. More serious symptoms are severe headache, nausea, weakness, dizziness, unconsciousness, and finally, death. Generally, COHG saturation above 60-70% will result in death if not treated. The COHG concentration in the blood will decrease if the victim is brought into fresh air. The rate of decrease is improved if they are given oxygen or put in a hyperbaric chamber.

Carbon monoxide is created whenever a carbonaceous fuel is burned. Such fuels include fuel gases (natural, propane, acetylene, etc.), wood, coal, plastics, cloth, gasoline, diesel, oil, and most all normal fuels. When an appliance is operating properly, it can produce nearly zero parts per million (ppm) CO. However, it's not unusual to have nearly 400 ppm in flue gases. A flue is the exhaust pipe leading from indoor appliances to the outside of the house, usually through the roof. Abnormal operation of an appliance can produce several thousand ppm of CO. Even though gas appliances can produce dangerous concentrations, these combustion product gases normally flow up and out of the flue harmlessly into the atmosphere. But, if this proper air flow is disrupted, the CO can seep into the living area.

Carbon monoxide intoxication is dependent upon three things: the concentration breathed, the rate inhaled, and the time of exposure. Generally, if a person breathes air containing 200 ppm CO for 7 hours, their blood would contain approximately 20% COHG. If the environment being inhaled contains 1000 ppm CO, a 20% level of COHG would occur in approximately 40 minutes. 10,000 ppm CO (1.0% in air) will be fatal if inhaled for only a few minutes. Physical activity and heavy breathing increase the poisoning rate. OSHA has set a limit of 50 ppm for the environment of workers during a normal eight-hour shift.

CO poisoning can occur from defective heating equipment, motor exhaust, industrial processes, or a fire. Many different factors must be analyzed to determine why the incident occurred. The victim's percentage of COHG should be measured as soon as possible to determine the severity of the exposure. The area where the exposure occurred must be ascertained, and then the cause of the high CO concentration.

CO is a product of incomplete combustion which occurs when fuel is burned with an inadequate supply of oxygen. At altitudes above 2000 feet, an appliance should be de-rated 4% for every 1000 feet above sea level, because less oxygen is available in the air. (De-rating is accomplished by reducing the exhaust orifice size so that less gas can pass through the appliance's outlet.) Thus, In Denver, Colorado, a normal 100,000 BTU per

Randolph J. Harris
BS, Ch.E, CFEI, CVFI, CCI, CPH
Fire, Explosion and Carbon Monoxide Expert
randy@harrisff.com
www.harrisff.com
720-244-0897

hour furnace should be de-rated to 80,000 BTU. The same furnace in Leadville, Colorado, should be de-rated to 60,000 BTU. If the gas appliance isn't de-rated, there is too much fuel available to burn, and high amounts of CO will be produced. An appliance that is operating on a gas pressure that is too high will have the same result.

A proper gas burner flame will be mostly blue in color with minor orange/yellow tips. Air normally flows into the combustion chamber and up the draft diverter. A very yellow/ orange flame will produce more carbon monoxide, sometimes accompanied by soot. The soot can accumulate in the flue and partially block the flow of combustion products from the appliance. This can cause combustion gases, including CO, to flow out into the living quarters.

A cracked heat exchanger can be a cause of CO poisoning. In a furnace, the flue gases are kept separate from the heated air by the heat exchanger (similar to a radiator). A crack in the heat exchanger can allow CO into the heated air that is distributed throughout the living area. In one incident, a heat exchanger was improperly manufactured and started to flake. The flaking metal substantially blocked the air flow, which caused large amounts of CO to be produced which then entered the living quarters.

Newer, high-efficiency furnaces often require different venting than what is normally present. If these are improperly assembled, CO can flow into the living quarters. Flues must be the proper diameter, properly attached and angled, and must extend far enough above the roof for proper venting. If a flue pipe (or chimney) becomes blocked, damaged, or corroded, CO can flow into a living space.

Physical configurations can also contribute to a CO incident. If a furnace's blower compartment is left open (or contains gaps or holes) it can create a vacuum in the furnace room. This can cause the flue gases to be distributed with the heated air.

Newer furnaces will have a door safety switch to prevent operation when the door is open or ajar. In carbon monoxide incident investigations, these switches have sometimes been found to be bypassed or improperly connected. Exhaust and vent fans can alter the air flow up and out of the flue.

Appliances must have an adequate air supply to operate properly. If they are operated in a confined area, air vents are necessary. In one incident, a structure was recently insulated which cut off the vents for air flow. The appliances (unvented propane heaters that had been in use for over 30 years) consumed the available oxygen, and produced high levels of CO, resulting in the death of a person.

There are many different aspects of a CO incident. By testing, the incident can usually, but not always, be duplicated if the physical conditions have not been altered. One incident was caused by several factors combined; the furnace was not de-rated, the gas pressure was too high, the blower compartment door was left ajar, the flue pipe didn't extend far enough above the roof, and the atmospheric and wind conditions contributed to cause a downdraft. If any one of these factors had not been present, the incident would not have occurred.

CO incidents must be investigated thoroughly. All possible causes must be taken into consideration. These causes must be analyzed to determine the most significant factor, and the contributing factors before responsibility can be properly assigned.

If you are involved in a CO Incident:

<u>Do not alter anything.</u>

Delay repairs or replacement until the incident can be fully investigated by a qualified expert(s). If the suspected appliance is removed, or venting altered, the real cause may never be determined.

Reproduced from Industry Update, Fay Engineering Corp., Summer Issue 1995.