# C.O. – THE SILENT KILLER

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Two small children were swimming and playing near their parent's new motorboat. One was seen staggering and was brought back on the boat and given water. The other was found 10 minutes later, under the boat. The cause of death was not drowning, it was carbon monoxide poisoning.

Teenagers were having a party in a modern house. Due to the excessive cigarette smoke, they turned on the whole-house attic fan for approximately three minutes. Everyone left except for two boys who slept over in the house. One never woke up again. The cause of death - carbon monoxide poisoning.

Carbon monoxide – the silent and odorless killer. Carbon monoxide is the number one cause of poisoning deaths. Fuel burning appliances, automobiles and generators make our lives much easier, however, they come with inherent hazards. Carbon monoxide poisonings are often thought to be either obvious or flukes. Careful investigation and analysis must occur to determine the true cause and prevent further deaths.

In the boat incident with the two small children, the operation of the boat was not well understood by the new owners or the seller. When the generator is running, warm water flows out of the side of the boat. This is lake water, which is used to cool the generator motor. It was not understood that deadly exhaust gasses were also exiting with this water stream. Generators are unregulated and therefore, produce enormous amounts of carbon monoxide. The 50,000 parts per million (ppm) carbon monoxide measured is 1,000 times the OSHA limit (for eight hours of exposure). On this very hot and calm day, the temperature of the cooled exhaust gasses was lower than the surrounding air, and settled on the water surface, (where the children were swimming). At these extreme concentrations, it would only take a few breaths to cause death.

The teenagers were having their party on an extremely cold winter night, so all the windows and doors were closed tight. The gas appliances in the home had been present for 15 years and were still operating fine after the poisoning. However, when the whole-house fan was turned on, it reversed the flow down the flue pipes; instead of up.

This also caused the furnace burner to operate improperly and produce large amounts of carbon monoxide, which dumped into the living quarters. Within three minutes, the carbon monoxide level throughout the home was 300 ppm. When the attic fan was turned off, the gas burner returned to normal operation. This concentration was not high enough to cause any ill effects to the partygoers by the time they left. However, the concentration was high enough for continued exposure to cause a build up in the blood of the two young men who remained. The carbon monoxide level in their blood slowly increased until one young man died and the other was put in the hospital.

Carbon monoxide incidents are usually caused by several factors combined. Very rarely is it caused by the "furnace failure" often noted by the gas company or fire department. Typically in buildings, most of the factors involve improper installation and/or lack of maintenance. Gas appliances can usually operate fairly well for years until that one time when something changes. This one additional factor is often "the straw that breaks the camel's back". The additional factor may allow the incident to occur, but is often not the primary cause.

Several people were starting to feel ill in an office building in an eastern city. The heat exchanger of the furnace had been replaced only two years before. They called a heating contractor. He found a cracked heat exchanger and red tagged the furnace. A lawsuit was filed against the furnace manufacturer.

Careful examination and testing indicated 14 separate problems, either related to original improper installation or poor maintenance. The heat exchanger was found cracked, however, this alone did not cause the poisoning. The blower position was such that even through there was a crack, no carbon monoxide entered the heated air. Furthermore, the crack resulted from not installing the new burners, which accompanied the new heat exchanger. The old burners were corroded, causing an improper flame pattern. The improper heating of the heat exchanger caused it to crack. A heating contractor replaced the "one shot" flame roll-out switch with an auto-resetting type. Thus, this furnace continued to cycle off and on in this improper state. However, these factors were not the primary cause of the poisoning.

The primary cause of the poisoning was two fold. The flue pipe exited the structure horizontally, out into a basement stairwell. The rectangular hole cut through the masonry wall was never properly sealed and large gaps were present. The second factor were holes cut in the cold air return duct for the furnace in the basement. This created negative pressure throughout the basement. Thus, the exhaust gasses in the basement stairwell were suctioned back into the basement, into the cold air duct and blown out with the heated air.

Four men traveling in a rented RV adventured across a rough field and bottomed out the rear corner. They continued on their way and camped that evening with several other RV's. That evening they were watching TV and drinking. One of the four came back from visiting friends and thought that he smelled exhaust. His three friends ridiculed him, pushed him out the door and locked it. This unkind act saved his life. In the morning the three were found dead from acute carbon monoxide poisoning.

The accident had caused damage. Impact with the ground had broken the hanger on the generator's exhaust pipe and pushed the exhaust pipe up underneath the skirting. The impact also caused the rear wall to separate slightly from the floor, causing a "chimney." When the generator was running, poisonous carbon monoxide gas traveled up the chimney and infiltrated the RV. Although the RV had a carbon monoxide detector, its battery was found lying on the bedside table. Apparently, the carbon monoxide detector had sounded, but the men thought it was a low battery alert and removed the battery.

In a mountain town, a man suffered a heart attack, brought on by carbon monoxide poisoning. The fire department and gas company found that debris in the chimney had fallen and partially blocked the flue pipe for the instantaneous water heaters. The chimney was cleaned and the water heaters put back into operation. My investigation revealed that the instantaneous water heaters were still dumping large amounts of carbon monoxide into the living quarters.

Original installation errors were found besides the dirty chimney. The appliances were not properly de-rated for altitude, and no outside combustion air ducts were present in the mechanical room. Careful examination showed that the metal of the heat exchanger had overheated, flaked and was now partially blocking the airflow through the appliances. Even though the flue had been cleaned, another poisoning incident could have occurred if these problems were not identified.

In conclusion, several factors frequently come together in order for a carbon monoxide poisoning incident to occur. It is necessary to look beyond the obvious and find all the contributing factors to understand a carbon monoxide poisoning event.

# CARBON MONOXIDE POISONING
## By Randolph J. Harris

Carbon monoxide 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 that oxygen normally combines with the hemoglobin in 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 will die from internal suffocation.

Normally, an average person's blood will contain just under 1% carboxyhemoglobin from normal body functions. Smokers can have 5 – 10% COHG (carboxyhemoglobin). Effects from COHG are usually not noticed at levels below 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 patient is brought into fresh air. The rate of decrease is improved if he is given oxygen or is 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. It's not unusual to have near 400 ppm in flue gases. Abnormal operation of an appliance can produce several thousand ppm. Even though gas appliances can produce dangerous concentrations, these combustion product gasses normally flow up and out the flue harmlessly into the atmosphere. But if this proper air flow is disrupted, the CO can seep into the living area.

CO 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% carboxyhemoglobin. If the environment being inhaled contains 1,000 ppm CO, a 20% level of carboxyhemoglobin would occur in approximately 40 minutes. 10,000 ppm (1.0% in air) will be fatal if inhaled for only a few minutes. Physical activities and heavy breathing increases the poisoning rate. OSHA has set a limit of 50 ppm for the environment of workers during a normal 8 hour shift.

CO poisoning can occur from defective heating equipment, motor exhaust, industrial processes, or from a fire. Many different factors must be analyzed to determine why the incident occurred. The victim's percentage of carboxyhemoglobin should be measured as soon as possible to determine the severity of the exposure. The area where the exposure occurred must be determined, 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 derated 4% for every 1000 feet above sea level because less oxygen is available in the air. (Derating is done by reducing the orifice size so less gas will enter the appliance outlet.) Thus, in Denver, Colorado, a normal 100,000 BTU per hour furnace should be derated to 80,000 BTU. The same furnace in Leadville should be derated to 60,000 BTU. If the gas appliance isn't derated, there is too much fuel available to burn and high amounts of CO will be produced. An appliance that is operating on too high a gas pressure 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 products of combustion from the appliance. Then combustion gases, including CO, can 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 the living space.

Physical configurations can also contribute to a CO incident. If a furnace's blower compartment door 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. These switches have been found bypassed or improperly connected. Exhaust and vent fans can alter the air flow up and out 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, produced high levels of CO, and killed a person.

There are many different aspects of a CO incident. By testing, the incident can usually be duplicated if the physical conditions have not been altered, but not always. One incident was caused by several factors combined; the furnace was not derated, 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 weren't 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 contributing factors before responsibility can be properly assigned

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