This document discusses the toxicity and exposure limits for exposure to carbon monoxide gas (CO). We give references and explanation regarding Toxicity of Carbon Monoxide, based on literature search and search on Compuserve's Safety Forum. This is background information, obtained from expert sources. This text may assist readers in understanding these topics. However it should by no means be considered complete nor authoritative.

Seek prompt advice from your doctor or health/safety experts if you have any reason to be concerned about exposure to toxic gases. Carbon monoxide poisoning can be fatal but exposure at lower limits can produce flu-like symptoms and headaches that are often mistaken for ordinary illness. Readers of this document should also see Backdrafting Appliances and see HEAT EXCHANGER LEAKS.

IF YOU SUSPECT CARBON MONOXIDE POISONING GO INTO FRESH AIR IMMEDIATELY and get others out of the building, then call your fire department or emergency services for help. Links on this page also direct the reader to carbon dioxide gas information in a separate document. Information Accuracy & Bias Pledge is at below-left. **Use links at the left of each page to navigate** this document or to view other topics at this website. **Green links show where you are** in our document or website.

Safety Suggestions: Install Carbon Monoxide Detectors in addition to Smoke Detectors

Carbon monoxide detectors are inexpensive and readily available, both as a battery-operated unit and as a unit that plugs into an electrical outlet in the home. No home should be without this safety protection, and homes with gas-fired equipment (natural gas or LP propane), space heaters, or other sources of risk should be extra cautious. Smoke detectors do not protect against carbon monoxide poisoning, and the opposite is also true. Carbon monoxide detectors do not warn of smoke or fire.

Guide to Inspecting Buildings for Visible Evidence of Conditions Likely to Produce Dangerous Carbon Monoxide Gas

The fact that you cannot see nor smell dangerous carbon monoxide gas does not mean that there is nothing to look for when assessing the safety of heating equipment. Not only are there easily spotted installation errors (the first list below), there may be more subtle but easily visible errors if you know what to look for (the second list below).

Visible building conditions risking carbon monoxide hazards

This is by no means the complete list of errors that can cause dangerous carbon monoxide exposure in buildings, but here are some common foul ups outside of the workplace that can cause dangerous levels of indoor carbon monoxide:

- **Space heaters**: improper use of gas or kerosene fired heaters can produce high indoor CO levels. *Warning:* Never go to sleep in an enclosed space with a space heater left operating. In addition to the CO hazards there is a risk of oxygen depletion which can also lead to asphyxiation.
- **Gas fired central heating equipment** combined with:
  - **Improper venting**, blocked, under-sized, over-sized, missing parts, improperly sloped chimney or flue. A variety of errors can cause a failure to vent combustion gases out of the building, allowing dangerous flue gases to build up indoors.
  - **inadequate combustion air.** If a heating appliance is installed in a small confined space it must be provided with outside combustion air. A service technician may tune and inspect a gas-fired boiler with the boiler room door open, finding that it seems to operate fine. When s/he closes it on leaving, there may be an inadequate or no opening for combustion air into the room.
  - **Venting small appliances into large cold chimneys**: Installation of small, higher efficiency gas-fired equipment into old homes at which the appliance is vented into a large (cold) masonry chimney. In such instances the heater may never develop sufficient heat and draft to actually vent up the chimney.
  - Also sometimes water heaters are left venting into a too-large, too-cold masonry chimney after a gas-fired boiler is converted to a high-efficiency direct-vent (no chimney) unit. One of my clients developed headaches every October - an event I traced to this condition in Poughkeepsie, NY. [DF re E.B. case 1988].
- **Car exhaust,** such as to occupants of rooms adjoining or even above a garage where car engines are left running
- **Un-vented gas fired water heaters**, often found venting directly into a basement utility room or even directly into a living area or bedroom.
- **CHIMNEY INSPECTION GUIDE** contains detailed suggestions for inspecting building chimneys including the detection of blocked chimney flues or indications that a chimney may be blocked.

Other clues which can suggest a risk of carbon monoxide hazards in buildings

- **CO detector alarms** Do not ignore this first line of defense. Install CO detectors near the heating equipment as well as in sleeping areas of the home. People have died after not believing their CO detector and taking out the batter to silence the annoying device which they believed was malfunctioning.
- **Missing parts**: Gas fired water heaters, furnaces, boilers which are missing flue vent connector components such as draft hoods and flue gas spill detection switches - it can be difficult to spot that something is missing unless you know what's supposed to be there. Review this topic with a trained heating service technician or plumber.
- **Clogged heater draft hood** from hair or other debris

- **Signs of flue gas spillage** Blocked flues will result in combustion gas spillage back into the building. Often this will cause:
    - **Rust** on heating equipment at the point of flue gas spillage - you can detect this even when the equipment is not operating
    - **Rusty debris** on the top of gas fired heating equipment below the draft hood
    - **Water condensation** on building surfaces may occur if gas-vented appliances are venting back into the building, especially on cool basement surfaces - you can only observe this when the equipment is operating
    - **Odors** of combustion products: while CO and CO2 are themselves odorless, if they are spilling from heating equipment, odors of other combustion products may be notices.

Testing for Carbon Monoxide

In addition to the installation of CO monitoring alarms in buildings, a variety of electronic and gas sampling equipment is available to make spot checks for hazardous gases. I have and have used a variety of these devices under a wide range of conditions.

While a "positive" indication of a gas is an important indicator of a hazard, a "negative" or "not found" result is nothing to rely on.

The fact that dangerous levels of CO are not present in a building at a particular instant is absolutely no guarantee that dangerous levels of CO (for example) may not occur even moments later. For example, opening a window, turning on a fan or clothes dryer, closing a door, and similar innocent acts can significantly change air flow, combustion air, and other building conditions.

Therefore spot tests for dangerous gases should not be relied upon to guarantee building safety. This is why the list of visual inspection items and proper heating equipment maintenance are so important.

Suggestions and content additions are invited. Contact me with items to add to these lists.

More Reading:
Heating System Check Recommended for Carbon Monoxide - CPSC Release 88-92

CHIMNEY INSPECTION GUIDE contains detailed suggestions for inspecting building chimneys including the detection of blocked chimney flues or indications that a chimney may be blocked.

MEDICAL EFFECTS of CO - Medical effects of Carbon Monoxide (CO) Poisoning

Many sources I (DF) reviewed indicated that if carbon monoxide exposure was subacute, that is if the person did not lose consciousness and was removed from the CO exposure before losing consciousness, then any medical effects were temporary. Indeed detection of CO exposure at a hospital is problematic since CO leaves the bloodstream quickly once a person is exposed to normal air. However *there is evidence that lasting physical damage may occur from carbon monoxide exposure*, though the popular press has not (2006) discussed the exposure level and duration necessary for these effects.

Heart muscle damage occurs from Carbon Monoxide (CO) exposure, screening recommended

31 January 2006 - The *New York Times* Science Section reports on a new study, released in JAMA's January 25 2006 Magazine Issue, and which indicated that people exposed to carbon monoxide suffer damage to their heart muscles and are at much greater risk for heart attacks in later years. The *Times* article asserted that CO Poisoning results in 40,000 emergency visits a year in the United States - the most common accidental poisoning event in the U.S. with an annual average accidental death rate of about 1000 people and average suicidal death rate of about 2400 people. [U.S. CDC] Five percent of such patients die in the hospital. Research was not cited regarding subacute exposures and exposures which do not result in a visit to a hospital. -- *New York Times* Science Section, January 31, 2006 p. F6, "After Crisis, Carbon Monoxide Still Takes a Toll."

The carbon monoxide exposure and heart muscle damage study was led by Christopher R. Henry, Minneapolis Heart Institute Foundation, in the current [Jan 2006] Journal of the American Medical Association The study examined the medical history of 230 people exposed to carbon monoxide and treated at hospital between 1994 and 2002, following their health to 2005. After 7 1/2 years, in this otherwise low risk (of heart failure) population, 25% of the originally-surviving patients had died - a rate about three times the average heart failure death rate statistic. For people who had suffered heart muscle damage the mortality rate was 38% with half of the mortalities being (apparently) traced to cardiovascular problems. The study concludes that people who are exposed to carbon monoxide should be screened for heart muscle damage. Heart muscle damage from CO poisoning (in the study) was characterized by elevated levels of cardiac troponin I (a type of protein) or creatine kinase-MB (a type of enzyme), and/or changes in diagnostic electrocardiogram (ECG). -- DJ Friedman paraphrasing the *NY Times* article and JAMA's news release regarding this study.

More references for this study:
see: *Heart Injury Due to Carbon Monoxide Poisoning Increases Long-Term Risk of Death*, JAMA January 25 2006. AMA news release 2006. This study was supported by an unrestricted educational grant from the Minneapolis Heart Institute Foundation. Study copies may be available from the JAMA/Archives Media Relations Department at 312/464-JAMA (5262) - mediarelations@jama-archives.org.

CO EXPOSURE LIMITS - Carbon monoxide exposure limits PEL and TLV set by OSHA and NIOSH

Carbon monoxide is a colorless, odorless, tasteless gas that, in its effects on humans, is a chemical asphyxiant - that is, it causes asphyxiation, or death by preventing a person from receiving adequate oxygen. When inhaled, carbon monoxide combines with hemoglobin in the blood more readily than oxygen does. Thus CO "displaces" or moves oxygen out from hemoglobin in the bloodstream. This interferes with oxygen transport by the blood.

A person suffering from carbon monoxide (CO) intoxication may first experience euphoria (similar to the effect of a martini or two), then carbon monoxide poisoning effects lead to a headache, followed by nausea and possibly vomiting as the concentration of carboxyhemoglobin in the blood increases. To prevent these effects, OSHA has established a PEL of 50 ppm for an 8-hr exposure, identical to the TLV. NIOSH, on the other hand, has decided to be more conservative and recommends a standard of 35 ppm. All of these concentrations refer to exposures with durations of 8 hr/day, 40 hr/week for a working lifetime and all are attempts to establish a "no effect" level.

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Table I. Effects of Carbon Monoxide Exposure and CO Exposure Limits		
PPM CO Exposure	Effects of Exposure to Carbon Monoxide at this level	Source/comment
0 ppm	No effects, this is the normal level in a properly-operating heating appliance	No carbon monoxide should be detected in residential properties. Possible brief technical exceptions occur.
9 ppm	Maximum allowable short term exposure	ASHRAE
10 - 24 ppm	Investigation needed to find source;	Health effects on humans uncertain.
25 ppm	Maximum allowable TWA exposure limit	OSHA. Used in personal CO alarms.
35 ppm	Maximum allowable workplace exposure limit for an 8-hour work shift	NIOSH (40 hour work week)
50 ppm	Maximum allowable workplace exposure limit for an 8-hour work shift	OSHA (40 hour work week)
125 ppm	Workplace alarm must sound	OSHA
200 ppm	Evacuate the area immediately.	Exposure at 200 ppm of CO causes dizziness, nausea, fatigue.
400 ppm	Evacuate the area.	3 hour exposure may be fatal.
800 ppm	Evacuate the area.	2-3 hour exposure causes convulsions, loss of consciousness, death.
1600 ppm	Evacuate the area.	
6400 ppm	Evacuate the area.	30 minutes of exposure causes convulsions, loss of consciousness, death
12,800 ppm	Evacuate the area.	1-3 minutes of exposure causes convulsions, loss of consciousness, death

NOTES to the Carbon Monoxide Effects Table: sources include OSHA, EPA, www.transducertech.com

ABBREVIATIONS: used with gas exposure limits:
PEL = permissible exposure limit. PEL's are a regulatory limitation to exposure used to specify the allowable exposure to a substance in the *workplace* and assume that the exposure takes place over an 8-hour shift in a 40-hour work week. Note that there are more stringent exposure limits for higher levels of exposure that may occur over a shorter time interval
PPM = parts per million of concentration of the gas of interest in air. 1 ppm means one part of gas to 1 million parts of air
MAX = maximum exposure in ppm for any individual in the work area over an 8-hour period
MSDS = Material Safety Data Sheet, published for every chemical or substance that may be hazardous; if an exposure limit has been published for a substance being discussed in an MSDS, that limit, such as TWA or PEL, is required to be included in the MSDS publication. Ref: 29 CFR 1910.1200 (g)(2)(i)(C)(2) and (g)(2)(vi). TWA's and PEL's are *not* available for most chemicals. There are simply too many chemicals, many of which have not gone through the rigorous scientific study and peer review required. The absence of an exposure limit for a substance should not be used to assume that a substance is not hazardous.
TIME = point in time when the maximum exposure will occur from the beginning of any 8-hour period
TE = total exposure in ppm per hour
TLV = threshold limit value: the level of exposure that a worker can experience in the workplace without an unreasonable risk of disease or injury. These are *not* estimates of "level of risk" for different exposure levels nor do they address the different means by which a person may be exposed to a substance. TLV's are specified by ACGIH, the American Conference of Government Industrial Hygienists. TLV's are guidelines prepared by ACGIH and are solely concerned with health risk. They do not address economic considerations. TLV's are not regulatory but rather are advisory. (See PEL and TWA which are specified by OSHA).
TWA = time weighted average exposure level. TWA's are a regulatory exposure limit. The TWA calculation takes into account that exposure level may vary over a time period.

Original document source

This carbon monoxide discussion file originated from a technical expert message board discussion on Carbon Monoxide and later Carbon Dioxide alarms, featuring comments by one of the leading authorities on CO, Jack Peterson, P.E., CIH, Ph.D., in May, 1987. NOTE: Daniel Friedman extracted CO and CO2 sections from that document, edited and added practical and field inspection-based information. Since its original publication this document has been expanded by reference materials from a variety of other sources.