Occupational Safety and Health Guideline for Carbon Monoxide

Introduction

This guideline summarizes pertinent information about carbon monoxide for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine whether new information is available.

Recognition

SUBSTANCE IDENTIFICATION

* Formula
CO

* Structure
(For Structure, see paper copy)

* Synonyms
Coal gas, carbon oxide, carbonic oxide, exhaust gas, flue gas

* Identifiers

1. CAS No.: 630-08-0
2. RTECS No.: FG3500000
3. DOT No.: UN 1016 18 (gas); NA 9202 67 (cryogenic liquid)
4. DOT label: Flammable gas, Poison gas (gas); Flammable gas (cryogenic liquid)

* Appearance and odor
Carbon monoxide is an odorless, colorless gas or, under high pressure, a liquid.

CHEMICAL AND PHYSICAL PROPERTIES

* Physical data

1. Molecular weight: 28.01
2. Boiling point (at 760 mm Hg): -191.5 degrees C (-312.7 degrees F)
3. Specific gravity (water = 1): 1.25 at 0 degrees C (32 degrees F)
4. Vapor density: 0.97
5. Freezing point: -205 degrees C (-337 degrees F)
6. Vapor pressure at 20 degrees C (68 degrees F): Greater than 1 atmosphere (760 mm Hg)
7. Solubility: Sparingly soluble in water; soluble in ethanol, methanol, and some organic solvents.
8. Evaporation rate: Not applicable.

* Reactivity

1. Conditions contributing to instability: Heat may cause containers of carbon monoxide to explode.
2. Incompatibilities: Contact of carbon monoxide with strong oxidizing agents, or halogen compounds causes a violent reaction.
3. Hazardous decomposition products: None reported.
4. Special precautions: None reported.

* Flammability

The National Fire Protection Association has assigned a flammability rating of 4 (severe fire hazard) to carbon monoxide.

1. Flash point: Not applicable.
2. Autoignition temperature: 609 degrees C (1128 degrees F)
3. Flammable limits in air (percent by volume): Lower, 12.5; upper, 74
4. Extinguishant: Let a small fire burn unless the leak can be stopped immediately. Use water spray, fog, or regular foam to fight large fires involving carbon monoxide.

Fires involving carbon monoxide should be fought upwind and from the maximum distance possible. Keep unnecessary people away; isolate the hazard area and deny entry. Isolate the area for 1/2 mile in all directions if a tank, rail car, or tank truck is involved in the fire. For a massive fire in a cargo area, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from the area and let the fire burn.

Emergency personnel should stay out of low areas and ventilate closed spaces before entering. Vapors may travel to a source of ignition and flash back. Vapors are an explosion and poison hazard indoors, outdoors, or in sewers. Containers of carbon monoxide may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool fire-exposed containers from the sides with water until well after the fire is out. Stay away from the ends of containers. Personnel should withdraw immediately if a rising sound from a venting safety device is heard or if there is discoloration of a container due to fire. Firefighters should wear a full set of protective clothing, including a self-contained breathing apparatus, when fighting fires involving carbon monoxide.

EXPOSURE LIMITS

* OSHA PEL

The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for carbon monoxide is 50 parts per million (ppm) parts of air (55 milligrams per cubic meter (mg/m(3))) as an 8-hour time-weighted average (TWA) concentration [29 CFR Table Z-1].

* NIOSH REL

The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for carbon monoxide of 35 ppm (40 mg/m(3)) as an 8-hour TWA and 200 ppm (229 mg/m(3)) as a ceiling [NIOSH 1992].

* ACGIH TLV

The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned carbon monoxide a threshold limit value (TLV) of 25 ppm (29 mg/m(3)) as a TWA for a normal 8-hour workday and a 40-hour workweek [ACGIH 1994, p. 15].

* Rationale for Limits

The NIOSH limit is based on the risk of cardiovascular effects [NIOSH

The ACGIH limit is based on the risk of elevated carboxyhemoglobin levels [ACGIH 1991, p. 229].

Evaluation

HEALTH HAZARD INFORMATION

* Routes of Exposure
Exposure to carbon monoxide can occur through inhalation of the gas and eye or skin contact with the liquid.

* Summary of toxicology

1. Effects on Animals: Carbon monoxide is an asphyxiant that exerts its toxic effects by combining with the hemoglobin of the blood, which decreases the amount of oxygen delivered to the tissues. The LC(50) in rats is 1807 ppm for 4 hours [NIOSH 1993]. A carboxyhemoglobin level of 5 percent increases the degree of myocardial ischemia associated with acute myocardial infarction in dogs [ACGIH 1991]. Rhesus monkeys with severe carbon monoxide poisoning died as a result of lowered blood pressure and ventricular fibrillation [Gosselin Tolerance to the effects of carbon monoxide poisoning has been observed in chronically exposed animals [Gosselin 1984]. Laboratory animals exposed to carbon monoxide exhibit decreases in motor nerve conduction velocity and cellular changes in peripheral nerves[Gosselin 1984]. Carbon monoxide can be transported across the placental barrier. The offspring of pregnant rats exposed to 150 ppm carbon monoxide weighed less at birth, showed reduced growth rates, and performed poorly on negative geotaxis tests and homing tests [NLM Perinatal death occurred in 43 of 123 offspring of pregnant rabbits exposed to 180 ppm carbon monoxide, compared with one death in a non-exposed control group. Birth weights in the carbon monoxide-exposed animals averaged 10 grams less than those in non-exposed controls [NLM 1993].
2. Effects on Humans: Carbon monoxide is an asphyxiant in humans. Inhalation of carbon monoxide causes tissue hypoxia by preventing the blood from carrying sufficient oxygen. Carbon monoxide combines reversibly with hemoglobin to form carboxyhemoglobin. The reduction in oxygen-carrying capacity of the blood is proportional to the amount of carboxyhemoglobin formed [Gosselin 1984]. All factors that speed respiration and circulation accelerate the rate of carboxyhemoglobin formation; thus exercise, increased temperature, high altitude, and anemia increase the hazard associated with carbon monoxide exposure[Gosselin 1984]. Other conditions that increase risk are hyperthyroidism, obesity, bronchitis, asthma, preexisting heart disease, and alcoholism [NLM 1993]. In tests with human volunteers breathing 50 ppm carbon monoxide (a concentration that produces 27 percent carboxyhemoglobin after an exposure of 2 hours), there was a significant decrease in time to onset of exercise-induced angina[Gosselin 1984]. Carbon monoxide can be transported across the placental barrier, and exposure in utero constitutes a special risk to the fetus. Infants and young children are generally believed to be more susceptible to carbon monoxide than adults. The elderly are also believed to be more susceptible to carbon monoxide poisoning [Gosselin A carboxyhemoglobin level of 0.4 to 0.7 percent is normally present in the blood of adults. In cigarette smokers, the range is 4 to 20 percent, which places smokers at greater risk in exposure situations [Clayton and Clayton 1982; ACGIH 1991]. A capacity to adapt to carbon monoxide exposure has been reported in several human studies. Healthy young men exposed to carbon monoxide at a concentration of 44 ppm for a prolonged period suffered no adverse health effects [ACGIH 1986]. Men exposed to 50 ppm for several days without relief complained of headaches, but exposure to 40 ppm for 60 days was without effect [ACGIH 1986]. Workers in the Holland Tunnel working 8-hour swing shifts of 2 hours in and 2 hours out at an average carbon monoxide exposure concentration of 70 ppm had average carboxyhemoglobin levels of 5 percent, and none had levels above 10 percent [ACGIH 1991].

* Signs and symptoms of exposure

1. Acute exposure: The signs and symptoms of acute exposure to carbon monoxide may include headache, flushing, nausea, vertigo, weakness, irritability, unconsciousness, and in persons with pre-existing heart disease and atherosclerosis, chest pain and leg pain.
2. Chronic exposure: Repeated bouts of carbon monoxide poisoning may cause persistent signs and symptoms, such as anorexia, headache, lassitude, dizziness, and ataxia.

EMERGENCY MEDICAL PROCEDURES

* Emergency medical procedures: [NIOSH to supply]

Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Material Safety Data Sheet required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may generate or involve carbon monoxide and lead to worker exposures to this substance:

* The manufacture and transportation of carbon monoxide

Operations near furnaces, ovens, stoves, forges, and kilns when they are being fired up to operating temperatures; firefighting, particularly in mines; testing of internal combustion engines; operations near portable stoves

Use in organic chemical synthesis, particularly in the Fischer-Tropsch process for petroleum products; in fuel gas mixtures for industrial and domestic heating; as a reducing agent in metallurgical processes such as the Mond process for the recovery of nickel; in the manufacture of metal carbonyl catalysts Liberation of exhaust from faulty equipment on autos, buses, airplanes, and boats; use of compressed air in respiratory devices in industry or breathing mixtures in diving, when the air is supplied from reciprocating oil-lubricated compressors

Methods that are effective in controlling worker exposures to carbon monoxide, depending on the feasibility of implementation, are as follows:

* Process enclosure Local exhaust ventilation General dilution ventilation Personal protective equipment

Workers responding to a release or potential release of a hazardous substance must be protected as required by paragraph (q) of OSHA's Hazardous Waste Operations and Emergency Response Standard [29 CFR

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation--a manual of recommended practice. 21(st) ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
2. Burton DJ [1986]. Industrial ventilation--a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.
3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.
4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.
5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

* Biological monitoring

Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite.

A readily available biological monitoring method for carbon monoxide involves the measurement of carboxyhemoglobin concentration in the blood by means of automated visible spectrophotometry. The recommended maximum allowable carboxyhemoglobin level for workers is 5 percent, which corresponds to an 8-hour exposure of 35 ppm. Exposure at the current PEL of 50 ppm for 8 hours will yield a carboxyhemoglobin level of 8 to 10 percent in most workers. A pre-exposure sample should be taken and analyzed to determine background carboxyhemoglobin levels resulting from smoking, various diseases, and non-occupational exposures. It is especially important that smokers and non-smokers be measured separately; the carboxyhemoglobin levels in smokers range from 3 to 10 percent and may be as high as 20 percent in cigar smokers.

WORKPLACE MONITORING AND MEASUREMENT

Neither NIOSH nor OSHA has a recommended method for full-shift sampling ofemployee exposure to carbon monoxide in the workplace.

However, the following analytical methods are available.

Determination of a worker's exposure to airborne carbon monoxide is made using an Ecolyzer direct reading field instrument. This instrument is capable of detecting carbon monoxide concentrations between 0 and 600 ppm. Several types of detector tubes are available to screen for the presenceof carbon monoxide; these tubes have a reported limit of detection of 0.5 ppm. This equipment and the ranges of carbon monoxide detection are described in the OSHA Computerized Information System [OSHA 1994].

Controls

PERSONAL HYGIENE PROCEDURES

If liquid carbon monoxide contacts the skin, workers should flush the affected areas immediately with tepid water, followed by washing with soap and water.

Clothing contaminated with liquid carbon monoxide should be removed immediately.

Workers should not eat, drink, use tobacco products, apply cosmetics, ortake medication in areas where liquid carbon monoxide is handled,processed, or stored.

STORAGE

Liquid carbon monoxide should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200]. Containers of carbon monoxide should be protected from physical damage and should be stored separately from strong oxidizing agents and halogenated compounds.

SPILLS AND LEAKS

In the event of a spill or leak involving carbon monoxide, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Stop the leak if it is possible to do so without risk.
2. Remove all sources of heat and ignition; no flares, smoking, or flames in hazard area.
3. Fully encapsulating, vapor-protective clothing should be worn for spills and leaks with no fire.
4. Water spray may be used to reduce vapors, but the spray may not prevent ignition in closed spaces.
5. Isolate the area until the gas has dispersed.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

* Emergency planning requirements

Carbon monoxide is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) (III) in USC 11022.

* Reportable quantity requirements for hazardous releases

Employers are not required by the emergency release notification provisions in 40 CFR Part 355.40 to notify the National Response Center of an accidental release of carbon monoxide; there is no reportable quantity for this substance.

* Community right-to-know requirements

Employers are not required by EPA in 40 CFR Part 372.30 to submit a Toxic Chemical Release Inventory form (Form R) to EPA reporting the amount of carbon monoxide emitted or released from their facility annually.

* Hazardous waste management requirements

EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA has specifically listed many chemical wastes as hazardous. Although carbon monoxide is not specifically listed as a hazardous waste under RCRA, EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above.

Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (703) 412-9810 (in the Washington, D.C. area) or toll-free at (800) 424-9346 (outside Washington, D.C.). In addition, relevant State and local authorities should be contacted for information on any requirements they may have for the waste removal and disposal of this substance.

RESPIRATORY PROTECTION

* Conditions for respirator use

Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of carbon monoxide exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

* Respiratory protection program

Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic [NIOSH 1987b] and the NIOSH Guide to Industrial Respiratory Protection [NIOSH 1987a].

PERSONAL PROTECTIVE EQUIPMENT

Workers should use appropriate personal protective clothing and equipmentthat must be carefully selected, used, and maintained to be effective inpreventing skin contact with liquid carbon monoxide. The selection of theappropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to liquid carbon monoxide.

To evaluate the use of protective materials with liquid carbon monoxide, users should consult the best available performance data and manufacturer's recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve liquid carbon monoxide.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes.

In addition to the possible need for wearing protective outer apparel e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day. Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness.

Protective clothing may interfere with the body's heat dissipation,especially during hot weather or during work in hot or poorly ventilated work environments.

References

ACGIH [1994]. Threshold limit values for chemical substances and physicalagents and biological exposure indices for 1994-1995. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

ACGIH [1986]. Documentation of the threshold limit values and biologicalexposure indices. 5th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [1985]. Hygienic guide series. Akron, OH: American Industrial Hygiene Association.

Baselt RC [1988]. Biological monitoring methods for industrial chemicals. Davis, CA: Biomedical Publications.

Braker W, Mossman AL [1980]. Matheson gas data book. 6th ed. Secaucus, NJ: Matheson Gas Products, Inc.

Bretherick L [1985]. Handbook of reactive chemical hazards. 3rd ed. London, England: Butterworths.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Clayton G, Clayton F [1982]. Patty's industrial hygiene and toxicology. rd rev. ed. New York, NY: John Wiley & Sons.

Clayton G, Clayton F [1991]. Patty's industrial hygiene and toxicology. th ed. Volume I, Part A and Part B. General Principles. New York, NY: John Wiley & Sons.

Cralley LJ, Cralley LV [1985]. Patty's industrial hygiene and toxicology. nd ed. Vol. 3. New York, NY: John Wiley & Sons.

DOT [1993]. 1993 Emergency response guidebook, guides 18 and 67. Washington, DC: U.S. Department of Transportation, Office of Hazardous Materials Transportation, Research and Special Programs Administration.

Genium [1991]. Material safety data sheet No. 35. Schenectady, NY: Genium Publishing Corporation.

Gosselin RE, Smith RP, Hodge HC [1984]. Clinical toxicology of commercial products. 5th ed. Baltimore, MD: Williams & Wilkins.

Lewis RJ, ed. [1993]. Hawley's condensed chemical dictionary. 12th ed. New York, NY: Van Nostrand Reinhold Company.

Lide DR [1993]. CRC handbook of chemistry and physics. 73rd ed. Boca Raton, FL: CRC Press, Inc.

Mickelsen RL, Hall RC [1987]. A breakthrough time comparison of nitrile and neoprene glove materials produced by different glove manufacturers. Am Ind Hyg Assoc J

Mickelsen RL, Hall RC, Chern RT, Myers JR [1991]. Evaluation of a simpleweight-loss method for determining the permeation of organic liquidsthrough rubber films. Am Ind Hyg Assoc J

NFPA [1986]. Fire protection guide on hazardous materials. 9th ed.

Quincy, MA: National Fire Protection Association.

NIOSH [1993]. Registry of toxic effects of chemical substances: Carbonmonoxide. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute forOccupational Safety and Health.

NIOSH [1992]. Recommendations for occupational safety and health: Compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 92-100.

NIOSH [1987a]. NIOSH guide to industrial respiratory protecion. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-116.

NIOSH [1987b]. Respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health

Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

NJDH [1992] Hazardous substance fact sheet: Carbon monoxide. Trenton, NJ: New Jersey Department of Health.

NLM [1993]. Hazardous substances data bank: Carbon monoxide. Bethesda, MD: National Library of Medicine.

Parmeggiani L [1983]. Encyclopedia of occupational health and safety. 3rd rev. ed. Geneva, Switzerland: International Labour Organisation.

Patnaik, P [1992]. A comprehensive guide to the hazardous properties of chemical substances. New York, NY: Van Nostrand Reinhold.

Sittig M [1991]. Handbook of toxic and hazardous chemicals. 3rd ed. Park Ridge, NJ: Noyes Publications.