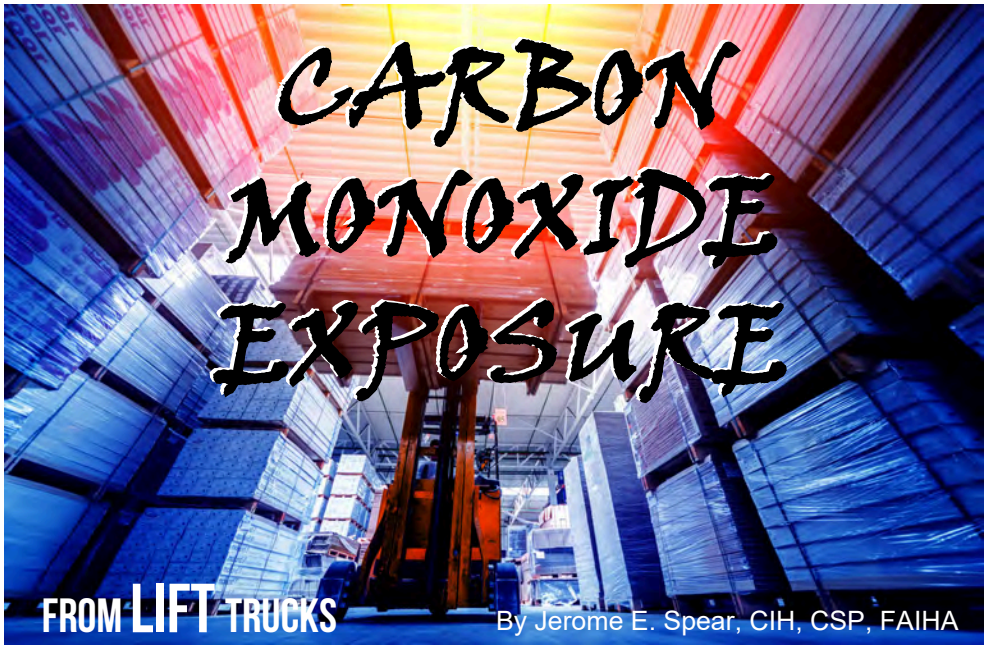


The use of lift trucks powered by internal combustion engines inside buildings and enclosed spaces creates the potential buildup of carbon monoxide (CO). Propane-powered (LPG) lift trucks represent 60% of all material handling vehicles and 80% of all internal combustion lift trucks. Although LPG lift trucks emit considerably less CO than gasoline-powered lift trucks, LPG lift trucks have the potential of emitting excessive CO levels when the trucks are not properly maintained and/or when used in areas with inadequate ventilation.

This paper summarizes the health effects of CO exposure and methods to control CO exposure associated with operating internal combustion lift trucks.

HEALTH EFFECTS OF CARBON MONOXIDE

CO is an odorless and colorless gas that is formed by incomplete combustion in internal combustion engines. When hydrocarbon fuels burn completely, carbon dioxide and water are formed. However, when the mixture burns incompletely, CO and other undesirable chemicals are created. Since CO has few irritating effects on people, workers have little warning of their exposure.

CO enters the body by inhalation and interferes with the blood's ability to carry oxygen. CO readily combines with hemoglobin in the red blood cells to form carboxyhemoglobin (COHb).

Excessive accumulations of COHb cause hypoxic stress in healthy individuals as a result of the reduced oxygen-carrying capacity of the blood. In individuals with cardiovascular disease, such stress can further impair cardiovascular function. Loss of consciousness begins when the worker's COHb level approaches 50%, and prolonged exposure can result in death. Other target organs of CO exposure include the central nervous system and the reproductive system.

The health effects and symptoms of CO exposure are based on the concentration and duration of exposure and are provided below:

Effects and Symptoms	CO Concentration (ppm)	Duration (Hours)
ACGIH TLV	35	8
OSHA PEL	50	8
NIOSH REL	35 200 (C)	10 -
Slight headache, discomfort	200	3
Headache, discomfort	400	2
Headache, discomfort	600	1
Confusion, headache, nausea	1000 - 2000	2
Tendency to stagger	1000 - 2000	1.5
Slight palpitation of the heart	1000 - 2000	0.5
Unconsciousness	2000 - 2500	0.5
Fatal	4000	<1

TLV - The Threshold Limit Value recommended by the American Conference for Governmental Industrial Hygienists (ACGIH).
PEL - The Permissible Exposure Limit enforceable by the Occupational Safety and Health Administration (OSHA).
REL - The Recommended Exposure Limit established by the National Institute for Occupational Safety and Health (NIOSH).
C - Ceiling Limit

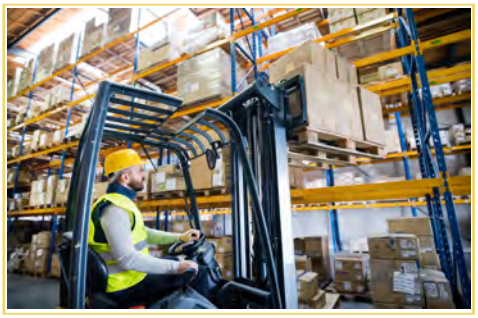
CONTROLLING CARBON MONOXIDE EXPOSURE

Exposure to CO due to emissions of internal combustion engines can be controlled by ensuring a sufficient quantity of fresh air changes and/or lowering the amount of CO emitted into the atmosphere. The amount of general dilution ventilation required depends on the following:

- Number of vehicles in operation
- Operating condition of vehicles
- Amount of CO generated by vehicles
- Volume of air space in the plant

The effectiveness of general dilution ventilation also depends on obtaining reasonably good airflow distribution.

Local exhaust ventilation should be utilized whenever internal combustion lift trucks are receiving a tune-up or other maintenance work that requires the engine to idle. Local exhaust ventilation on a stationary lift truck can be accomplished by connecting a long, noncollapsible, negative-pressure hose to the vehicle's tailpipe and venting the exhaust emissions directly to the outdoors.



Lift truck operators' exposures to CO can be monitored using a calibrated single-gas CO monitors that the operator wears for the duration of the shift. Based on the results of exposure monitoring, general ventilation should be increased and/or the CO emissions should be reduced.

Reducing CO Emissions

To reduce CO emissions, consider the following options:

- ***Battery-powered lift truck***

Battery-powered lift trucks eliminates the CO emission issue; however, they are initially more expensive when all of the necessary equipment is considered. Batteries, chargers, and a properly equipped charging area are needed, which should be factored into the cost evaluation. Slower travel and lift speeds, limited horsepower, and difficulty meeting an eight-hour work intensive duty cycle are other limitations with battery-powered lift trucks.

- ***Diesel-powered lift trucks.***

Diesel-powered lift trucks generate significantly less CO than equivalently sized propane or gasoline trucks. However, one problem associated with diesel fuel is the diesel particulate matter and various other harmful constituents (such as polynuclear aromatic hydrocarbons) that are associated with diesel exhaust. Some of the constituents of diesel exhaust are suspected of causing cancer.

- ***Retrofit options.***

Installing catalytic converters on lift trucks may reduce CO levels 70 to 90% from original concentrations. Installing fuel emission controllers that monitor the engine and exhaust systems to deliver a more precise fuel mixture to the engine may further reduce CO emissions and provide improved fuel economy. Installing catalytic mufflers is another retrofit option that refines the exhaust gas prior to exiting.

- ***Consider using propane additives.***

Propane additives reduce heavy-end buildup in the carburetor, improve engine combustion, and improve fuel economy. Propane additives may reduce CO emissions by 50 to 60%.

- ***Perform periodic tune-ups of lift trucks.***

Lift trucks should receive a periodic tune-up so that less than 1% (preferably 0.5%) of CO is discharged. A CO analyzer (designed for performing tailpipe emission tests) should be used when performing periodic lift truck tune-ups to determine the amount of CO that is emitted.

- ***Driving techniques.***

Driving techniques play a role in reducing CO emissions from internal combustion lift trucks. Teach lift truck operators to minimize CO emissions by reducing warm-up time, avoiding cold starts, minimizing idling time, avoiding erratic braking and accelerating, and not racing the engine. Storing or parking lift trucks in cold areas such as freezers should be avoided to reduce the warm-up time of the engine and exhaust gases.

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