Prevent Carbon Monoxide Poisoning from Forklifts

Success strategies for electric and fuel-driven forklift fleets

Washington State Department of
Labor & Industries

SHARP
Safety & Health Assessment & Research for Prevention

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Notes:

WISHA refers to the Washington Industrial Safety and Health Act.

DOSH is the Washington State Department of Labor & Industries' Division of Occupational Safety and Health.

Unless otherwise indicated, statistics and examples in this document pertain to Washington State.

Introduction

Carbon monoxide (CO) poisoning from internal combustion forklifts is common in Washington State. This document illustrates the health dangers to employees and the economic effects of CO poisoning. Employers are encouraged to adopt a CO prevention plan using the strategies outlined in this publication. The strategies include:

1. Use of electric forklifts
2. Control of CO and reduced fuel costs for combustion engine forklifts

Useful information included in this document includes:

- Economic Impact of CO Poisonings
  - Case studies on recent company-wide poisonings
- Electric Forklifts
  - Company experience with electric forklifts
  - Forklift cost-comparison worksheet
- Fuel-Driven Forklifts
  - Save fuel costs by reducing CO emissions
  - In-house emissions testing
  - New emission regulations and catalytic converter technology
- Recommendations for CO monitoring
- Employee Training Checklist

The purpose of this document is to educate employers on the risks and costs of CO poisoning. Use this document to investigate whether electric lifts are affordable for your company. If you continue to operate fuel-driven lifts indoors, follow this document to design a comprehensive CO prevention strategy that prevents poisonings, uses the latest technology available, and is cost-effective.

If you operate fuel-driven forklifts indoors, you are strongly encouraged to:

- Review the costs and benefits of electric forklifts
- Save fuel costs and reduce CO poisoning risk with a comprehensive CO prevention strategy

Carbon Monoxide (CO) Poisoning

Carbon monoxide (CO) is odorless, tasteless, colorless, non-irritating and cannot be detected by any of the senses. Because it cannot be detected, employees can be exposed to very high levels without realizing there is a problem.

What are the toxic effects?

Early symptoms of CO exposure are flu-like and nonspecific: headache, nausea, dizziness, visual disturbances, and rapid breathing. A person may feel weak and disoriented, making it difficult to escape the environment. Organs that are highly dependent on oxygen – such as the brain and heart – are essentially "starved" during CO poisoning, and severe poisoning can lead to unconsciousness, permanent brain injury and death. In pregnant women, CO can reach the fetus and cause harm.

CO does not accumulate in the body. Once exposure has stopped and fresh air is inhaled, the lungs exhale CO and it is removed from the body. Breathing pure oxygen or use of a hyperbaric chamber (pure oxygen administered under pressure) can be administered to speed the removal of CO from the blood.

Technical Tip: CO is a chemical asphyxiant that when inhaled, binds tightly to hemoglobin in the blood forming carboxyhemoglobin (COHb) and preventing the blood from carrying oxygen. Medical providers may determine COHb blood levels in the course of treatment. COHb blood levels can also be used to estimate the amount of CO present in the air at the time of the poisoning.

What sources generate CO?

Carbon monoxide (CO) is produced by the incomplete combustion of carbon-containing fuels. Sources that generate CO include:

- Internal combustion engines, such as forklift engines powered by:
  - Gasoline
  - Liquefied petroleum gas (LPG, e.g. propane)
  - Diesel
- Small gas- or propane-powered engines can generate CO and should never be used in enclosed spaces. Examples include:
  - Area heaters
  - Pressure washers
  - Compressors
  - Generators
  - Floor buffers
  - Other fuel-burning power tools

Why is it dangerous to use fuel-driven forklifts indoors?

- Even low levels of CO can make your employees ill.
- CO can accumulate rapidly in the environment. How much and how quickly depends on:
  - The number of forklifts idling or operating
  - How well the engines are tuned
  - Length of time the forklifts operate
  - How fast fresh air and ventilation dilute the CO

Forklifts that operate outside do not typically pose a threat for CO poisoning because the exhaust is diluted into the ambient environment. Electric forklifts do not emit carbon monoxide.

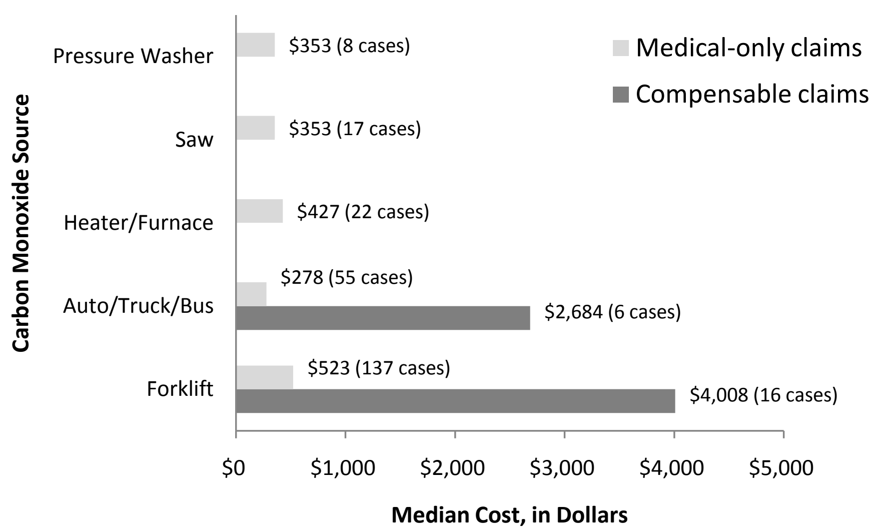
Economic Impact of Carbon Monoxide (CO) Poisoning

Workers' compensation claims data show that forklifts are the most frequent source of occupational CO poisoning in Washington State from 2000 – 2005 (154 out of 345 claims accepted for CO poisoning or 45%).

Cost of CO workers' compensation claims in Washington State

The figure below shows the median costs for CO claims from 2000 to 2005, by the top 5 CO sources. Most workers' compensation claims incur medical-only costs; examples of these costs are emergency room treatment and medical bills. Claims for individuals who miss four or more days of work are described as "compensable" and these costs include all medical costs as well as time loss (kept-on-salary) benefits and disability benefits. Not only are forklift-related CO claims the most frequent; they are the most expensive. In 2000 – 2005, there were 137 medical-only CO claims caused by forklifts with a median cost of $523 per claim (half of the 137 claims cost less than this amount and half cost more). The 16 more serious, compensable, forklift-CO claims had median costs of $4,008, with compensable costs ranging from a minimum of $55 to a maximum claim cost of $69,000. These costs affect an employer's bottom line.

Median workers' compensation cost for CO claims, 2000 - 2005



Be aware! CO claims were reviewed and the following factors were commonly associated with CO poisoning caused by forklifts:

- Use of fuel driven forklifts indoors.
- Use of fuel driven forklifts in or near controlled atmosphere (CA) rooms or in cold storage (rooms with little to no ventilation).
- Renting a forklift for the first time, or renting from a different vendor.
- Failure to verify emission tests of rental lifts.
- Use of fuel driven forklifts during cherry export packing.
- Building ventilation not working properly.
- Re-routing of forklift traffic through populated work areas.
- Extensive idling by a forklift or diesel truck with workers nearby.
- Spill cleanup and re-stacking of collapsed produce.

Controlled atmosphere storage rooms

Controlled Atmosphere (CA) rooms are used in produce-packing warehouses for long-term storage of fruits and vegetables. Washington State is a leader in CA storage technology, and has the largest volume of CA storage anywhere in the world. In 1997, 67% of all apple storage space in Washington State was in the form of CA storage (Washington State Department of Agriculture, Plant Services Division).

From 1994 to 1999, approximately 41 percent of CO poisonings specific to fruit packing and storage occurred in cold rooms or open CA rooms. These rooms are inherently designed with no fresh air ventilation and CO levels can build quickly inside them. Because so many poisonings occur in conjunction with opened CA rooms, and because CA technology is growing, produce packers are highly encouraged to consider using electric lifts in these rooms.

Tip: Electric forklifts are the only reliable tool for safe movement of produce within opened CA rooms. Their costs should be budgeted into the operating and construction costs associated with CA storage.

Economic impact – case studies

Indirect costs associated with CO poisoning include:

- Absenteeism
- Employee turnover
- Re-training costs
- Reduced attention to product quality
- Poor employee morale
- Investigation costs
- Risk of third party litigation
- Public relations issues
- Cost of market delays

The following five case examples illustrate workers' compensation costs and WISHA penalties associated with CO poisoning. In the fruit packing industry or warehouse setting, a single CO event typically leads to multiple workers becoming ill, which drives up all costs.

Tip: With so many employees at risk and with some types of poisonings predictable, preventing these injuries is cost-effective.

Case Study 1: Cherry fumigation and export packing

When:	**June 2004**
Where:	**Fruit packing company**
Number of Workers Poisoned:	**45**
Workers' Comp. Cost:	**Approximately $32,000**
WISHA Penalty:	**$14,000**

After working 4 to 5 hours in a large warehouse that had been sealed according to pest fumigation protocols, employees were ill and unconscious. Ambulances evacuated all sick workers to the local emergency room (ER). Using the carboxyhemoglobin (COHb) levels found in workers' blood drawn at the ER, WISHA estimated the airborne CO levels inside the plant had ranged from 266 to 532 ppm; this exceeds WISHA's ceiling limit of 200 ppm.

Cause of Poisoning:

A DOSH investigation revealed that four rental lifts emitted excessive CO (5% to 6%). Three employer-owned forklifts showed good maintenance and emitted less than 1% CO. All seven lifts were fitted with catalytic converters. In this incident, there were no engineering or administrative controls in place such as electric powered lifts, ventilation, and CO alarms.

Case Study #2: Cherry fumigation and export packing

When:	**July 1997**
Where:	**Fruit packing plant**
Number of Workers Poisoned:	**89 (1/3 total workforce)**
Workers' Comp. & WISHA Costs:	**Approximately $114,000**

Cause of Poisoning

The cause of this cherry packing poisoning was the same as described on the previous page. Electric forklifts are needed in a sealed warehouse.

Case Study #3: Unloading idling diesel truck with an LPG forklift

When:	**September 2004**
Where:	**Food distribution center**
Number of Workers Poisoned:	**4**
Workers' Comp. Costs:	**Approximately $1,254**
WISHA Penalty:	**$4,000**

Four warehouse personnel, including the forklift driver, were unloading an idling diesel truck with one LPG-powered forklift. All employees were treated with oxygen at the local ER for symptoms of headache, rapid heart rate, nausea, dizziness, light-headedness and urge to pass out.

Cause of Poisoning

Sources of CO included the propane lift as well as the idling diesel truck. The warehouse had some natural ventilation, but no mechanical ventilation. Idling vehicles, no CO alarms and poor employee training contributed to this incident.

Case Study #4: Vegetable inventory in cold room

When:	**September 2002**
Where:	**Produce wholesale company**
Number of Workers Poisoned:	**8**
Workers' Comp. & WISHA Costs:	**Approximately $7,359**

After 2 hours in the cold room, one employee suffered unconsciousness and others had severe headache, nausea, and fatigue. Using the COHb blood levels taken at the ER, WISHA estimated airborne exposures inside the cold room at 350 ppm; this exceeds the WISHA ceiling limit of 200 ppm.

Cause of Poisoning

The cause of this poisoning was one propane powered forklift operating continuously during the sorting and packing. There was no ventilation and access doors were either shut or hung with heavy plastic. Electric lifts were needed.

Case Study #5: Apple inventory in a cold room

When:	**January 2003**
Where:	**Fruit packing warehouse**
Number of Workers Poisoned:	**6**
Workers' Comp. Costs:	**$139,754 (2,503 lost work days)**
WISHA Penalty:	**$10,200**

After 3 hours of inventorying apples in a cold room, employees recognized that they had symptoms of headache, nausea, and fatigue. Mistaking these symptoms for the flu, employees continued to work. Upon their arrival, the fire department shut-down the facility, evacuated all employees, and had the cold room ventilated with ambient air; CO levels were at 600 ppm.

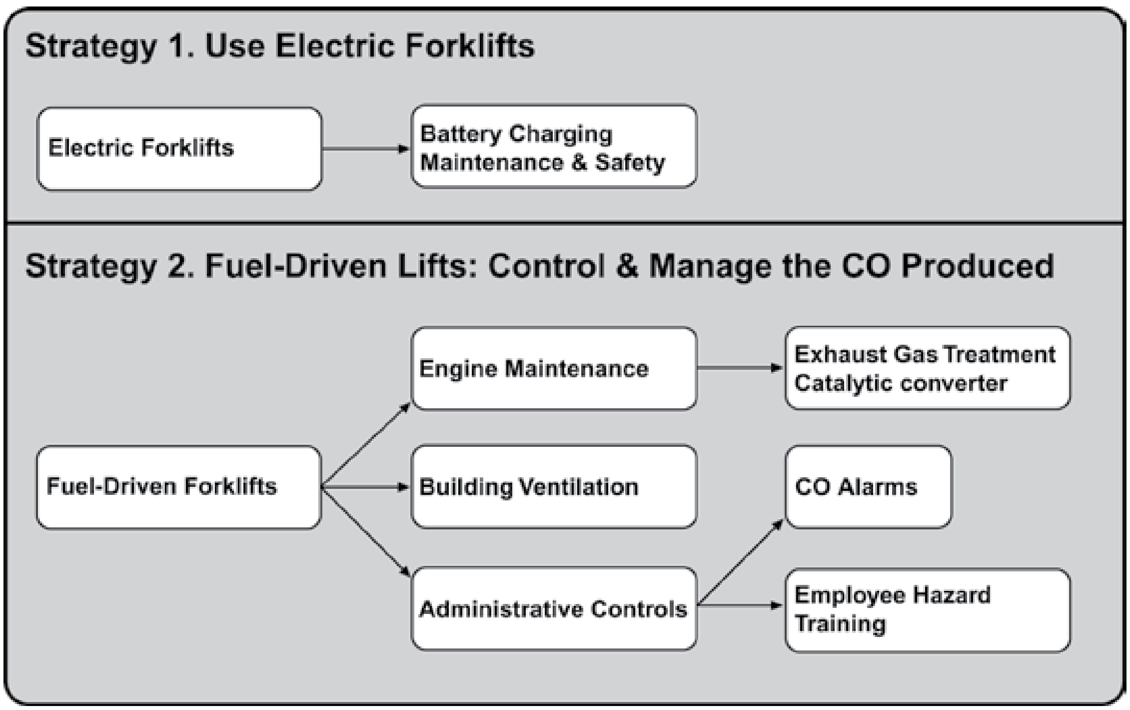
Cause of Poisoning

Two propane-powered forklifts, no ventilation, and no CO alarms contributed to this incident. Lack of employee training on the hazards of CO resulted in a costly delayed response to this incident.

CO Prevention Strategies You Need to Know

The figure below shows two strategies to prevent CO poisoning from forklifts. Electric forklifts, illustrated at the top of the diagram, require no CO control measures. Fuel-driven forklifts, illustrated at the bottom, require engine maintenance, building ventilation and administrative controls to control CO emissions. The elements for both strategies are discussed in detail in the following sections.

For fuel-driven forklifts, fuel cost savings are a benefit of keeping forklift engines tuned. Be sure to see the Engine Maintenance section, page 19.



Electric forklift on far left, LPG-powered forklift on right.

Strategy 1.
Electric Forklifts – Facts & Company Experience

Electric forklifts do not produce CO and are the most reliable solution to eliminate CO poisoning in your workplace. Electric forklifts are the only type of lift that should be used in spaces that are indoor, small and enclosed, and/or have no ventilation. Examples where electric lifts are most appropriate include the following situations:

- All indoor spaces
- Enclosed spaces with little or no ventilation
- Refrigerated storage warehouses
- Cold rooms
- Controlled atmosphere rooms
- Cargo containers and trucks

Electric Forklifts

Key points to consider with electric lifts

- Because electric lifts do not produce CO, the costs associated with managing CO are eliminated.
- **Purchase Price and Operating Costs.** While the purchase price of electric lifts is greater than fuel-driven lifts, operating costs on an electric lift are much less. A material handling company in Yakima, Washington, has documented through their guaranteed preventative maintenance program that the average annual operating cost of an electric forklift is $0.73 per hour less than LPG-powered forklifts. **This is a savings of $7,300 over 10,000 operating hours for the electric lift.**
- **Operating Life.** The operating life of some manufacturers' electric forklifts is 12,000 – 14,000 hours; this is greater than the 10,000 hour operating life of a comparable LPG-powered lift by the same manufacturer. One company has reported at least 4 more years of life with electric forklifts (12-year life) compared to their propane-powered lifts (8 year life, see the Company Profile #2 on page 17). When comparing the costs of electric lifts to fuel-driven lifts the operating life will greatly affect the annualized costs (see Worksheet in Appendix A).
- **Acceleration Speed.** Electric lifts do accelerate at speeds slower than a fuel-powered forklift.
    - Employers who use electric lifts have reported that this reduction in speed has unexpected benefits. While the work continues at a steady pace, risk for pedestrian accidents, lift tip-over, and tire wear are reduced. See Company Profile #2 for estimated cost savings on tires related to acceleration speed.
- **Risk Reduction.** Money invested on electric forklifts is money saved on potential CO poisoning. In the case studies described on pages 7-9, companies incurred workers' compensation costs and WISHA penalties ranging from approximately $5,000 to $150,000.
- **Right Tool for the Job.** Because cold rooms and CA rooms have limited ventilation, the proper materials handling tool is an electric lift. The purchase and use of electric lifts should be included in your company budget and standard operating procedures required for successful CA room storage.

Battery life and charging

- A high-quality battery may come with a 5-year or 1500 charge-cycle warranty. Battery lifespan can range from 3 years under very poor maintenance, 5 to 7 years for most consumers, and up to 12 years under optimal care and use applications.
- Personnel need technical training to charge and maintain batteries to maximize the lifespan. Without proper maintenance, battery life will be significantly reduced.
- Before purchasing an electric lift, work with your insurance company and local fire department to ensure that battery storage and maintenance will be acceptable.
- Discuss battery recycling and recovery options with your vendor at the time of battery purchase.

Batteries and battery chargers for electric forklifts.

Example of a battery safety sign and emergency body shower in a battery charging room.

Battery safety

Employees should be educated on the hazards associated with lead acid batteries. Battery charging areas should be dedicated, well-ventilated spaces. The primary safety and health hazards with lead acid batteries include:

- **Hydrogen Gas.** Battery charging produces hydrogen gas as a by-product. Hydrogen gas is explosive and odorless. To remove hydrogen gas, the charging area needs to be well ventilated (see Forklifts and Other Powered Industrial Trucks WAC 296-863). Hydrogen gas detectors are recommended.
- **Sulfuric Acid.** Lead acid batteries contain sulfuric acid, a corrosive that burns the skin and eyes. Eye goggles and rubber gloves are required when handling batteries. An eyewash station is required in the battery charging area (see Safety and Health Core Rules, First Aid WAC 296-800-150).
- **Shock.** Contact of bare hands with both battery terminals at the same time can result in shock.
- **Battery Weight.** Electric forklift batteries may weigh up to 3,000 pounds. A mechanical lifting device is needed to move the batteries between the forklift and charging station. It is essential to properly secure the battery load at all times to prevent injury.

Using electric forklifts: Two company profiles

Two fruit packing companies who have adopted electric forklifts were interviewed about their experiences with electric lifts. Strategies for bringing electric lifts into their fuel-driven fleets are discussed, along with electric forklift performance and costs. To help compare the cost of electric lifts with fuel-driven lifts, a cost analysis worksheet (Appendix A) is provided. When costs are compared on an annual basis, electric lifts are competitive in price with fuel-driven forklifts. Use the worksheet, along with information from your local vendor, to estimate the short- and long-term costs of either fuel-driven or electric forklifts.

Large company - Profile #1

A large fruit packing warehouse in eastern Washington has begun the long-term process of replacing fuel-driven forklifts with electric lifts. The company has over 700,000 square feet (ft^2) of warehouse space with 70% of this space in refrigeration. They employ approximately 400 workers with 100 trained lift drivers, and operate two 9-hour shifts seven days per week. Beginning in 2002, a total of 35 out of 70 fuel-driven lifts have been replaced.

Motivation for this change was an awareness of CO poisoning at other fruit packing warehouses and a desire to reduce their risk. Their strategy was to replace LPG forklifts used in small, refrigerated, high-use areas first, while continuing their existing maintenance and tune-up program for the remaining fuel-driven lifts.

Carbon Monoxide Concentrations

CO levels are measured using a fixed CO meter and individual badge dosimeters. The CO meter is permanently located in the packed fruit segregation area, where CO levels are highest.

Before electric lifts were used. Area CO levels could be as high as 90 ppm with an 8-hour Time-Weighted Average (TWA) of about 50 ppm. This exceeds the WISHA Permissible Exposure Limit (PEL) of 35 ppm over an 8-hr TWA.

After electric lifts were introduced. Area CO levels rarely exceed the 35 ppm threshold that activates the ventilation system. The 8-hour TWA is typically about 15 ppm. Full shift worker exposure levels have declined from about 20 ppm to about 4 ppm.

Electric Forklift Performance

Lifting. The electric forklifts readily achieve the rated lifting capacity of 5,000 pounds. Lifting with electric lifts is quicker and the engine doesn't need to be revved to generate hydraulic pressure. Lifting is unaffected by the battery charge until the charge is insufficient. At this point the "lift interrupt" is triggered and the lift stops working. At this point the battery is re-charged.

Speed. Electric lifts are as fast as LPG lifts but cannot accelerate as quickly. Management considers this to be a positive aspect, because there is less erratic and irresponsible driving.

Maneuverability. Electric forklifts have a tighter turning radius, reducing the amount of tailswing during a turn. Tailswing refers to the distance the rear of the forklift swings away from the lift during a turn. Tailswing is a primary cause of pedestrian injuries around forklifts. A tighter turning radius increases operating efficiency and reduces the potential for injuries.

Battery Charging vs. Refueling. A charged battery lasts 6 to 8 hours, slightly longer than the refueling interval of 4 to 6 hours for the LPG lifts. The amount of time to change a battery, about ten minutes, is comparable to the amount of time needed to refuel an LPG powered forklift.

Costs and Savings Associated with Electric Forklifts

Initial Costs. Approximately $300,000 dollars have been spent since 2002 on this initiative. Costs include 17 electric lifts as well as 2 batteries and one charger per lift.

Battery Costs. Initial cost of $4,000 - 5,000 per battery, but volume purchases can bring this cost down.

Operating Costs. Operating costs were not estimated.

Maintenance (Labor). Considerably less labor is required to maintain electric forklifts compared to LPG forklifts. One FTE is needed to oversee battery charging operations, including the removal and replacement of batteries from the forklifts.

Maintenance (Parts). Electric motors require considerably less maintenance compared to LPG engines. Tire costs are approximately $1,000/year for LPG lifts versus $300/year for the electric forklifts. The motor and transmission for electric lifts transfer power in a way that essentially eliminates wheel spinout, thus saving tire wear.

Medium-size company - Profile #2

A small fruit packing warehouse in eastern Washington operates two 8-hour shifts, five days per week through most of the year. They employ approximately 200 workers, with 25 to 30 employees trained to drive forklifts. A large fraction of their 140,000 ft^2 packing and warehouse is refrigerated.

Motivation for using electric lifts came from recognition of potential CO poisoning, followed by CO exposure monitoring that confirmed elevated CO concentrations. The strategy used was to replace all LPG forklifts used inside the warehouse over a several year period. In 1993 they began purchasing electric lifts, as of 2005 they own 13 electric lifts and 4 LPG lifts.

Carbon Monoxide Concentrations

Carbon monoxide concentrations are no longer monitored at this company. No WISHA citations have been received and no workers have been hospitalized or diagnosed with CO poisoning at this company.

Electric Forklift Performance

Lifting. Forklifts readily achieve the rated lifting capacity of 5,000 pounds. The lifting abilities of electric and LPG forklifts have been observed to be similar.

Speed. Electric lifts are as fast as LPG lifts, but cannot accelerate as quickly. This has not affected the efficiency of materials handling and conveyance in the warehouse.

Maneuverability. Maneuverability has been observed to be similar between electric and LPG lifts.

Battery Refueling. A charged battery lasts 6 to 7 hours. Battery changes require two people, more effort, and take approximately 5 to 10 minutes longer to complete compared to refueling a LPG forklift.

Battery Life. Battery lifespan has been 8 to 10 years.

Costs and Savings Associated with Electric Forklifts

Initial Costs. Costs for the lifts already purchased were not available. Recently the company received a quote of $33,000 for a 5,000-lb capacity electric forklift, two batteries and a charger. A comparable LPG lift was believed to cost $21,000 at this time.

Battery Costs. Several 950 amp batteries were recently purchased for $4,100 each.

Battery Charging Room. While their initial battery room utilized existing space, a 1,000 ft^2 battery charging room was constructed as part of a recent facility upgrade. The ventilated room is equipped with 15 battery chargers stacked vertically in a rack with a pair of batteries. The company also elected to install a hydrogen gas detector.

Operating Costs. The fuel costs of LPG forklifts were never tracked and compared with the operating cost of electric lifts.

Maintenance. Electric lifts require considerably less in-house maintenance labor as compared to LPG lifts. The cost of parts and outside labor was tracked for electric and LPG forklifts over a two-year period from 2001 to 2002. Parts and outside labor costs, per operating hour, were much lower at $0.45 for electric lifts as compared to $1.25 for LPG-powered lifts. In this comparison, lift age was similar: the electric lifts were approximately 5.1 years old compared to 5.7 years for the LPG-powered lifts. With an average annual usage of about 1,200 hours per forklift, this is a cost savings of almost $1,000 per forklift per year. Tires were found to last two to three times longer on electric lifts. When LPG lifts accelerate quickly, the tires spin and wear the tread. This does not happen with the slower accelerating electric lifts.

Operating Life. Company is still using electric lifts purchased 12 years ago. In contrast, they have experienced that LPG-powered lifts typically need to be replaced after about eight years.

Strategy 2.
Fuel-Driven Forklifts – Control CO & Save Fuel Costs

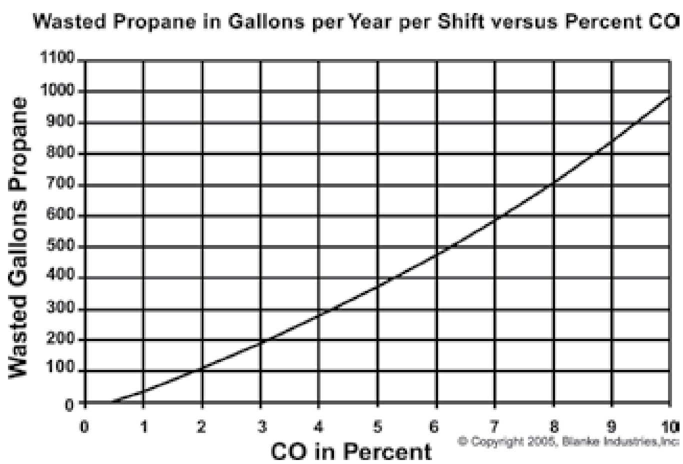
Save Fuel Costs by Reducing CO Emissions!

Engine maintenance

Improperly tuned engines are not efficient. When engines are properly tuned and CO emissions are reduced, fuel is used more efficiently. This produces real savings on fuel costs. The target emission rate for CO is 1% or less.

A forklift that emits 5% CO wastes approximately 375 more gallons of propane per year per shift compared to a lift that emits 0.5% CO (see figure below). Traditionally, over one-half of the fork lifts tested by one industry vendor were found to emit 5% or more of CO.

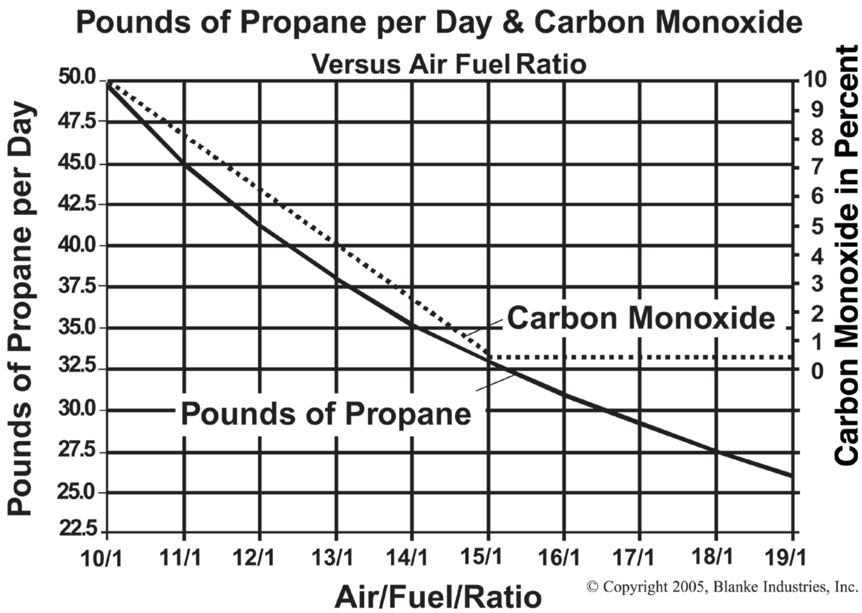
At propane fuel prices of $1 to $2 per gallon, lifts emitting 5% CO may waste $375 to $750 per year on a single 8-hr shift. A fleet of 10 lifts may waste up to $3,750 to $7,500 per year on a single shift and $7,500 to $15,000 with two shifts.



Why do low CO emissions save on fuel?

All combustion processes require air, fuel and heat to burn. In an engine, the air to fuel (A/F) ratio describes the balance between two of these key factors. The theoretical ratio at which all propane fuel will be burned using all of the oxygen in the air is 15.2 lbs of air burned for every 1 lb of fuel (the A/F ratio is 14.7:1 for gasoline engines.)

The relationship between the A/F ratio, propane consumption, and carbon monoxide emissions is shown in the figure on the next page. Notice that as the A/F mixture approaches 10:1 and becomes “rich”, fuel consumption increases and carbon monoxide emissions increase to approximately 10%. Such rich mixtures containing more fuel are not well balanced and combustion is less complete. **Rich mixtures not only burn more fuel than necessary, but they generate high levels of CO as waste gas.** In “lean” A/F ratios (ratios > 15.2:1), excess air is present during combustion, leading to elevated production of nitrogen oxides (NO_x), another toxic gas pollutant. **The optimal A/F mixture for propane engines is a ratio of 15.2:1. Engines tuned to this ratio get the best fuel economy and emit low CO emissions at approximately 0.5%.** For more information on how emission testing can save fuel costs, see Blanke Industries’ technical bulletin Use of CO & Tune-ups to Lower Fuel Costs (Technical Bulletin No. TB-FL0108, accessed on February 13, 2009, at **www.blankeindustries.com/bulletins/ForkliftTechnicalBulletin2.pdf)**.

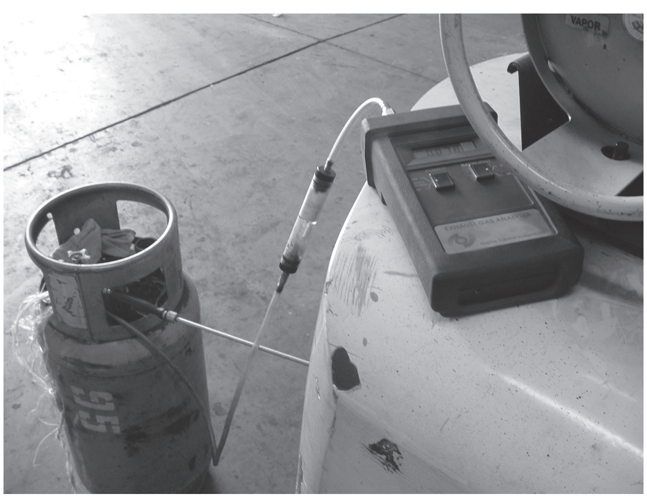


Carbon monoxide emissions testing

Carbon monoxide emission testing is essential for fuel-driven forklifts that operate indoors. **The carbon monoxide concentration in forklift emission should be 1% or less; concentrations greater than this indicate the need for an engine tune-up.** Routine CO exhaust checks make good business sense and can be performed in-house with convenient and easy to use hand-held CO exhaust gas analyzers. Such analyzers are commercially available for $1,000 and up. Savings in fuel costs may pay for the cost of an emission analyzer.

Tip: Consultants from L&I's Division of Occupational Safety and Health (DOSH) are available for assistance with emission testing, particularly for small employers. These consultations provide free, confidential, no-penalty assessments. Consultation does require that you correct any serious hazards noted. See the DOSH contact information provided on page 30 for more information.

In-house forklift emissions testing.



Fuel-driven lifts: The latest in catalytic converters

While a forklift can be tuned to emit 0.5% to 1% CO, this is still 5,000 to 10,000 ppm of CO. This emission concentration may still be enough to accumulate and cause poisoning in certain work operations. You can determine whether you need catalytic converters through area and personnel sampling.

When used properly, catalytic converters reduce CO in raw exhaust gas. They convert the harmful exhaust emissions of CO, hydrocarbons (HC), and nitrogen oxides (NO_x) into less harmful emissions of nitrogen, water vapor, and carbon dioxide.

When should catalytic converters be used?

- When fuel-driven lifts operate in semi-enclosed and well-ventilated areas.
- When workers are in close proximity to exhaust fumes.
- When the warehouse product is adversely affected by exhaust emissions.
- **Use electric forklifts** if the space is enclosed, not ventilated or poorly ventilated.

What kinds of catalytic converters are available?

Lifts that are currently equipped with converters are likely to be using **two-way catalytic converters** that remove CO and hydrocarbons (HC) from exhaust gas. While two-way converters can reduce CO emissions, they may not perform consistently. Rich running engines may contain more CO in the emissions than can be removed. CO emissions vary with operating condition (i.e. idle, cruise, full load) and two-way converters, which require an external air induction, are not able to adjust for these different conditions. Though widely available in the past, two-way converters are being phased out of production and have become obsolete with the advent of three-way catalytic converters.

Three-way catalytic converters remove CO and HC like two-way converters, but they also remove NO_x from exhaust gas. To work properly, 3-way converters require installation of an air-to-fuel ratio controller. The controller ensures that all three contaminants are present in the correct proportions for maximum emissions reductions. The retail price for a 3-way converter and controller may range from approximately $1,500 to $2,500. Check with your local vendor for more information on converter installation costs, maintenance costs and projected lifespan.

Do catalytic converters eliminate all CO in exhaust gas?

No. A three-way catalytic converter is expected to reduce CO emissions by 70 to 90 percent. Performance of a three-way converter will depend on engine maintenance, the setting of the A/F ratio controller, the state of the fuel system, and the catalyst technology used. In an unventilated space, the performance of a two or three-way catalytic converter may not be enough to prevent CO poisoning. The root of the problem remains that CO accumulates quickly in enclosed spaces, and can cause harmful health effects even at low levels. While catalytic converters may substantially reduce the risk of a CO poisoning, they do not eliminate the risk entirely.

Keep these points in mind about catalytic converters:

- Catalytic converters require well maintained engines, tuned to the right A/F ratio. Propane burning engines that run rich (A/F ratio < 15.2:1) will contain more CO emissions in the raw exhaust than can be converted to CO_2 (carbon dioxide). Carbon monoxide poisoning could occur from a rich running engine equipped with any type of catalytic converter.
- Two-way catalytic converters require oxygen in the exhaust gas to convert harmful CO into less harmful CO_2. This is usually supplied by an external air induction device and if the device is not functioning correctly performance will suffer.
- Two-way catalytic converters can overheat when used on a poorly maintained engine. This can destroy the converter in a few weeks and in certain applications (paper handling for instance), can be a fire hazard.
- Installation of a catalytic converter does not qualify a forklift to be used in refrigeration rooms, cold storage rooms, or other non-ventilated spaces. Electric lifts should be used in these areas.

See Appendix B for important information on the Environmental Protection Agency's (EPA's) forklift emission regulations that took effect in 2004 and in 2007.

Building ventilation and administrative controls

Ventilation

Building ventilation alone should not be relied upon to prevent CO poisoning when fuel-driven forklift are used indoors. Along with ventilation, factors that affect the risk of CO poisoning include:

- Employee proximity to forklift exhaust.
- Adequate dilution of forklift exhaust gases with room air.
- Consistent engine and catalytic converter maintenance.
- Regular testing of CO emissions, including vendor testing of rental lifts.

It is challenging to accurately determine dilution ventilation requirements for warehouse vehicles and forklifts. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends 5,000 cubic feet per minute (cfm) dilution ventilation for every 60 horsepower propane fueled forklift (ACGIH Committee on Industrial Ventilation. Industrial Ventilation: A Manual of Recommended Practice, 23rd edition. Chapter 10 Specific Operations, Section 10.85 Vehicle Ventilation, page 10-140. ACGIH, Cincinnati, OH, 1998).
This recommendation assumes: a) forklift CO emissions do not exceed 1%; b) forklift operation does not exceed 50% of the working day; c) good distribution of airflow must be provided; and d) total volume of the warehouse space must amount to 150,000 ft^3/lift truck or more.

Administrative controls

Monitoring for carbon monoxide

Air monitoring of CO is needed to assess the risk for CO poisoning. Air monitoring is used to determine whether employees are exposed to CO concentrations under or above the Permissible Exposure Level (PEL) and to alert staff to an emergency. For a list of the CO PELs, please see page 29.

The two main approaches to monitoring for CO are:

1. Ambient area and survey monitoring
2. Personal monitoring on the worker's shirt lapel (breathing zone)

Personal electronic detectors (see table on the next page) with high- and low-level alarms are recommended as a practical and economical choice. These detectors are available at moderate cost and could be used for every-day monitoring as well as kept on hand for upset conditions when high CO levels might be anticipated. When buying any monitor, special attention should be paid to measurement accuracy, pre-programmed alarm levels, maintenance, calibration procedures and instrument life. See a safety vendor for more information.

CA rooms are continually monitored for several environmental parameters, such as temperature, humidity, nitrogen, and carbon dioxide. Consider integrating a CO alarm into the room's environmental monitoring system.

Key features of different CO monitoring equipment

Monitor Type	Result Display	Passive Emergency Alert[1]	Average Exposure (PEL)[2]	Maint. & Calibration	Accuracy	Instrument Life	Cost[3]
Ambient Area and Survey Monitoring							
Stationary Electronic Monitors[4]	Digital	Yes	Yes	High	High	Years	$$$
Hand-held electronic survey (mobile)	Digital	No	No	High	High	Years	$$,$$$
Detector Tubes	Color Change	No	No	n/a	Low(± 25%)	1 day	$
Personal Monitoring							
Passive Badges	Color Change	No	Yes	n/a	Low(± 25%)	1 day	$
Personal Electronic Detectors	Digital	Yes	Yes	n/a	Varies	Up to 2 years	$$

[1]Assuming the monitor is turned on in the morning and functioning properly, refers to whether the monitor can alert to an emergency during a busy work day.

[2] Refers to whether the monitor can calculate 8-hr time weighted and 5 minute average exposures that can be used to determine compliance with the PEL.

[3]Approximate Cost: $ = $15 each; $$ = $200 - $500; $$$ = $500 - $1,000; $$$ = > $1,000

[4] Stationary electronic monitors require careful placement within the worker-occupied and forklift travel zones. Monitors that are placed outside of the worker-occupied zone and that do not measure the air that employees breathe may fail to alert in an emergency. Stationary monitors will become troublesome if the alarm chronically sounds and is routinely ignored.

Tip: Residential carbon monoxide detectors are not intended for use in an occupational setting. The built-in alarm point on residential detectors may not be accurate or low enough to detect workplace CO exposures.

Tip: Consultants from L&I's Division of Occupational Safety and Health (DOSH) are available for assistance with emission testing, particularly for small employers. These consultations provide free, confidential, no-penalty assessments. Consultation does require that you correct any serious hazards noted. See the DOSH contact information provided on page 30 for more information.

Employee training and hazard communication

Who should be trained?

It is critical to train forklift mechanics and operators on CO so that they can accept their responsibility to prevent poisonings. Both warehouse employees who work near forklifts and their supervisors should be trained.

What should the training cover?

Use the sample CO Training Checklist provided in Appendix C to guide your training.

Fuel Driven Forklifts

Summary

Carbon monoxide poisoning from forklifts is common in Washington State. Reducing your risk for CO poisoning makes good business sense, and this guide provides the details to help you choose the strategy that is right for you.

The first strategy to consider in preventing CO poisoning is the use of electric forklifts, particularly in non-ventilated spaces such as cold rooms and controlled atmosphere rooms. Company experiences with electric forklifts, as well as a forklift annualized cost-comparison worksheet, is provided.

The second strategy, for fuel-driven forklifts, is rooted in good engine maintenance that saves money and reduces CO emissions. If you use fuel-driven lifts indoors, include the following in your comprehensive strategy to prevent CO poisoning:

- Maintain engines at the proper air to fuel ratio. Target CO emissions at 0.5% to 1%, and save money on fuel costs at the same time.
- Use catalytic converters to reduce CO emissions.
- Conduct routine engine tune-ups.
- Conduct routine in-house emission testing to ensure CO emissions are 0.5% to 1%.
- Provide adequate general ventilation in areas where forklifts operate.
- Conduct area CO monitoring to determine whether electric lifts or fuel-driven lifts with catalytic converters are needed. Conduct personal CO monitoring of workers to determine their exposure. Keep a few personal CO alarms on hand for use during upset conditions, when CO poisoning could be a problem.
- Educate lift drivers and mechanics on their role in preventing CO poisoning. Educate all workers and supervisors on CO sources, symptoms, and action to take during a poisoning.

Regulations and Resources

Permissible exposure limits (PELs) for carbon monoxide

There are laws that govern the amount of CO in the air that workers can breathe. These standards do not apply to forklift tailpipe emissions; they apply to the ambient air where employees are working. Knowing which standards apply to your business can be a challenge. The following table lists the predominant standards and recommendations. How do you figure out which standard applies to you? Consider the following:

1. Is your state regulated by the Occupational Safety & Health Administration (OSHA)? Go to **www.osha.gov/dcsp/osp** to find out.
2. If your state is governed by OSHA, follow the column titled OSHA PEL in the table below.
3. If your state has its own State-OSHA Plan, then you need to check with your state's labor department to find out what the relevant standards are. Use the State Plan Directory at **www.osha.gov/dcsp/osp** to find out who to call. (Note: State-OSHA standards are at least equivalent to OSHA, but they can be more stringent (e.g., a lower PEL, such as in Washington State).
4. If you want to follow the best safety practices, strive for the levels listed in the NIOSH and ACGIH columns. These are recommendations rather than standards. The NIOSH column is particularly applicable if the work shift is 10 hours long rather than 8 hours long.
5. If your business is located in Washington State, follow the last column which is specific to Washington's Industrial Safety and Health Act (WISHA).

Standards for carbon monoxide in air

Time Interval[1]	OSHA PEL[2]	NIOSH REL[3]	ACGIH TLV[4]	WISHA PEL[5]
10-hr TWA[6]	--	35 ppm	--	--
8-hr TWA	50 ppm	--	25 ppm	35 ppm
Ceiling Value[7]	--	200 ppm	--	200 ppm[9]
IDLH[8]	--	1200 ppm	--	1500 ppm

[1]This is the length of time to which the standard applies

[2]Occupational Safety & Health Act, Permissible Exposure Level

[3]National Institute for Occupational Safety and Health, Recommended Exposure Level

[4]American Conference of Governmental Hygienists, Threshold Limit Value

[5]Washington Industrial Safety & Health Act, Permissible Exposure Level

[6]TWA: Time-weighted average

[7]NIOSH ceiling values should not be exceeded at any time

[8]Immediately Dangerous to Life or Health, exit immediately

[9]WISHA ceiling value is a 5 minute average

Helpful resources

Washington State Department of Labor & Industries

Warning! Carbon Monoxide (CO) Gas! Posters (publication #81-1-2005) and Pamphlets (#81-2-2005) can be obtained free from the SHARP Program at the Department of Labor & Industries: **https://lni.wa.gov/safety-health/safety-research/sharp-publications/?pg=1&index=SHARP** or by calling 1-888-667-4277. The materials are bilingual in English and Spanish.

Forklift Safety Guide for Employers. Available at: **https://lni.wa.gov/forms-publications/F417-031-000.pdf** (PDF file).

Carbon Monoxide. hazard alert available at: **https://lni.wa.gov/safety-health/preventing-injuries-illnesses/hazardalerts/CarbonMonoxidePoisoningsAtIndoorWorkPlaces.pdf**

National Institute for Occupational Safety and Health (NIOSH)

NIOSH Alert, *Preventing injuries and deaths of workers who operate or work near forklifts.* DHHS (NIOSH) Publication Number 2000 – 112a. August 2000. Available at **https://www.cdc.gov/niosh/docs/2001-109/.**

DOSH Consultation Services:

To learn more about DOSH Consultation Services, go to: **https://www.Lni.wa.gov/Consultation**. To speak with someone directly, call the regional office near you.

Regional Phone Contacts

Everett	425-290-1431
Seattle	206-281-5533
Tacoma	253-596-3917
Tumwater	360-902-5472
E. Wenatchee	509-886-6570
Spokane	509-324-2543

List of Acronyms

A/F Ratio	Air to Fuel Ratio
CA	Controlled Atmosphere
CFM	Cubic Feet per Minute
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COHb	Carboxyhemoglobin
EPA	Environmental Protection Agency
HC	Hydrocarbon
LPG	Liquefied Petroleum Gas (includes propane)
NO_x	Nitrogen Oxides (includes Nitric Oxide, NO, and Nitrogen Dioxide, NO_2)
PEL	Permissible Exposure Limit
PPM	Parts Per Million
WISHA	Washington Industrial Safety & Health Act

Appendix A.

Cost Analysis Worksheet of Electric and Fuel-Driven Forklifts

The following table outlines the major annual costs associated with both electric and LPG-powered forklifts. The list may not be complete, but it is a starting point for comparing the two types of forklifts. Work with your forklift vendor to estimate the costs and benefits of either type of lift.

Annual Cost Analysis for Electric and Fuel-Driven Forklifts*			
OWNERSHIP COST		**LPG**	**Electric**
1	Truck Capacity	lb	lb
2	Price of Truck	$	$
3	Estimated Truck Life	yrs	yrs
4	**Annual Cost of Truck Ownership (Line 2/3)**	$/yr	$/yr
5	Cost of a pair of batteries (2)	----	$
6	Estimated cost of battery recycling & disposal	----	$
7	Estimated life of battery pair	----	yrs
8	**Annual Cost of Battery Ownership (Line (5+6)/7)**	----	$/yr
9	Charger Cost	----	$
10	Charger Life	----	yrs
11	**Annual Cost of Charger Ownership (Line 9/10)**	----	$/yr
12	**Total Annual Ownership Cost (Lines 4+8+11)**	$/yr	$/yr
ENERGY COST			
13	Fuel Cost	$/yr	$/yr
14	Annual Hours of Operation	hrs/yr	hrs/yr
15	**Total Annual Energy Cost (Lines 13 x 14)**	$/yr	$/yr
MAINTENANCE COST			
16	Yearly Maintenance Labor Cost (include emission testing)	$/yr	$/yr
17	Yearly Maintenance Parts Cost (include catalytic converter)	$/yr	$/yr
18	**Total Annual Maintenance Cost (Lines 16+17)**	$/yr	$/yr
COST TOTALS			
19	**Total Annual Cost (Lines 12+15+18)**	$/yr	$/yr

* Adapted from Yausa Batteries Inc's Web site, before they sold their industrial battery line.

Additional costs that may be difficult to quantify but that should be listed:

- Cost of battery storage room vs. propane fuel tank replacement & maintenance.
- Cost of CO monitors and badges.
- Cost savings realized by averting workers' compensation claims and WISHA penalties related to CO poisoning.

Appendix B.

Environmental Protection Agency (EPA) Emission Regulations

The EPA has adopted regulations that govern the emissions of new forklifts (EPA 40 CFR part 1048: Control of emissions from new, large nonroad spark-ignition engines; **www.epa.gov/otaq/largesi.htm**). The regulations apply to all *new* (not previously owned) large spark-ignition engines rated at 19 kW or more; this will include most industrial forklifts. The regulation is two-tiered. Tier 1 went into effect January 2004 and was a standard of 50 g/kW-hr for CO emissions. Tier 2 took effect in 2007 and the standard for CO emissions was reduced to 4.4 g/kW-hr*. As of this writing in 2009, engine manufactures must ensure that each new large spark-ignited engine sold now meets the Tier 2 emission standards.

What do the EPA regulations mean for me and my workers?

The EPA regulations have brought advancements in engine technology to the forklifts bought and sold today. The intention is that CO poisoning from fuel-burning forklifts may be reduced in the future. When reviewing the use of your forklift fleet, consider the following:

- Forklifts manufactured in 2003 or earlier were not typically sold with catalytic converters. The risk of CO poisoning from these lifts, particularly when used indoors, is high.
- Forklift engines manufactured from 2004 to 2006 were required to meet the EPA's Tier 1 emission standard described above.
- Forklift engines manufactured starting in 2007 need to meet the most strict, Tier 2, CO emission standard of 4.4 g/kW-hr*. To meet this Tier 2 standard, the effectiveness and durability of emission controls are further advanced. For example, engines meeting Tier 2 standards must have a dashboard light that indicates when the engine's emission controls are malfunctioning. These engines are using post-oxygen sensors and have higher catalytic converter durability compared to previous year models.
- You may not disable any emission controls installed on your engine. Follow the manufactures recommendations for maintaining the emission controls over the life of the engine (see EPA 40 CFR part 1048: Control of emissions from new, large nonroad spark-ignition engines; **www.epa.gov/otaq/largesi.htm**).
- Forklifts manufactured in 2007 or later, if properly maintained, should generate much lower concentrations of CO than previously manufactured lifts. Please remember that even low CO emissions in poorly ventilated or non-ventilated spaces (such as refrigeration and cold rooms) can still build to poisonous levels depending on the size of the space, the number of forklifts operating, and length operating time. While CO poisoning risk is reduced with newer fuel-burning forklifts, the risk is only eliminated with the use of electric forklifts.

*NOTE: While a direct conversion of the units "g/kW-hr" into "percent" CO emission is not mathematically possible, testing shows that 4.4 g/kW-hr is equivalent to approximately less than 0.5% CO (pers. communication, Steven Griffin, Intertek Carnot Emission Services, December 2008).

Appendix C.

Carbon Monoxide (CO) Employee Training Checklist

The following checklist can serve as a guide for topics that should be covered in employee training.

Date Discussed	Topic
	Discuss where carbon monoxide gas is generated at your company.
	Carbon monoxide gas cannot be detected by the senses. You: ☐ Cannot taste it ☐ Cannot smell it ☐ Cannot see it
	Signs and Symptoms of CO Poisoning ☐ Feels like sudden onset of the flu ☐ Headache ☐ Dizziness ☐ Nausea ☐ Rapid breathing ☐ Chest pain ☐ Unconsciousness ☐ Death
	How drivers can protect themselves and others: ☐ Do not allow lifts to idle. ☐ Keep engines well tuned to emit 1% CO or less. ☐ Do not adjust the carburetor outside of a tune-up. ☐ Maintain catalytic converters. ☐ Do not operate fuel-driven lifts in non-ventilated areas. ☐ Immediately remove lifts suspected of high CO from operation. ☐ Be wary of rental lifts. Ask the vendor what % CO they emit. ☐ Other (?).
	How employees can protect themselves and others: ☐ Do not work in confined areas with fuel-driven lifts. ☐ Do not work in sealed fumigation rooms with fuel-driven lifts. ☐ Report non-working ventilation immediately to supervisor. ☐ Notify supervisor immediately if CO monitor alarms. ☐ Seek help immediately if you suspect CO poisoning. ☐ Watch for illness in your co-workers. ☐ Other (?)
	Pay attention to unusual situations that have caused CO poisoning in the past: ☐ Restricted ventilation for any reason. ☐ Non-functional ventilation. ☐ Use of rented forklifts without knowledge of CO emissions. ☐ Upset conditions such as restacking collapsed storage. ☐ Re-routed forklift traffic closer to worker stations. ☐ Other (?)
	CO Monitoring in the workplace ☐ What the CO monitors do. ☐ What the alarms mean. ☐ Action to take when an alarm sounds. ☐ Other (?)
	Emergency Response ☐ Seek fresh air immediately if you suspect CO poisoning. ☐ Call 911 for victims who are ill or unconscious.

Appendix C, continued

Educational posters and pamphlets, titled *Warning! Carbon Monoxide Gas!* are available in English and Spanish from Labor & Industries. Download these documents from: **http://www.Lni.wa.gov/Safety/Research/HazardousChem/CarbonMonoxide/default.asp** or call the SHARP Program at 1-888-667-4277.

Before the training identify all possible sources of CO.
All combustion engines produce CO gas. Examples include:

- ☑ Fuel-driven forklifts
- ☑ Heaters
- ☑ Idling trucks
- ☑ Sprayers
- ☑ Generators
- ☑ Power washers
- ☑ Portable saws
- ☑ Floor scrubbers

To reinforce the concept that all fuel-burning combustion engines produce CO gas, ask your employees to think about engines they may have at home that produce CO. Home fatalities do occur from generators and heaters used in non-ventilated garages and sheds adjacent to the home.

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A Note about this Publication

The purpose of this document is to educate employers on different strategies that can be used to prevent carbon monoxide poisonings from internal combustion forklifts. Mention of proprietary names does not constitute endorsement by Labor & Industries or the SHARP Program.

An electronic copy of this report can be found at: **http://www.Lni.wa.gov/Safety/Research/HazardousChem/CarbonMonoxide/default.asp**.

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