PROPANE-POWERED
LIFT TRUCKS AND
ICE RESURFACERS

PREVENTIVE MAINTENANCE FOR SAFE PERFORMANCE

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ASTE
ASSOCIATION SECTORIELLE TRANSPORT ENTREPOSAGE

irsst

APSAM

Addendum

In table 2 of page 8 with the line entitled **Carbon monoxide (CO)**, we should read 0.4-0.8% with the idle.

However, **for a recent vehicle (2001 and more) provided with new technology**, this variation of concentrations could be 0.1- 0.8%. Moreover, the analysis of combustion gases cruising speed is not necessary for these vehicles.

Lift trucks are used in the establishments of numerous economic activity sectors while ice resurfacers are mainly used in arenas.

These vehicles as well as other similar equipment (sweepers, elevated work platforms, etc.) are run by propane-powered internal combustion engines. However, technological changes have significantly changed their maintenance and are contributing to a considerable reduction in toxic gas emissions.

Exposure risks

Perfect combustion generates carbon dioxide (CO_2) and water vapour. However, when combustion is incomplete[1], it also produces gases that are more toxic, such as carbon monoxide (CO) and nitrogen oxides (NO_x), depending on the fuel and the condition of the components determined by their maintenance. Improper operation of these vehicles or their use in a small space (trailer or railway car) or insufficiently ventilated space (refrigerated warehouse) can expose workers to toxic gases.

Carbon monoxide

Carbon monoxide (CO) is a toxic (asphyxiant), colourless, odourless, and non-irritating gas. Therefore, it cannot be detected by the senses alone. In fact, the odours from combustion are due to hydrocarbons (HCs) and NO_x. CO enters the body through the respiratory tract (inhalation) and attaches to the blood's hemoglobin. Since hemoglobin has 210 times greater affinity for CO than for oxygen (O_2), it can no longer transport O_2 towards the body's organs.

Exposure to CO can have acute (short-term) or chronic (long-term) effects, depending on the concentration and the duration of exposure. These are the main symptoms:

Acute effects	Chronic effects
• Headache, dizziness, and vertigo • Impaired vision and judgement • Drowsiness • Nausea and vomiting • Confusion, loss of consciousness, coma • Death	• Headache • Weakness, fatigue and vertigo • Insomnia, irritability • Memory impairment • Worsening of an existing cardiovascular disease

Nitrogen dioxide (NO_2)

Depending on the time and effort necessary to perform tasks,particularly for arena ice resurfacers, combustion also produces nitric oxide (NO); this unstable gas transforms into nitrogen dioxide (NO_2). Depending on the concentration, NO_2 is irritating for the eyes, throat and lungs. Long exposures to high concentrations can result in a serious lung problem (œdema).

[1] Incomplete combustion occurs when there is insufficient oxygen for the fuel (propane) to react completely with O_2 to produce CO_2 and water.

Regulations

The *Act respecting occupational health and safety* (AOHS) states, in section 51. (8), that:

> "Every employer must take the necessary measures to protect the health and ensure the safety and physical well-being of his worker. He must, in particular […] see that no contaminant emitted […] adversely affects the health or safety of any person at a workplace."

Schedule I of the *Regulation respecting occupational health and safety* (ROHS) specifies the permissible exposure values (PEVs), and subsection 10.19 (1) of Part X of the *Canadian Occupational Health and Safety Regulations* requires that the threshold limit values comply with those established by the *American Conference of Governmental Industrial Hygienists* (ACGIH). Table 1 summarizes these values for the contaminants emitted by a vehicle's internal combustion.

TABLE 1
REFERENCE VALUES

		ROHS		ACGIH®	
		TWAEV	STEV	TLV®-TWA	TLV®-STEL
Contaminant	Carbon monoxide (CO)	35 ppm	200 ppm	25 ppm	—
	Nitrogen dioxide (NO_2)	3 ppm	—	3 ppm	5 ppm
	Carbon dioxide (CO_2)	5,000 ppm	30,000 ppm	5,000 ppm	30,000 ppm

TWAEV: Time-Weighted Average Exposure Value (8 hours).
STEV: Short-Term Exposure Value (15 minutes).
TLV®-TWA: Threshold Limit Value Time-Weighted Average.
TLV®-STEL: Threshold Limit Value Short-Term Exposure Limit.
ppm: Parts per million.

Air quality in arenas

In Québec, the **Régie du bâtiment** (government building authority) issued a communiqué entitled "*La qualité de l'air dans les arenas*" (air quality in arenas) recommending that the **level of CO in the ambient air never be allowed to exceed 20 ppm**. This recommendation is also applied by the Association québécoise des arénas, in the *Guide de sécurité et de prévention dans les arénas*.

> "It is recommended that the level of CO in the ambient air of an arena be kept below 20 ppm."[2] (Free translation)

[2] Chapter 4. Air quality, section 4.1.2, Table 4.2: Description of the main contaminants in arenas.

Means of prevention

Replacement with electrical vehicles

The performance of electrical vehicles has been improved in recent years, thus allowing an interesting alternative. These are the main advantages:

- No harmful gas emissions
- Vehicle generally has a longer life cycle
- More costly to purchase, but no expense for fuel
- Less noisy
- Less maintenance

ELECTRICAL
LIFT TRUCK

ELECTRICAL
ICE RESURFACER

Ventilation

General ventilation provides fresh air to the establishment in addition to evacuating the vitiated air and, as a result, the combustion gases.

The basic ventilation rate required per lift truck, according to the ACGIH, is 5,000 cubic feet per minute, or 8,495 cubic metres per hour.

Section 103 of the ROHS refers to Table 1 of Schedule III to determine the minimum number of air changes per hour based on an establishment's classification. For example, in a maintenance garage, there must be a minimum of four air changes per hour. Also, surplus ventilation may be required when lift trucks with internal combustion engines are used[3].

A system for collection at source for scavenging the maintenance workstation should be installed. This equipment, illustrated in Figure 1, must be able to be adapted to the different exhaust systems of lift trucks.

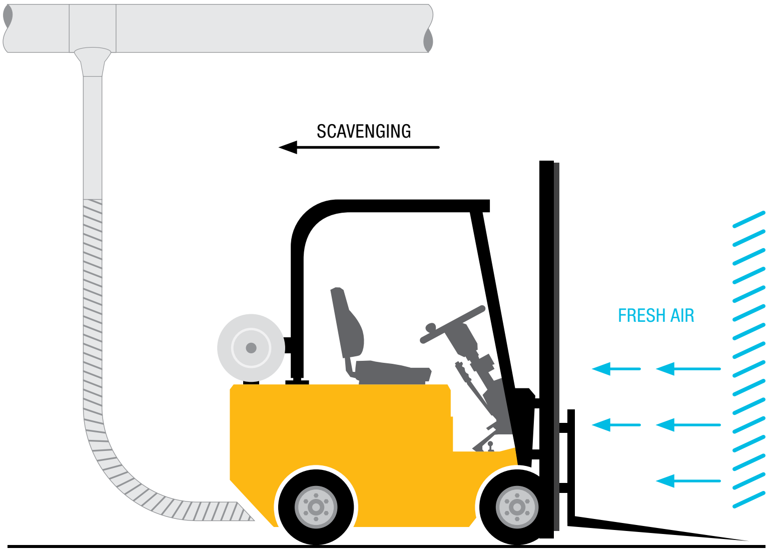


FIGURE 1
LOCAL VENTILATION OF A MAINTENANCE WORKSTATION

[3] ROHS Table 3 in Schedule III.

Preventive maintenance

Toxic gas emissions can be controlled by applying a maintenance program for all components, particularly those for the systems involved in combustion (ignition, air and electrical supply, engine cooling, etc.). A competent mechanic must perform, based on best practices, carburetion maintenance and adjustment and combustion gas analysis.

SAMPLING PROBE INSERTED INTO THE ENGINE OUTLET

The gas analysis must be done when the engine has reached the operating temperature, using an analyzer equipped with accessories for inserting the sampling probe into the exhaust system without diluting the gases. This probe can also be inserted into the engine outlet. Table 2 and Figure 2 present the suggested concentrations for balancing the combustion gases during preventive maintenance of propane-powered vehicles, regardless of the probe insertion site.

TABLE 2
RECOMMENDED CONCENTRATIONS FOR COMBUSTION GASES DURING MAINTENANCE OF A PROPANE-POWERED VEHICLE

GASES EMITTED	RECOMMENDED CONCENTRATIONS
Carbon monoxide (CO)	0,1 – 0,8% (idling) 0,5 – 0,8% (cruising speed)
Oxygen (O_2)	0,8 – 2%
Hydrocarbons (HCs)	< 200 ppm for analyzers calibrated with hexane as reference < 400 ppm for those calibrated with propane as reference
Carbon dioxide (CO_2)	Equal to or greater than 11%

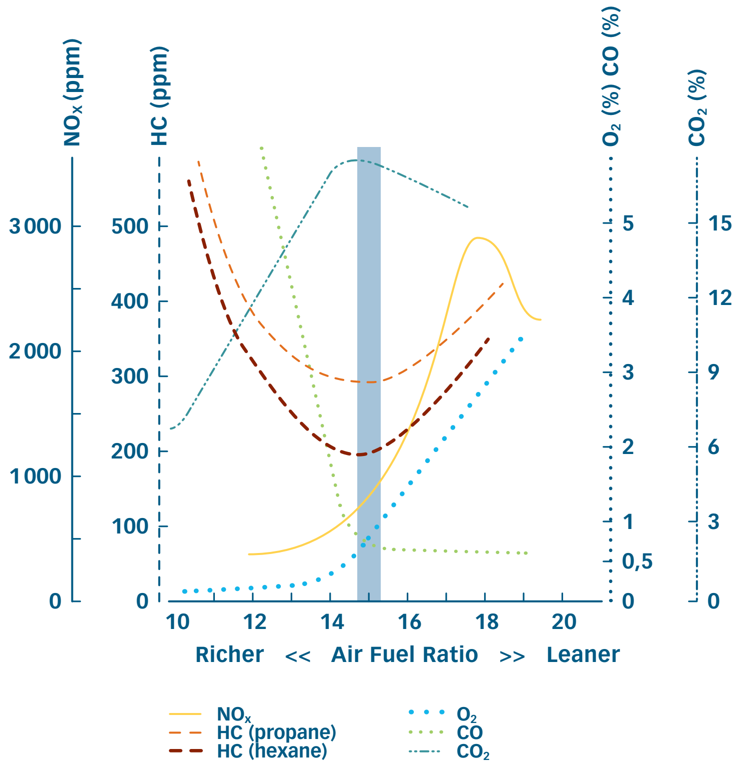


FIGURE 2
BALANCING COMBUSTION GASES FOR AN IDEAL AIR-FUEL (PROPANE) RATIO

Also, the analyzer must undergo verification and regular calibration, by using standard gases reflecting the range of concentrations recommended in Table 2. In order to target the proper concentration of hydrocarbons (HCs), the analyzer can be calibrated by using different gases (hexane, propane) recommended by the manufacturer as reference gases.

Certificate of qualification

According to the *Regulation respecting certificates of qualification and apprenticeship regarding gas, stationary engines and pressure vessels*:

- The certificate in gas carburetion techniques (TCG) is required for the following work: the installation, putting into service, inspection, maintenance, repair or removal of components, including the fuel tanks, for the supply of gas-powered internal combustion engines and for filling road vehicle tanks and cylinders.
- The certificate in cylinder and vehicle filling (RBV) is also required for the filling of cylinders and fuel tanks of gas-powered vehicles.

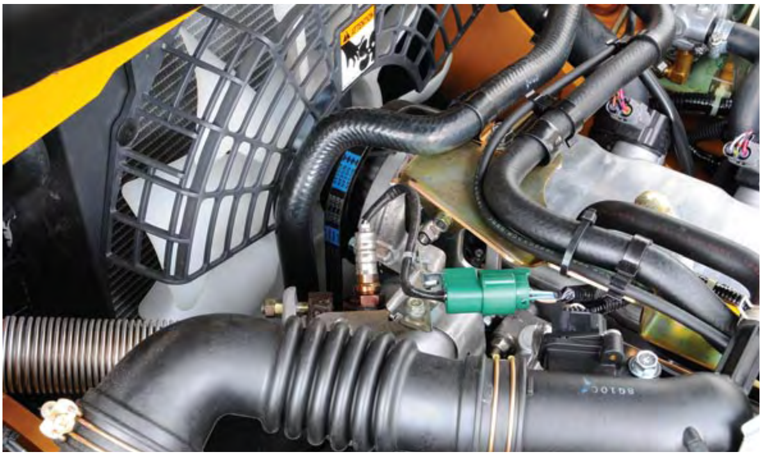
PROPANE CYLINDER

Technological evolution

Since 2001, lift trucks and ice resurfacers are equipped with systems meeting the American pollution control standards of the *California Air Resources Board* (CARB). These systems are mainly comprised of an *Electronic Control Unit* (ECU), an exhaust system with a 2-way or 3-way catalyst, and one or two oxygen sensors. However, their presence does not mean that the maintenance program can be eliminated. Nevertheless, the recommendations in Table 2 can no longer serve as reference when readings are taken in the exhaust system.

ELECTRONIC CONTROL UNIT (ECU)

The ECU is a microprocessor that controls several components (injectors, sensors, throttle valve, etc.) in order to obtain balanced combustion. The O_2 sensors adjust and maintain the richness of the mixture (air-fuel stoichiometric ratio) for the vehicle's performance and to reduce the toxic gases emitted. The gases are then treated by the catalyst, which reduces the amount of CO and HCs emitted. If it is a 3-way catalyst, it also reduces the NO_x.



OXYGEN SENSOR

If the catalyst is in good condition, the analyzer's readings taken in the exhaust system will be almost zero. The analyzer's probe must therefore be inserted into the engine outlet via an opening that must be tightly closed after the analysis. The service life of a catalyst is approximately 5 to 7 years, under good conditions. The latter is maintained by the ECU, but mainly by **regular maintenance of all components**. To make a good diagnosis and do the appropriate corrections, mechanics must have received training and have the necessary equipment.

CATALYTIC TREATMENT
OF EMISSION GASES

PREVENTIVE MAINTENANCE
AND TECHNOLOGICAL
EVOLUTION

The ECU and the catalytic treatment of emission gases are not a substitute for **good maintenance** of the vehicle and **appropriate ventilation of the premises**.

Changing the carburetor of ice resurfacers

The carburetion system of ice resurfacers is often assembled with a small carburetor. Considering that the work performed by these vehicles requires the application of a load over long periods (more than five consecutive minutes), the carburetor could be replaced by another of larger capacity. A 3-way catalyst and an oxygen sensor can also be installed. These changes provide solutions, but result in significant costs. They must be analyzed in relation to the purchase of a new vehicle that complies better with the regulations and their requirements.

Work method

The operator's manoeuvres have an impact on safety and on the mechanical condition and, as a result, gas emissions. It is therefore important that good procedures be adopted. Here are a few recommendations:

- Drive smoothly, avoiding jerking and sudden accelerations
- Do not operate the vehicle unnecessarily
- Warm up the vehicle outdoors if possible; otherwise, connect the exhaust pipe to local ventilation (see Figure 1)

Detector in ambient air

To comply with the requirements of the ROHS, establishments can use fixed CO monitors. If the establishment has a mechanical ventilation system, these monitors can adjust the flow rate in order to increase the dilution and control the contamination of the premises. Otherwise, the establishment must implement an emergency procedure that takes into account alarm levels:

35 ppm: AERATION
200 ppm: IMMEDIATE EVACUATION

Residential detectors must be prohibited in commercial and industrial establishments.

Before acquiring detectors, an establishment must consider certain aspects relating to the methods of use, installation and maintenance.

Here are several of them:

- Identify the CO emission sources
- Evaluate the CO concentrations in the ambient air in order to determine the location of the detectors
- Evaluate the areas to be considered in order to establish the necessary number of detectors
- Identify the presence of other gases or vapours, corrosive products and explosives in the ambient air (phenomenon of interference)
- Evaluate seasonal differences in temperature and humidity
- Evaluate the air movement from fans, diffusers, or other components, which can result in an incorrect response by the detection system
- Validate the operation of the detectors in the case of a power outage
- Verify whether the alarm is sufficiently audible at each workstation
- Establish an emergency procedure in the event an alarm should sound
- Establish a maintenance, verification and calibration schedule, based on the manufacturer's recommendations (or more frequently)

Detector calibration consists of verifying the accuracy of the reading by means of a certified standard gas and of adjusting the detection system's electronic components when necessary. The concentration of the standard should preferably be 35 ppm, in order to ensure response at the lowest alarm level, the TWAEV.

Establishments can also use dosimeters (personal detectors) for evaluating worker exposure, particularly those workers working in confined spaces or in any other hazardous situations.

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