MATERIAL HANDLING VEHICLES

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1.0 SCOPE

This data sheet provides property loss prevention recommendations for the selection, operation and maintenance of various types of material handling vehicles, including industrial lift trucks, automated guided vehicles (AGVs) and laser guided vehicles (LGVs), typically used indoors. Electrically powered vehicles are limited to those having Li-ion batteries smaller than 50 kWh. Hazards associated with indoor hydrogen fueling are also addressed.

1.1 Hazards

Using standard industrial trucks in or near flammable or explosive atmospheres creates the following hazards:

A. Flames or sparks from the exhaust can become an ignition source.

B. Flashback produced by vapor being drawn into and ignited in the combustion engine system can ignite the flammable or explosive atmosphere.

C. Overspeed of the engine can occur due to combustion of flammable vapor in the engine.

D. Hot surface temperatures of the exhaust system and other engine components may act as an ignition source.

E. Leaking hydraulic oil from material handling vehicles is commonly ignited on hot surfaces such as the engine block or exhaust.

F. Arcs and sparks from electrical equipment and starter motors are potential ignition sources.

G. Sparks from the discharge of static electricity or from friction (e.g., tines dragging along the floor) can be an ignition source.

1.2 Changes

October 2024. Interim revision. The following changes were made:

A. The document was renamed ″Material Handling Vehicles″ to reflect the wider scope of vehicles covered by the data sheet.

B. Added recommendations for Automated Guided Vehicles (AGVs).

C Updated loss data for the recent 20-year period (2004-2024).

D. Provided new guidance on charging stations.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Use FM Approved equipment, materials, and services whenever they are applicable and available. For a list of products and services that are FM Approved, see the *Approval Guide,* an online resource of FM Approvals.

2.2 Construction and Location

2.2.1 All Material Handling Vehicles

2.2.1.1 Provide a designated location for parking material handling vehicles during idle periods, and separate the location from manufacturing and storage areas using one of the following:

A. A minimum space separation of 5 ft (1.5 m) between the garaged material handling vehicles and combustibles

B. A one-hour fire-rated barrier between the garaging area and combustibles

2.2.1.2 Provide a designated location for service and repair of material handling vehicles, and separate the location from manufacturing and storage areas using one of the following:

A. A minimum space separation of 35 ft (11 m) between the service and repair area and combustibles

B. A one-hour fire-rated barrier between the service and repair area and combustibles

2.2.1.3 Provide guard rails, bollards, or telltales around piping exposed to damage near passageways and at exposed drain, gage, and hose connections on sprinkler risers. Warning of overhead piping may be suspended by metal strips (to create noise).

2.2.2 Battery-Powered Material Handling Vehicles

2.2.2.1 Do not place electrical chargers within storage racking.

2.2.2.2 Locate single-panel charging installations serving one or two material handling vehicles so that readily ignited material is not located closer than 5 ft (1.5 m) from the truck or the charging equipment.

2.2.2.3 Locate multiple-panel battery-charging installations, including Li-Ion battery installations for batteries smaller than 50 kWh, serving more than two material handling vehicles including Li-ion battery installations for batteries smaller than 50 kWh in a cut-off room.

2.2.2.4 Locating multiple-panel battery-charging installations in a separate area along an exterior wall or in a maintenance area is acceptable if the conditions below are met.

2.2.2.4.1 Maintain a minimum space separation of 5 ft (1.5 m) between any combustibles and the battery chargers.

2.2.2.4.2 Provide automatic sprinklers designed to deliver a density of 0.3 gpm (12 mm/min) over the most remote 2,500 ft^2 (230 m^2) with a hose stream demand of 250 gpm (950 L/min) for a duration of 60 minutes or protection for the occupancy, whichever is greater. Use FM Approved sprinklers with a temperature rating of 160°F (70°C).

2.2.2.4.3 Provide natural ventilation at high points in the exterior walls or roof.

2.2.2.5 In occupancies where lint, combustible dust, and flyings may be present, locate battery-charging equipment in a separate room with positive pressurization arranged so the buildup of these materials about the charging equipment can be minimized.

2.2.2.6 Provide physical protection around the battery chargers to prevent mechanical damage from material handling vehicles.

2.2.3 Gasoline- and Diesel-Powered Material Handling Vehicles

2.2.3.1 Refuel gasoline and diesel-powered material handling vehicles outdoors or in a well-ventilated, detached building.

2.2.4 Gas-Powered Material Handling Vehicles

The recommendations in this section relate to LPG-, CNG-, and hydrogen-powered material handling vehicles.

2.2.4.1 Provide an outdoor shelter or a detached building of lightweight noncombustible construction for storage of material handling vehicles when not in use. If gas-powered material handling vehicles are stored indoors, adhere to all of the following:

A. Locate the material handling vehicles in a designated area within the building. If the building's volume is less than that stated below, provide a designated cut-off room with damage-limiting construction in accordance with Data Sheet 1-44, *Damage-Limiting Construction*:

1. 180,000 ft^3 (5,100 m^3) for LPG
2. 110,000 ft^3 (3,100 m^3) for CNG
3. 87,500 ft^3 (2,480 m^3) for Hydrogen

B. Store the material handling vehicles at least 50 ft (15 m) from an MFL wall or sprinkler risers.

C. Provide automatic sprinkler protection in accordance with:

1. Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*, for LPG- and CNG-powered trucks.
2. Data Sheet 7-91, *Hydrogen*, Section 2.4 for hydrogen-powered trucks.

D. Close the valve supplying fuel from the cylinder to the engine while parked in the designated storage area.

2.2.4.2 LPG- and CNG-powered material handling vehicles having detachable fuel cylinders may be stored within the building when not in use without the building volume limitations and safeguards recommended in Section 2.2.4.1 if the fuel cylinders are removed prior to storage. When removing the tanks, follow the refueling procedure in Section 2.2.4.5 for replacing LPG and CNG cylinders.

2.2.4.3 Store spare LPG and CNG cylinders outdoors in accordance with Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*.

2.2.4.4 Refuel material handling vehicles having permanently mounted LPG or CNG fuel cylinders, and refill detachable cylinders, outdoors at least 50 ft (15 m) away from important buildings.

2.2.4.5 Detachable LPG and CNG fuel cylinders may be exchanged indoors at least 20 ft (6.0 m) away from open flames or other ignition sources if, prior to disconnecting the empty tank, the fuel supply is shut off at the tank and the engine is operated until all fuel in the system is consumed.

2.2.4.6 Locate LPG and CNG storage tanks up to 2,000 gal (7.6 m^3) water capacity used for refueling material handling vehicles having fixed fuel cylinders, and for refilling detachable cylinders, at least 50 ft (15 m) from important buildings. Locate larger tanks in accordance with Data Sheet 7-55, *Liquefied Petroleum Gas (LPG) in Stationary Installations.*

2.3 Occupancy

2.3.1 All Material Handling Vehicles

2.3.1.1 Keep tops of storage piles as far as practical below sprinklers but not less than 3 ft (0.9 m) to reduce the possibility of breakage of sprinklers and other overhead piping. This clearance also provides for water distribution from sprinklers over the piles.

2.3.1.2 Use an appropriately rated material handling vehicles to transport closed containers of ignitable liquid. Refer to Table 2.3.1.2 for guidance on determining the suitability of a material handling vehicle for hazardous (classified) environments.

Table 2.3.1.2. Recommended Types of Material Handling Vehicles for Various Occupancies

Location	*Typical Occupancies*	*Material Handling Vehicles* [b,c]
Indoor or outdoor locations containing materials of ordinary fire hazard	• Grocery warehouse • Cloth storage • Paper manufacturing and working • Textile processes except opening, blending bale storage, and other Class III locations • Bakery • Leather tanning • Foundries and forge shops • Sheet-metal working • Machine-tool occupancies	Electrical: Type E Gasoline: Type G Diesel: Type D LPG: Type LP CNG: Type CN Dual-fuel: Type G/LP or G/CN Hydrogen: Type H2
Class I, Division 1[a] locations in which explosive concentrations of flammable gas or vapor may exist under normal operating conditions, or where accidental release of hazardous concentrations of such materials may occur simultaneously with failure of electrical equipment	There are few areas in this division in which material handling vehicles would be used	Electric: Type EX
Class I, Division 2[a,e] Locations in which ignitable liquid or flammable gas is handled in closed systems or containers from which they can escape only by accident, or locations in which hazardous concentrations are normally prevented by positive mechanical ventilation	• Paint mixing, spraying, or dipping • Storage of flammable gases in cylinders • Storage of ignitable liquids in drums or cans • Solvent recovery • Chemical processes using ignitable liquids • Paper and cloth coating using ignitable solvents in closed equipment	Electric: Type EE or EX Diesel: Type DY
Class II, Division 1[a,f] Locations in which explosive mixtures of combustible dust may be present in the air under normal operating conditions, or where mechanical failure of equipment might cause such mixtures to be produced simultaneously with arcing or sparking of electrical equipment, or in which electrically conductive dust may be present	• Grain processing • Starch processing • Starch molding (candy manufacturing) • Wood/flour processing	Electrical: Type EX
Class II, Division 2[a] Locations in which explosive mixtures of combustible dust are not normally present or likely to be thrown into suspension through the normal operation of equipment, but where deposits of such dust may interfere with the dissipation of heat from electrical equipment, or where such deposits may be ignited by arcing or sparks from electrical equipment	• Storage and handling of grain, starch or wood flour in bags or other closed containers • Grinding of plastic molding compounds in tight systems • Feed mills with tightly enclosed equipment	Electrical: Type EE or EX preferred Type ES Gasoline: Type GS[d] Diesel: Type DS[d] or DY LP-Gas: Type LPS[d] Dual-fuel: Type GS/LPS[d] and GS/CNS[d]

Table 2.3.1.2. Recommended Types of Material Handling Vehicles for Various Occupancies (continued)

Location	*Typical Occupancies*	*Material Handling Vehicles* [b,c]
Class III, Division 1[a] Locations in which easily ignitable fibers or materials producing combustible brands are handled, manufactured, or used	• Opening, blending, or carding of cotton or cotton mixtures • Cotton gins • Sawing, shaping, or sanding areas in cordage plants	Electrical: Type EE preferred, Type ES[a] Diesel: Type DY
Class III, Division 2[a] Locations in which easily ignitable fibers are stored or handled (except in process of manufacture)	• Storage of textile and cordage fibers • Storage of excelsior, kapok, or Spanish moss	Electrical: Type ES Gasoline: Type GS[d] Diesel: Type DS[d] LP-Gas: Type LPS[d] Dual-fuel: Type GS/LPS[d] and GS/CNS[d]

a. Hazardous location as classified in the *National Electrical Code* (NFPA 70), and Sec. 32 of the Canadian Electrical Code. See Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations*.
b. Type G (gasoline), Type D (diesel), Type LP (LP-Gas), and Type G/LP (gasoline and LP-Gas) material handling vehicles are considered to have comparable fire hazards.
c. Type GS (gasoline), Type DS (diesel), Type LPS (LP-Gas), and Type GS/LPS (gasoline and LP-Gas) material handling vehicles are considered to have comparable fire hazards.
d. Acceptable if kept clean and well maintained.
e. For Group D environments. Also valid for Group C environments if FM Approved for that environment.
f. For Group F and G environments.

2.3.1.3 Ensure a permanent label is present on all material handling vehicles that are rated for hazardous (classified) locations to indicate that special safeguards have been provided.

2.3.2 Gasoline-Powered and Diesel-Powered Material Handling Vehicles

2.3.2.1 Shut off the material handling vehicles engine before gasoline of diesel refueling is started. Ensure the engine remains off during refueling.

2.3.2.2 Exercise care to avoid spilling gasoline or diesel or overfilling the tank. Ensure spilled fuel has dissipated or been flushed away before starting the engine.

2.3.2.3 Provide bonding and grounding between the hose nozzle or can spout and the tank to minimize accumulation of static electricity.

2.3.3 Gas-Powered Material Handling Vehicles

2.3.3.1 Use steel cylinders for LPG-powered material handling vehicles.

2.3.3.2 Do not expose gas-powered (LPG, CNG or hydrogen) trucks to high temperatures near ovens, furnaces, or other sources of high temperature, except for extremely short intervals. Never leave the material handling vehicle unattended near ovens and furnaces.

2.3.4 Duel Fuel-Powered Material Handling Vehicles

The following recommendations cover material handling vehicles powered by two fuels; either gasoline and LPG or gasoline and CNG.

2.3.4.1 Follow the recommendations for both types of fuels used to power the lift truck.

2.3.4.2 Follow manufacturer's recommended operating procedures for fuel supplies.

2.4 Protection

2.4.1 Provide fire extinguishers suitable for a fire involving the fuel used in the lift truck as follows:

A. Equip each gasoline, liquid petroleum gas (LPG), diesel, gasoline/LPG, battery-powered, compressed natural gas (CNG), and hydrogen-powered industrial truck with a 5 lb (2.3 kg) dry chemical extinguisher rated for ignitable liquids and gases.

B. Provide a 10 lb (4.5 kg) dry-chemical extinguisher at each gasoline or diesel refueling location rated for ignitable liquids and gases.

C. Provide a Type C extinguisher on electric vehicles.

2.5 Equipment and Process

2.5.1 Gas-Powered Material Handling Vehicles

2.5.1.1 Avoid exposing CNG and hydrogen cylinders to corrosive environments. Prolonged exposure can cause weakening of the tank's composite structure due to stress corrosion cracking, resulting in violent failure.

2.5.1.2 Provide interlocks on CNG tank refill dispensers to prevent CNG tanks being filled at pressures higher than the working pressure of the fuel cylinder. Check dispenser pressure controls and relief valves monthly for proper operation.

2.6 Operations and Maintenance

2.6.1 All Material Handling Vehicles

2.6.1.1 Stop all vehicles in place upon the operation of a fire alarm or sprinkler flow alarm. Vehicles should not obstruct:

A. Fire doors

B. Gates

C. Personal fire escape routes

2.6.1.2 Establish a system of regularly scheduled preventive maintenance. At a minimum, include the following:

A. Periodic checks of fuel lines, carburetor, fuel tanks, electrical equipment, lubrication, and safety devices

B. Rubber, plastic, or composite hoses

C. Re-filling connections on fuel tanks

If any deficiencies are identified, have the material handling vehicle removed from service and repaired.

2.6.1.3 Keep written records of the maintenance activities showing the type of service and any repairs that are made.

2.6.1.4 Ensure all maintenance and repairs are carried out by qualified personnel.

2.6.1.5 Ensure replacement parts comply with manufacturer's specifications and maintain the certification of the correct hazardous (classified) environment (e.g., ensure replacement batteries for type EX electric material handling vehicles are listed for flammable or explosive environments).

2.6.1.6 Check when reinstalling batteries after charging that they are an equivalent or higher rating than the battery type marked on the rated material handling vehicles.

2.6.1.7 Keep material handling vehicles free from accumulations of oil, grease, and lint. Clean with steam or alkaline solutions.

2.6.1.8 Keep all enclosures and protective covers around the engine and exhaust system in place at all times when material handling vehicles are operating. This is particularly important with battery-powered material handling vehicles used in hazardous (classified) locations because safe operation is dependent on these enclosures.

2.6.2 Gas-Powered Material Handling Vehicles

2.6.2.1 Provide a documented preventive maintenance program that includes frequent recorded inspections of the gas fuel supply and delivery system to avoid creating hazardous conditions as a result of the escape of the LPG, CNG, or hydrogen.

2.6.2.2 Visually inspect the cylinders for physical damage prior to use.

2.6.2.3 Do not fill permanently mounted fuel tanks beyond the maximum filling capacity according to the following temperature at filling point: 80% of liquid capacity between 10°F and 40°F (-12°C and 4°C) or 85% of liquid capacity between 40°F and 70°F (4°C and 21°C).

2.6.2.4 Fill compressed gas cylinders by weight in accordance with the listing agency's standard (e.g., fill U. S. Department of Transportation [DOT] cylinders in accordance with DOT regulations).

2.6.2.5 Have all flammable gas cylinders inspected and requalified when they reach the end of their design life (the design life will be specified by the cylinder manufacturer). Ensure fuel tanks that do not pass requalification are emptied and disposed of safely.

2.6.3 Li-ion Battery Powered Material Handling Vehicles

2.6.3.1 Establish a system of regularly scheduled inspection of all Li-ion battery powered material handling vehicles that includes:

A. Physical damage

B. Faulty wiring/connections

c. Damaged battery packs

Damaged or faulty material handling vehicles that include li-ion battery packs should be moved to a safe outdoor location.

2.6.4 AGVs

2.6.4.1 Automatically stop all vehicles in place upon the operation of a fire alarm or sprinkler flow alarm. Material handling vehicles should not obstruct:

A. Fire doors

B. Gates

C. Personal fire escape routes

2.6.4.2 Establish a system of regularly scheduled inspection of all AGV/LGVs that includes:

A. Physical damage

B. Faulty or damaged wiring/connections

C. Up-to-date firmware

C. Communication connections, e.g., Wi-Fi, campus cellular networks, proprietary communications protocols

D. Operation and cleanliness of proximity and/or optical sensors

If any deficiencies are identified, have the vehicle removed from service and repaired.

2.7 Training

2.7.1 Restrict the use of material handling vehicles to personnel trained in their operation.

2.8 Electrical

2.8.1 Install all battery charging equipment in accordance with the standards of the *National Electrical Code* (NEC or local equivalent).

2.9 Safeguards for Indoor Hydrogen Fuel Dispensing

2.9.1 General

2.9.1.1 Locate material handling vehicle fueling stations outdoors or in a detached building where feasible.

2.9.1.2 Locate and arrange bulk hydrogen storage, compression equipment, and supply piping outdoors in accordance with Data Sheet 7-91, *Hydrogen.*

2.9.1.3 Design and install hydrogen dispensing systems in accordance with Data Sheet 7-91.

3.0 SUPPORT FOR RECOMMENDATIONS

3.1 General

Material handling vehicles are used at facilities, both indoors and outdoors, for moving and lifting materials. They are essential to the operation of most facilities because of their efficiency in material handling. Their use, however, introduces hazards of fire, explosion, mechanical damage, and water damage.

Material handling vehicles have made it possible to pile storage to greater heights, increasing the difficulties of firefighting and, unless proper clearances are maintained, decreasing the effectiveness of sprinklers. Also, collisions with sprinkler piping can impair protection and release quantities of water on equipment or goods.

Some of the largest losses on record have occurred when material handling vehicles handling ignitable liquid have dropped their loads, breaking or spilling the liquid from the containers, which is then ignited by hot surfaces or sparks from the truck.

Material handling vehicles are available in various designs to suit the type of load to be handled. They are powered by storage batteries and by gasoline, diesel, LPG, CNG, hydrogen, or combination gasoline and LPG or gasoline and CNG (dual-fuel) engines.

3.1.1 Operation and Maintenance

Careless operation of material handling vehicles can lead to severe damage in many forms, including physical damage to building fixtures. Widespread damage may occur if water is released from a broken pipe or fitting on an automatic sprinkler or industrial water system. Fire doors and other important fire protection equipment intended to limit the size or spread of fire may be rendered inoperative by being struck by a truck. Mechanical damage to process piping, equipment, drums, or tanks may release ignitable liquids or other hazardous material, causing fire.

In the period 2004 through 2024, sprinkler pipe breakage accounted for nearly one-third of all losses reported to FM involving material handling vehicles. Sprinkler leakage resulting from lift truck operation is most likely to occur in storage areas where trucking activities are concentrated. Most accidents have been caused by careless operation of high-lift trucks. Operators failed to consider sprinkler piping while raising stock, or failed to leave adequate clearance between a load and overhead piping while moving with the mast raised. Gauge connections at risers, hose connections, feeder mains, and even risers have been broken. In a few reported cases, a section of roof collapsed when a column was knocked out from under it.

Operators of material handling vehicle fleets have established courses of instruction for prospective truck operators to lessen chances of accidents and decrease equipment wear. Accidents endanger equipment and buildings, fire-protection equipment, operators, and other personnel. Material handling vehicles make numerous stops and starts and work much of the time under heavy load. This hard service causes excessive wear on trucks if inexperienced or improperly trained operators are permitted to use them.

The severe service to which material handling vehicles are subjected should be recognized in arranging truck-maintenance schedules. Fire hazard is increased by the operation of dirty, poorly maintained trucks. Failure of control equipment may result in damage to the building or sprinkler piping.

3.2 Battery-Powered Material Handling Vehicles

3.2.1 General

Plastic vehicle shells, insulation, battery boxes, and accumulated grease deposits on a battery-powered material handling vehicles are combustible material that could be ignited and involve the material handling vehicle in a fire.

The principal source of ignition is short circuits in wiring. Fires have also resulted from electrical arcs, current being left on, ignitable liquid being unsafely carried, and collision.

3.2.2 Lead-Acid Batteries

Small quantities of hydrogen evolve from a lead-acid battery on charge and can introduce a potential fire and explosion hazard. An electrical disturbance may cause a fire in grease and dirt on the truck, insulation, or charging equipment.

3.2.3 Li-ion Batteries

Recommendations in this standard apply to all Li-ion batteries when they remain installed in the material handling vehicles during charging and they are smaller than 50 kWh independent of the battery type, i.e., Lithium Cobalt Oxide ($LiCoO_2$), Lithium Manganese Oxide ($LiMn_2O_4$), Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$), Lithium Iron Phosphate ($LiFePO_4$), Lithium Nickel Cobalt Aluminum Oxide ($LiNiCoAlO_2$), Lithium Titanate (Li_2TiO_3). The scenario is still a single material handling vehicle catches fire but is separated from combustibles and other material handling vehicles by at least 1.5 m (5 ft). The fire is controlled/ suppressed by the ceiling sprinklers.

When in thermal runaway, batteries release flammable gases, it is the flammable gases produced by these batteries that generate the hazards, including non-thermal and fire. For example, Lithium iron phosphate batteries are a lower capacity battery, sometimes they do not self-ignite the flammable gases; however, the flammable gases can accumulate and be ignited by any other ignition source(s). Presentations are publicly available online with videos available on the FM YouTube channel which demonstrate the li-ion battery hazard which support the importance of isolating the charging stations from the main occupancy.

3.2.4 Ventilations Rates for Battery-Charging Rooms

During the recharging process, a lead battery releases hydrogen and oxygen through the electrolysis of sulfuric acid. The beginning of gassing is determined by the battery voltage. The amount of gas created depends on the current that isn't absorbed by the battery, and can be used in the electrolysis process.

As the battery reaches its full state of charge, the acceptance of current becomes less, and more hydrogen is liberated.

If ventilation is required it needs to maintain the concentration of hydrogen vapor at or below 25% of the lower explosive limit (LEL). The LEL for hydrogen in air is 4%, so maintaining the hydrogen vapor concentration in a room at or below 25% LEL equates to 1% hydrogen concentration.

The ventilation requirements are dependent on the rate of hydrogen being released. The equation below can be used to determine the amount of hydrogen being liberated from the batteries.

English Units:

$H = A_h \times dF \times C_n \times \alpha$

Where:

H is the rate of release of hydrogen vapor (ft^3/hour).

A_h is the total ampere hours of all the batteries.

dF is the finish rate (overcharge); if unknown, assume 5% (as a fraction, e.g., 0.05).

C_n is the total number of cells for all the batteries.

α is the average release rate of hydrogen generation (ft^3/Ampere hour/cell). A value of 0.016 can be assumed based on commonly used batteries.

Metric Units:

$H = 0.03\ A_h \times dF \times C_n \times \alpha$

Where:

H is the rate of release of hydrogen vapor (m^3/hour).

A_h is the total ampere hours of all the batteries.

dF is the finish rate (overcharge); if unknown, assume 5% (as a fraction, e.g., 0.05).

C_n is the total number of cells for all the batteries.

α is the average release rate of hydrogen generation (m^3/Ampere hour/cell). A value of 0.0045 can be assumed based on commonly used batteries.

Once the rate of release of hydrogen vapor is known, the ventilation rate needed to maintain concentrations at or below 25% LEL can be determined. The equation below can be used to determine the ventilation rate required.

English Units:

$$ACH = \frac{26H}{C_{H2}} - H \Big| 0.0043V_{space}$$

Where:

ACH is the number of air changes per hour.

H is the total hydrogen discharge within the room (gpm).

C_{H2} is the concentration of hydrogen within the room (%).

V_{space} is the volume of the room (gal).

Metric Units:

$$ACH = \frac{100H}{C_{H2}} - H \Big| 0.0167V_{space}$$

Where:

ACH is the number of air changes per hour.

H is the total hydrogen discharge within the room (L/min).

C_{H2} is the concentration of hydrogen within the room (%).

V_{space} is the volume of the room (liters).

3.2.5 FM Approved Types

Battery-powered material handling vehicles are available in four types, specially designed and safeguarded for use in locations ranging in hazard from ordinary to extra:

A. Type E material handling vehicles have the minimum necessary safeguards and are for use in ordinary-hazard areas.

B. Type ES material handling vehicles have additional safeguards to prevent emission of sparks from the electrical system and to limit surface temperatures. They are recommended for areas where easily ignitable fibers are stored or handled (except in the process of manufacturing).

C. Type EE material handling vehicles have their electric motor and all other electrical equipment completely enclosed and are recommended for use in hazardous locations other than those that require Type EX.

D. Type EX material handling vehicles are of explosion proof (Class I, Group D), or dust-tight (Class II, Group G) construction and are recommended for areas where there are likely to be explosive mixtures of flammable vapor or combustible dust during normal operations.

3.3 Gasoline-Powered Material Handling Vehicles

Most of the reported fires involving gasoline-powered material handling vehicles were the result of gasoline spills during refueling. Other fires resulted from breaks or leaks in gasoline connections. The released gasoline can be ignited by the hot engine, by the ignition system when starting, by other electrical equipment, and by exhaust or other sparks. Other fires result from defective insulation on wiring, greasy deposits, or leaking hydraulic oil. Some are caused by exhaust sparks igniting combustibles in the vicinity, and some result from upsets and collisions.

Potential fire sources that cannot be completely eliminated by safeguards include gasoline that may leak from the fuel, starting, and ignition systems, and sparks from the exhaust system. Limitations on locations in which gasoline-powered material handling vehicles may be used are recommended.

3.3.1 FM Approved Types

Two types of FM Approved gasoline-powered material handling vehicles are available: Type G and Type GS. Type G material handling vehicles have the minimum necessary safeguards and are recommended for use in occupancies of light fire hazard. Type GS material handling vehicles have additional safeguards in the electrical exhaust and fuel systems and are recommended for occupancies where there are readily ignited combustible materials, as outlined in Table 2.3.1.2. When ordering, specify the complete listed type designation to ensure the proper safeguards will be supplied.

3.4 Diesel-Powered Material Handling Vehicles

Diesel-powered material handling vehicles, except the specially safeguarded Type DY, are similar to gasoline-powered material handling vehicles. However, the fuel hazard is less than that of gasoline-powered material handling vehicles because of the higher flash point of diesel fuel. Loss experience with diesel-powered material handling vehicles has been limited. Less than 5% of the reported industrial material handling vehicles losses involved diesel-powered trucks.

3.4.1 FM Approved Types

Three types of FM Approved material handling vehicles are available: Types D, DS, and DY. The fire hazard of Types D and DS are considered comparable to Types G and GS gasoline-powered material handling vehicles, respectively.

The Type DY diesel-powered material handling vehicles is equipped with additional safeguards that make it less hazardous than a Type DS material handling vehicles. Surface and exhaust gas temperatures are limited to a maximum of 325°F (163°C), there is no electrical system, and other safeguards are provided to minimize the fire hazard normally associated with internal-combustion engines.

3.5 LPG-Powered Material Handling Vehicles

LPG-powered material handling vehicles not only present the same hazards as gasoline-powered material handling vehicles, but also those of a combustible gas under high pressure.

The greatest potential danger is ignition of gas leaking from poorly maintained fuel connections being released during operation of the relief valve. Operation of the relief valve is possible from overfilling, fire exposure to the container, and high local temperatures near ovens, furnaces, or other high-temperature equipment. About two-thirds of the fires and explosions involving LPG material handling vehicles result from breaks or leaks in the fuel connections.

Special safeguards reduce the hazard of gas leakage during normal operation and refueling (see Figure 3.5). As with gasoline-powered material handling vehicles, the hazards of LPG-powered material handling vehicles cannot be eliminated completely by safeguards. Therefore, limitations on locations in which they may be used is recommended.

A liquid-withdrawal system is illustrated. In a vapor-withdrawal system the vaporizer would be omitted but the regulator would be retained, the hot water lines would be omitted, and the hydrostatic relief valve would not be required.

3.5.1 FM Approved Types

Two types of FM Approved material handling vehicles are available: Type LP and Type LPS. The fire hazard of these material handling vehicles is comparable to Types G and GS gasoline-powered material handling vehicles, respectively.

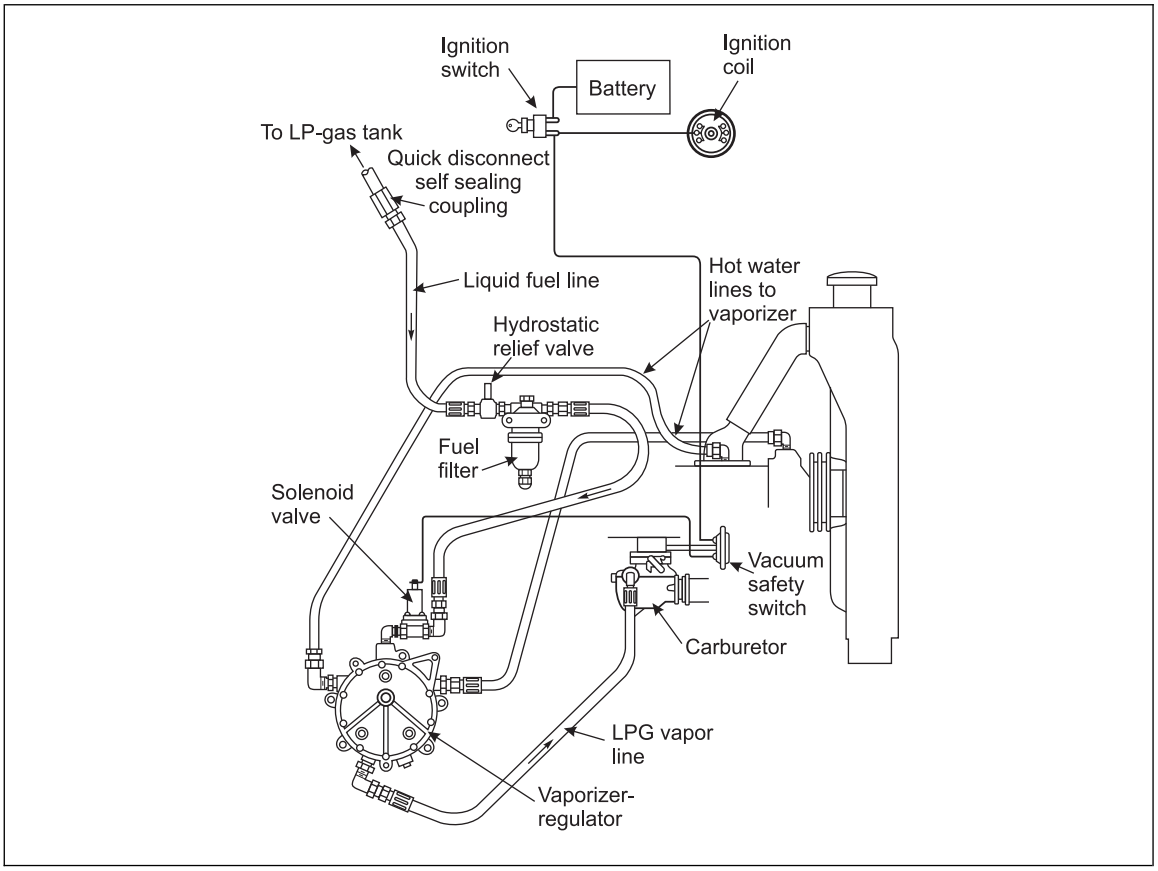

Fig. 3.5. Arrangement of components of LPG fuel system for material handling vehicles

3.6 Dual Fuel-Powered Material Handling Vehicles

Dual fuel-powered material handling vehicles that are factory assembled have been FM Approved. These material handling vehicles are capable of being powered by either gasoline or LPG. They are available as Type G/LP and Type GS/LPS. They have the hazards and limitations of both gasoline and LPG-powered industrial material handling vehicles.

3.7 CNG-Powered Material Handling Vehicles

CNG-powered material handling vehicles are similar to LPG-powered material handling vehicles. Loss history for CNG-powered material handling vehicles is limited, which may be due to their restricted use in industry.

Recent losses in the automotive industry, where CNG-powered material handling vehicles are becoming more common, are similar to those of LPG, with one exception. The cylinders for CNG are made of a composite material that is susceptible not only to mechanical damage but to breakdown if exposed to corrosive environments and can weaken if constantly overfilled.

As with LPG-powered material handling vehicles, CNG-powered material handling vehicles are fitted with special safeguards to reduce the hazard of gas leakage during normal operations and refueling. However, the hazard cannot be eliminated completely by safeguards. Therefore, limitations on locations in which they may be used are recommended.

3.8 Hydrogen-Powered Material Handling Vehicles (HPLTs)

The power source for HPLTs is typically a battery replacement module (BRM) that contains a fuel cell or a hybrid fuel cell/battery system designed to replace conventional battery packs. Hydrogen gas is stored in an onboard reservoir with a typical water capacity of up to 4.8 gal (18 L) at a very high pressure. As an example, an H35-rated material handling vehicle has a nominal working (service) pressure of 5100 psi (35 MPA; 350

bar). These high pressures are necessary to fill the reservoir with sufficient hydrogen (approximately 4.4 lb [2 kg]) to operate the material handling vehicle for several hours before the next fueling.

3.9 Loss History

Hundreds of losses involving lift trucks were reported to FM during a recent 20-year period. The vast majority of these incidents have been the result of impacts, including collapse of racking, damaged process equipment, broken service lines (water, electricity, and gas) and water damage from broken sprinkler systems.

The causes of fire included the following:

- A battery in a AGV exploded, igniting a fire throughout the building.
- A gas leak from a forklift that involved a roll paper storage area.
- A forklift hit a gas line and the gas was ignited by the exhaust of the lift truck.
- An electrical spark ignited flammable vapor.
- Propane leaked from a fuel cylinder and ignited on the exhaust.
- A forklift ignited nearby waste paper.
- A drum containing diesel fuel was ruptured by a lift truck during transport and the fuel was ignited.

4.0 REFERENCES

4.1 FM

Data Sheet 1-11, *Fire Following Earthquakes*
Data Sheet 5-1, Electrical Equipment in Hazardous Locations
Data Sheet 5-49, *Gas and Vapor Detectors and Analysis Systems*
Data Sheet 7-91, Hydrogen
Data Sheet 7-50, *Compressed Gases in Portable Cylinders and Bulk Storage*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-55, *Liquefied Petroleum Gas (LPG) in Stationary Installations*

4.2 Other

American Society of Mechanical Engineers (ASME). *Hydrogen Piping and Pipelines.* ASME B31.12-2008.

Bauwens, C.R., and S.B. Dorofeev. “CFD Modeling and Consequence Analysis of an Accidental Hydrogen Release in a Large Scale Facility.” International Conference on Hydrogen Safety, 9-11 September 2013, Brussels.

Compressed Gas Association (CGA). *Hydrogen Vent Systems.* CGA G-5.5-2014

European Industrial Gas Association (EIGA). *Gaseous Hydrogen Stations.* IGC Doc 15/06/E.

National Fire Protection Association (NFPA). *Hydrogen Technologies.* NFPA 2.

National Fire Protection Association (NFPA). *National Electrical Code.* NFPA 70.

National Fire Protection Association (NFPA). *Powered Industrial Trucks Including Type Designations, Areas of Use, Conversion, Maintenance, and Operations.* NFPA 505.

SAE International. *Compressed Hydrogen Surface Vehicle Refueling Connection Devices,* J2600, October 2002.

SAE International. *Fueling Protocol for Gaseous Hydrogen Powered Industrial Trucks,* J2601-3, June 2013.

International Electrotechnical Commission (IEC). *Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems.* IEC EN 61508.

APPENDIX A GLOSSARY OF TERMS

FM Approved: Products and service that have satisfied the criteria for Approval by FM Approvals. Refer to the *Approval Guide* for a complete list of products and services that are FM Approved.

Ignitable liquid: Any liquid or liquid mixture that has a measurable flash point. The hazard of a liquid depends on its ability to sustain combustion or create a flammable vapor-air mixture above its surface. Flash point

is one way of understanding if a liquid can create that flammable vapor-air mixture. For a liquid to burn in a pool, it must have a fire point as well as a flash point. Ignitable liquids include flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn.

APPENDIX B DOCUMENT REVISION HISTORY

The purpose of this appendix is to capture the changes that were made to this document each time it was published. Please note that section numbers refer specifically to those in the version published on the date shown (i.e., the section numbers are not always the same from version to version).

October 2024. Interim revision. The following changes were made:

A. The document was renamed Material Handling Vehicles to reflect the wider scope of vehicles covered by the Data Sheet.

B. Added recommendations for Automated Guided Vehicles (AGVs).

C. Updated loss data for the recent 20-year period (2004-2024).

D.Provided new guidance on charging stations.

January 2023. Interim revision. The following changes were made:

A. Updated guidance for li-ion battery powered trucks.

B. Updated the definition for ignitable liquids to align with Data Sheet 7-32, *Ignitable Liquid Operations*.

January 2021. Interim revision. Hydrogen storage and dispensing recommendations were relocated to Data Sheet 7-91, *Hydrogen*.

October 2015. A new section was added to address safeguards for indoor fueling of lift trucks powered by hydrogen fuel cells (Section 2.9).

July 2014. A new section was added to address safeguards for indoor dispensing of lift trucks powered by hydrogen fuel cells (Section 2.9).

July 2013. Minimum separation distance was revised in recommendations 2.1.2.1 and 2.1.2.2.

October 2011. The following changes have been made:

A. Changed the title of the data sheet to better reflect the scope.

B. Added recommendations for hydrogen-powered and compressed natural gas-powered industrial trucks.

C. Added information on ventilation requirements for battery-charging areas.

D. Changed the guidance for areas where multiple batteries are charged; a cutoff room is now recommended.

E. Added recommendations for operator training, and certification of equipment after repair by certified technicians.

January 2000. The document has been reorganized to provide a consistent format.

February 1991. The document was completely revised.