LIQUEFIED PETROLEUM GAS (LPG) STORAGE IN STATIONARY INSTALLATIONS

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1.0 SCOPE

This data sheet applies to liquefied petroleum gas (LPG) stored outdoors in stationary containers at end-user sites. Recommendations are provided to help prevent accidental LPG releases, and to mitigate fire and explosion damage to property if releases occur.

Sections 2.2 through 2.9 apply to storage in pressurized tanks up to 100,000 gal (380 m^3) water capacity, as are commonly found at commercial, industrial, and warehouse facilities where LPG is used as a fuel or to supply a manufacturing process. Section 2.10 covers storage in refrigerated (near atmospheric) containers and large pressurized containers. The latter are considered to be single units greater than 100,000 gal (380 m^3).

Recommendations in this data sheet are intended to be implemented in addition to applicable code requirements and good engineering practices for design, construction, and operation of fixed LPG storage installations.

Data sheets covering portable LPG cylinders, LPG-fired industrial heating equipment, indoor LPG piping, chemical processes, engine testing, and LPG-fueled lift trucks are listed in Section 4.1.

1.1 Changes

October 2013. This data sheet has been rewritten and reformatted. The following are the key changes.

A. Recommendations pertinent to the following basic safeguards have been added:

- Corrosion control of underground piping and tanks
- Operating and maintenance procedures
- Supervision of contractors
- Training
- Automatic emergency isolation devices
- Emergency response

B. Recommendations for separation distances between main buildings and LPG installations have been revised.

C. Recommendations for providing seismic shut-offs on LPG installations in earthquake-prone locations have been referred to DS 1-11.

D. Damage-limiting construction is recommended for vaporizer buildings.

E. Recommendations are provided for leak checking of LPG piping systems.

F. Roof-top LPG tank installations are addressed.

1.2 Superseded Information

Previous recommendations for storage of portable LPG containers (cylinders) have been superseded by recommendations in DS 7-50.

2.0 LOSS PREVENTION RECOMMENDATIONS

2.1 Introduction

Accidental releases of liquefied petroleum gas (LPG) from fixed storage containers, unloading stations, vaporizers, and connecting piping can result in severe explosion and fire damage to exposed buildings and their contents. The majority of property loss can be prevented by the following basic safeguards for LPG installations:

- Design and build robust systems.
- Follow proper operating and maintenance procedures.
- Provide effective personnel training.

On-going management support for a property conservation policy that addresses LPG hazards, as recommended in Section 2.8, is critical for successful implementation of all safeguards.

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

2.2 Location and Construction

2.2.1 Storage Tanks and Unloading Stations

2.2.1.1 Locate LPG storage tanks and unloading stations well away from main buildings, as follows:

A. Provide a separation distance of 200 ft (61 m) from important buildings and operations.

B. If a 200 ft (61 m) separation distance is not feasible due to site constraints, provide as much separation as possible, or at least the distances as shown in Figure 1 and Table 1.

Note: A 200 ft (61 m) separation distance is considered the minimum distance to help mitigate damage to adjacent buildings in the event of a large accidental LPG release. However, this distance may not mitigate all damage in the event of a tank rupture (BLEVE) or deflagration (if escaped vapor from the tank enters into buildings). Distances in Part B, Figure 1 and Table 1, will help facilitate emergency response and firefighting for small releases. They are not intended to protect against potential fire and explosion resulting from a large release. Section 3.2 provides additional discussion on space separation.

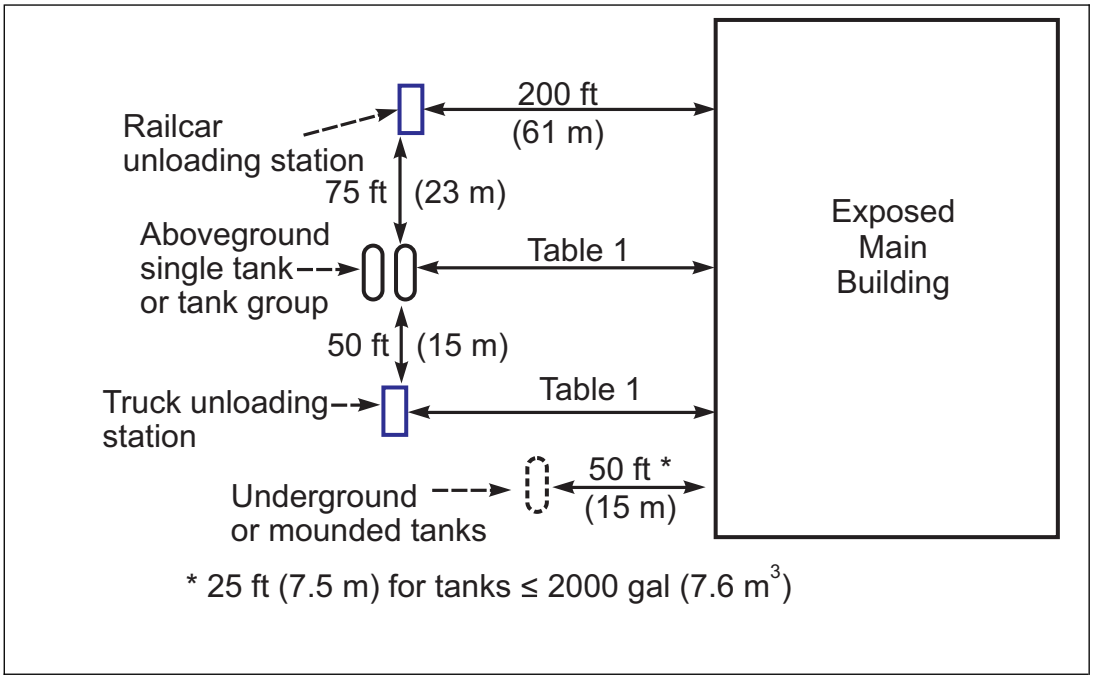

Fig. 1. Separation distances for LPG storage and unloading

Table 1. Separation Distances to Main Buildings for Aboveground Stationary LPG Tanks and Unloading Stations

Tank Capacity[2], gal (m^3)	*Single Tank, ft (m)*	*Tank Group,[1] ft (m)*
500 - 2000 (1.9 - 7.6)	25 (7.5)	Aggregate Capacity not exceeding 2,000 gal (7.6 m^3) 25 (7.5)
> 2000 - 60,000 (7.6 - 230) [4.1 - 124]	75 (23)	Aggregate Capacity not exceeding 180,000 gal(680 m^3) 200 (61)
> 60,000 - 100,000 (230 - 340)	150 (46)	
Unloading station	Same discance as tank or tank groupbeing filled	

[1]Provide at least 5 ft (1.5 m) horizontal separation between tanks in the same group. Separate tank groups from other tank groups by at least 75 ft (23 m).
[2]Tank water capacity.

2.2.1.2 Where tanks do not meet the spacing recommended in Table 1, provide either of the following:

A. An automatic emergency isolation system in accordance with 2.5.5.5

B. Water spray protection on the exposed building walls designed in accordance with Section 2.4.1

2.2.1.3 Locate LPG storage and unloading away from plant courtyards or sites where released vapor will flow toward important buildings, pits, pipe/cable trenches, or outdoor equipment.

2.2.1.4 Orient tanks, tank trucks, and railcars so the longitudinal center line axis does not point at important buildings, equipment, or fixed storage tanks.

2.2.1.5 Separate ignitable liquid storage tanks from aboveground LPG tanks in accordance with Data Sheet 7-88, Table 2.

2.2.1.5.1 If separation is less than that recommended in Data Sheet 7-88, protect the LPG tank with water spray designed per Section 2.4.2.

2.2.1.6 Locate LPG tanks at least 50 ft (15 m) away from exposures created by buildings of combustible construction or outdoor storage of combustible commodities. (See Section 3.2.3 for additional guidance.)

2.2.1.6.1 If separation is less than 50 ft (15 m), protect the tank in accordance with Recommendation 2.2.1.5.1.

2.2.1.7 Locate LPG storage and unloading stations in areas accessible to emergency response equipment and responders.

2.2.1.8 Arrange railcar siding and truck access routes to minimize exposure to plant buildings.

2.2.1.9 Provide fencing around aboveground tanks or buried installations if located in areas accessible to public ways or adjoining property.

2.2.1.10 Provide aboveground tanks, tank groups, or mounded tanks with barriers, posts, curbing, or other positive means to prevent public or plant vehicles from passing over or impacting the tank(s).

2.2.1.11 Separate aboveground tanks from overhead power lines so a break in the line will not allow the exposed ends to contact the tank.

2.2.1.12 Arrange tank supports as follows:

A. Mount horizontal and vertical tanks on concrete or on steel supports protected with FM Approved 2-hour fireproofing insulation.

B. Horizontal tanks not exceeding 2000 gal (7.6 m^3) water capacity may be mounted on unprotected steel saddles or supports as follows:

1. Concrete foundation more than 12 in. (30 cm) above ground: locate the bottom of the tank 2 to 12 in. (5 to 30 cm) above the top of the foundation.

2. Concrete or paved surface at grade level: locate the bottom of tank not more than 24 in. (60 cm) above the concrete or the pavement.

2.2.1.13 Install pressurized LPG tanks outside of dikes, depressions in the terrain, or other unfavorable ground features where escaped vapor will be prone to accumulate.

2.2.1.13.1 If tanks have connections below the liquid level and contain more than 2000 gal (7.6 m^3) water capacity for butane storage, or 15,000 gal (57 m^3) for propane storage, grade the ground under and surrounding the tank to direct liquid spills to an evaporation impoundment area away from the tank or any adjacent tanks or equipment. Design the impoundment and drainage in accordance with API 2510.

2.2.1.14 When tanks are buried, install them as follows:

A. Locate tanks at least 5 ft (1.5 m) horizontally from other buried tanks, underground pipes, and services such as steam, water, electricity, and sewer.

B. Provide the area above the tanks with fencing, barriers, posts, curbing, or other positive means to prevent vehicle traffic from passing over the tanks.

C. Provide a minimum of 1 ft (0.3 m) cover.

D. Back-fill using tamped, clean sand or earth free from rocks, abrasives, and corrosive material.

E. Locate the relief valve, vent stacks, man-heads, and aboveground piping within a fenced enclosure, and protect against mechanical damage.

F. Extend the relief valve with a vent stack to discharge vertically upward least 7 ft (2.1 m) above the earth cover.

G. In areas where tanks are exposed to high groundwater and/or possible flooding, provide anchorage designed in accordance with Section 2.2.5.3.

2.2.1.15 If tanks are mounded, install as follows:

A. Provide earth over the tank to form a minimum 1 ft (0.3 m) cover at the angle of repose of the fill used, or a noncombustible retaining wall may be placed around the tank and filled with earth.

B. Use tamped, clean sand or earth free from rocks, abrasives, and corrosive material.

C. Provide a protective cover, such as a layer of stone and geotextile, on top of mounding materials subject to erosion.

2.2.1.16 Where fire-resistive insulation is provided for aboveground tanks, install as follows:

A. Use FM Approved tank insulation materials.

B. Install and maintain insulation in accordance with the manufacturer's directions and API 2218, *Fire-proofing Practices in Petroleum and Petrochemical Plants.*

C. Insulate the entire tank, including the covers and piping up to 20 ft (6.1 m) away.

D. Follow the insulation manufacturer's instructions for surface preparation and coating application.

E. Install removable insulating sections so pressure-vessel inspectors will have access to the tank marking or nameplate and covers.

2.2.1.17 Do not locate LPG tanks on building roofs.

2.2.1.17.1 Where rooftop installations are unavoidable, provide all of the following safeguards in addition to the applicable recommendations for aboveground tanks:

A. Provide an emergency isolation system, regardless of tank size, in accordance with Section 2.5.5.5. In addition to the activation means in 2.5.5.5.1, provide an FM Approved open path LPG vapor detection system arranged to activate the tank emergency isolation system at 10% of LFL.

B. Use fire-resistant roof and wall construction within 75 ft (23 m) of the tank.

C. Provide separation of at least 75 ft (23 m) from any building walls with openable or fixed windows, doors, or other openings and air intakes to air conditioning and ventilating or other equipment.

D. If the tank is closer than 75 ft (23 m) to air intakes, provide vapor detection at the entry or inside the intakes, arranged to actuate the tank emergency isolation system and close the intake if concentration reaches or exceeds 10% of LFL.

E. Route all fill piping outside of the building.

F. Locate the fill connection and unloading station outdoors where escaped vapor will not accumulate in courtyards, below grade, or partially enclosed spaces.

G. Seal all pipe chases and openings in the roof where escaped LPG vapor might flow to.

H. Require the presence of at least two qualified operators during LPG transfer. Have one operator stationed at the unloading station and one on the roof at the propane tank with a radio or other means of direct communication.

2.2.1.18 If temporary installation of a fixed LPG tank is necessary, provide the following:

A. Install the tank on a level, firm foundation and locate it away from the following:

1. Important buildings

2. Buildings with subgrade spaces or multiple stories

3. Areas surrounded or partially surrounded by buildings, such as courtyards

4. Areas where the grade slopes down toward buildings

5. Areas adjacent to cable/pipe trenches or pits

6. Fire protection equipment (e.g., fire pumps and tanks) other than hydrants

7. Important yard storage and high-value equipment

8. Heavily traveled areas

9. Exposure to external fire involving ignitable liquid storage, other combustible yard storage, or combustible structures

B. Protect service connections from mechanical damage and vehicular impact.

C. Design temporary connections and piping in accordance with the recommendations for permanent installations.

D. Secure temporary tanks against accidental movement, including seismic exposure.

E. Inspect temporary tanks and temporary piping for leaks and mechanical damage prior to each use.

F. Remove temporary installations promptly when no longer needed.

2.2.2 LPG Vaporizers and Gas-Air Mixers

2.2.2.1 Locate vaporizers outdoors in open areas and away from tanks, main buildings, courtyards and unloading stations. Provide at least the separation distances in accordance with Table 2.

Table 2. Separation Distances[1] for Outdoor LPG Vaporizers

Exposure	*Direct-Fired[2]*	*Indirect-Fired*
Main building, blank noncombustible wall	Any	Any
Opening in main building wall	50 ft (15 m)	20 ft (6.1 m)
Storage tank	15 ft (4.6 m)	5 ft (1.5 m)
Relief valve discharge	75 ft (23 m)	Any
Unloading station	75 ft (23 m)	Any

[1]These distances will not protect against severe damage to main buildings in the event of a large accidental release of LPG occurring at the vaporizer or piping.
[2]Including gas-fired water bath units and boilers for indirect-fired units.

2.2.2.2 If a vaporizer must be installed inside a building, do the following:

A. Locate it in a dedicated building that is preferably detached from any main building (Figure 2, Location I or II), or attached to the outside wall (Figure 2, location III).

B. Design damage-limiting construction in accordance with Data Sheet 1-44.

C. Provide the minimum separation from openings in main building walls in accordance with Table 2.

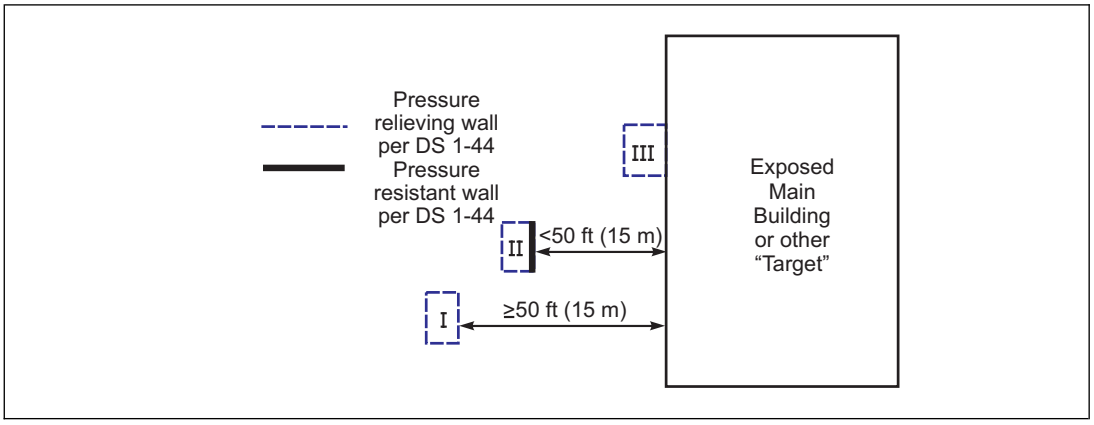

Fig. 2. Location and construction of vaporizer buildings

2.2.2.3 If a fuel-fired steam boiler or other appliance is inside a vaporizer building, separate the fired appliance from the vaporizer by a vapor-tight interior wall of lightweight noncombustible construction.

2.2.2.4 Locate gas-air mixers outdoors or in a detached building in accordance with Figure 2.

2.2.3 Outdoor Piping

2.2.3.1 Do not install LPG piping in crawl spaces or bury it under main buildings.

2.2.3.2 Place buried LPG piping in a separate trench located as far as practical away from other underground lines such as steam, water, sewer, or electric.

2.2.3.3 Locate all buried pipe joints, including welds, at least 10 ft (3 m) from wall entrances or any other points where the pipe may be rigidly held against ground movement.

2.2.3.4 Cover all buried pipe with at least 6 in. (15 cm) of well-compacted sand or noncorrosive, nonabrasive, stone-free earth, plus at least 2 ft (0.61 m) of well-tamped noncorrosive backfill that has no large stones.

2.2.3.5 Support buried pipe at all points on a minimum 6 in. (15 cm) deep base of well-compacted sand.

2.2.3.6 Remove any temporary support blocking prior to covering and backfilling new or repaired pipe.

2.2.3.7 Seal openings around all buried pipes, such as electric conduit, sewer, steam, or water, gas-tight with cement grout or asphaltic mastic where they enter buildings through walls or floors, where the openings are within 75 ft (23 m) of buried LPG lines.

2.2.3.8 Prepare accurate location records with photographs and as-built drawings prior to covering new underground piping installations.

2.2.3.9 Provide impact protection for aboveground piping.

2.2.3.10 Design building entrance piping in accordance with DS 7-54.

2.2.4 Seismic Hazards

Apply the following seismic location and construction recommendations to LPG installations located in FM 50-year through 500-year earthquake zones, as defined in Data sheet 1-2, Earthquakes.

2.2.4.1 Perform a seismic loading analysis based on ASCE 7 or other recognized code to ensure aboveground, rooftop, and buried LPG tanks and piping that expose high-value property have been designed to resist the anticipated seismic loads. (See also DS 1-2, Appendix C, the section titled "Equipment Restraint/Location and Nonstructural Component Anchorage.")

2.2.4.2 Use tank restraints that provide positive attachment (anchorage) to the foundation in accordance with ASCE 7. Do not rely on tank restraint by friction effects alone (Figure 3).

Fig. 3. Horizonal tank restraint by friction only

Many other restraining methods can be used (see Figure 4 for one solution). A common solution is to provide anchor bolts through the steel support into the pier (Figures 4 and 5). Typically, these would be cast-in-place bolts. Alternatively, a steel member, such as a channel, could be embedded on top of the concrete pier. The steel member would have bolts/rebar welded to it on the side against the concrete (that would then transfer the forces into the concrete). The steel tank support is welded directly to this embedded member, or four-way stops are welded to the embedded member that then bear against the tank if it moves. Bolts and steel members, as well as the concrete pier, must be correctly sized and designed to resist the expected seismic forces.

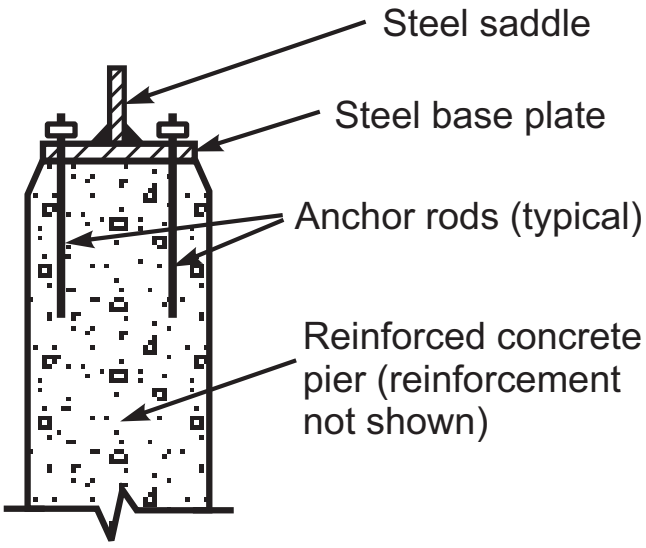

Fig. 4. Seismic anchoring for horizontal LPG tank (schematic)

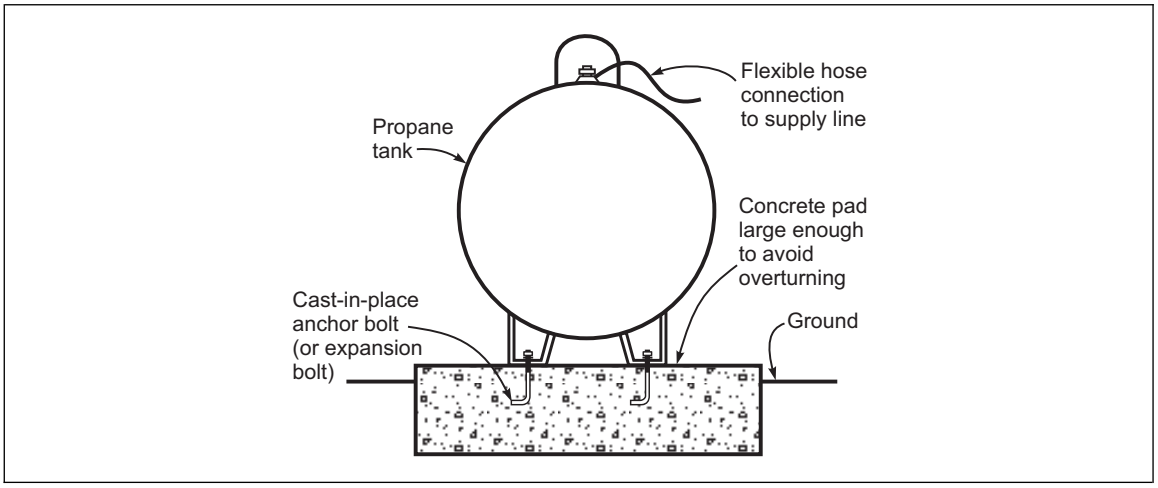

Fig. 5. Example of seismic anchorage for small propane tanks (source: FEMA)

2.2.4.3 Determine horizontal seismic forces in accordance with the requirements of the local building code, but not less than a horizontal force equal to 50% of the weight of the equipment acting on the equipment's center of gravity.

2.2.4.4 Adhere to the following seismic safeguards for piping in addition to code requirements:

A. Do not use cast iron for valves, fittings, or supports.

B. Use welded piping systems.

C. Refer to DS 2-8, Earthquake Protection for Water-based Fire Protection Systems, for seismic design of water spray fire protection systems.

D. Provide clearance where LPG piping passes through foundations, walls, and floors

2.2.5 Flood Hazards

2.2.5.1 Consult DS 1-40, *Flood,* to evaluate and protect against flood exposures for the facility location.

2.2.5.2 Locate LPG installations on elevations that are at least 2 ft (0.6 m) higher than the predicted 500-year flood elevation, and at least 500 ft (152 m) from direct wave impacts and or high flood-flow velocities (i.e., above 7 fps [2 m/s]).

2.2.5.2.1 Where aboveground tanks are located in flood-prone areas, provide anchorage and foundations to resist the forces of buoyancy, moving water, and wave impact.

2.2.5.3 Avoid locating underground tanks in areas exposed to high groundwater or possible flooding.

2.2.5.3.1 Where such locations are unavoidable, provide anchorage to prevent flotation.

2.2.5.4 Assume storage tanks are empty when determining buoyancy and overturning forces, and full when designing supports and foundations to resist maximum gravity loads.

2.3 Occupancy

2.3.1 Inherently Safer Occupancy

2.3.1.1 Limit the diameter of pipe headers serving as tank manifolds to the size necessary to supply facility demand.

2.3.1.2 Where multiple tanks are connected to a common manifold, limit the number of in-use tanks to the minimum needed to supply the end-use equipment.

2.3.2 Housekeeping

2.3.2.1 Maintain high standards of housekeeping around storage tanks, unloading stations, and vaporizers.

2.3.2.2 Do not allow combustible materials to be stored near LPG installations.

2.3.2.3 Remove or close-cut vegetation such as brush, trees, weeds, or grass within 20 ft (6 m) of a tank, vaporizer, or unloading station.

2.3.2.4 Conduct regular recorded housekeeping inspections and provide a procedure to report, track, and promptly correct any identified deficiencies.

2.3.3 Ventilation

2.3.3.1 Provide continuous mechanical ventilation with intakes within 12 in. (0.3 m) of the floor, with a ventilation rate of at least 1 cfm/ft^2 (0.30 m^3/min/m^2) of floor area in vaporizer buildings.

2.3.3.2 Provide a ventilation-failure alarm to a constantly attended location.

2.4 Protection

2.4.1 When water-spray systems are used for exposure protection of building walls (Section 2.2.1.2), provide automatic spray nozzles to ensure complete coverage of the exposed wall in accordance with Data Sheet 1-20, *Protection against Exterior Fire Exposure,* Section 2.4, Active Exposure Protection, using hydraulic design criteria for “storage greater than 30 ft.”

2.4.1.1 Provide additional nozzles specifically arranged to protect windows.

2.4.1.2 Activate the water-spray system using automatic fire detectors, located to ensure prompt activation of the water-spray system. (See Data Sheet 2-0, *Installation Guidelines for Automatic Sprinklers;* Data Sheet 4-0, *Special Protection Systems;* and Data Sheet 4-1N, *Fixed Water Spray Systems for Fire Protection.*

2.4.2 Where water spray is provided on aboveground storage tanks and unloading stations, design in accordance with Data Sheet 4-1N and as follows:

A. Automatic fixed system with a minimum application rate of 0.3 gpm/ft^2 (12 mm/min) of external tank surface (water spray) or over the pad area (deluge)

B. Minimum nozzle pressure in accordance with DS 4-1N

C. Water spray demand flow equals simultaneous operation of all nozzles protecting the largest single tank or tank group, whichever flow rate is higher.

D. The minimum water supply duration is 2 hours for combined water spray and hose or monitor stream design flows.

E. Provide FM Approved water spray equipment.

2.4.3 Provide yard hydrants and/or monitor nozzles for emergency manual fire protection of storage, unloading, and vaporizer equipment.

2.4.3.1 Design yard hydrants per Table 3.

Table 3. Hose Stream Demand for Outdoor LPG Tanks

Hose Stream Demand		
Single Tanks	GPM	M^3/min
≤30000	250	.95
> 30000	500	1.9
Tank Groups (largest tank)		
≤30000	500	1.9
> 30000	1000	3.8
Half the above demand is acceptable if water spray or insulation is provided on the tank.		
Minimum duration: 2 hours		

2.4.3.2 Locate hydrants to allow hose application under varying wind conditions, and provide space separation of at least 75 ft (23 m) and no more than 200 ft (60 m) from the storage tanks.

2.4.3.3 Where used, design monitor nozzles as follows:

A. Use FM Approved manual or automatic oscillating nozzles.

B. Set the discharge pattern so all portions of the tank or tank group are wetted.

C. Provide enough nozzles and at least 75 ft (23 m) clearance from the tanks to allow effective manual operation regardless of wind direction.

2.5 Equipment and Processes

2.5.1 Storage Tanks

2.5.1.1 Design, fabricate and install LPG storage tanks in accordance with the requirements of the applicable pressure vessel code, such as PD 5500, AS 1210, or Section 8 of the *ANSI/ASME Boiler and Pressure Vessel Code.*

2.5.1.2 Establish the maximum allowable working pressure (MAWP) based on the vapor pressure of the LPG to be stored, in accordance with the local code requirements.

2.5.1.3 Provide each tank with pressure-relief valves having flow capacity and start-to-discharge settings in accordance with the applicable local code.

2.5.1.4 Provide redundant external pressure-relief devices on three-way or Y-type (“multi-port”) connections to facilitate isolation and removal of the devices for testing and maintenance at regular intervals in accordance with Section 2.6.4.4 below.

2.5.1.5 Arrange pressure-relief devices to discharge vertically in a safe outdoor location where the released gas will not be obstructed by piping or other equipment or confined under a weather canopy.

2.5.1.6 Provide a vertical relief vent stack that extends at least 7 to 10 ft (2.1 to 3 meters) above the tank top and incorporates the following additional features:

A. Painted or galvanized metal vent pipe strong enough and braced or supported to withstand exit stream forces.

B. Stack diameter larger than relief valve outlet.

C. A loosely fitting, corrosion-resistant rain cap on the top of the stack.

D. Arrange water drain holes so any gas discharge will be directed away from tanks, piping, or other equipment.

E. Do not use return bends or any fittings that would direct the discharge in any direction other than vertical.

F. If a canopy or weather hood is provided above the tank, extend the vent stacks above the height of the canopy.

2.5.1.7 Provide manual shut-offs on each tank connection (nozzle) other than the relief device connections.

2.5.1.8 Provide a fixed maximum liquid level gauge on each tank.

2.5.1.8.1 Limit the diameter of container openings for liquid level gauge connections to a No. 54 drill (1.4 mm) or provide an excess flow valve on the connection.

2.5.2 Vaporizers, Tank Heaters, and Gas-Air Mixers

2.5.2.1 Where a vaporizer or gas-air mixer is needed, use an FM Approved model.

2.5.2.2 Arrange vaporizer pressure-relief devices to discharge vertically in a safe outdoor location where the released gas will not be obstructed by piping or other equipment or confined under a weather canopy.

2.5.2.3 Provide gas-fired vaporizers with combustion safeguards.

2.5.2.4 Avoid the use of tank heaters.

2.5.2.4.1 Where tank heaters are unavoidable, adhere to the following recommendations:

A. Do not use internal heating coils or direct-fired gas burners.

B. Conduct a hazards review to identify potential heater failure modes and ensure adequate safeguards are provided to prevent overheating or another malfunction that could lead to loss of containment.

C. Provide excess flow and emergency isolation valves for any liquid or vapor connections between the tank and the heater in accordance with Section 2.5.5 below.

D. Obtain and implement the heater manufacturer's written operating and maintenance procedures.

E. Obtain and implement the heater manufacturer's written procedures for calibration and functional testing of the safety interlocks.

F. Ensure tank wall heaters, such as catalytic heaters, can be removed for regular inspection of the tank surface.

2.5.2.5 Provide safeguards for gas-air mixers as follows:

A. Conduct a documented process hazards analysis to establish adequacy of safety interlocks to prevent LPG/air deflagrations in the event of process upsets and deviations from design operating conditions, including low gas pressure, power failure, high gas pressure, etc.

B. Take air supply from outdoors.

C. Provide capability for remote emergency shutdown of the LPG supply to the mixer.

2.5.3 Unloading Stations

2.5.3.1 Support permanent piping and connection fittings on a robust bulkhead designed to withstand the force of a pull-away without damage to piping.

2.5.3.2 Provide derailing devices, wheel blocks, and warning signs at railcar unloading stations.

2.5.4 Outdoor Piping

2.5.4.1 Select and install piping materials, gaskets, valves, and piping systems in accordance with applicable local codes and this section.

2.5.4.2 Use valves with disks, seats, diaphragms, and packing resistant to the action of LPG and rated for the maximum pressure to which they are to be subjected.

2.5.4.3 Use steel-body valves or other metallic valves allowed by applicable codes and recommended for LPG service by the valve manufacturer.

2.5.4.4 Provide hydrostatic relief valves on liquid LPG piping sections between shut-off valves, sized to prevent excessive buildup of pressure by thermal expansion of trapped liquids. Arrange the relief valves as follows:

A. Direct relief device discharge away from piping equipment and buildings.

B. Set hydrostatic relief devices to open in accordance with the design code.

2.5.5 Emergency Isolation System

The goal of this section is to provide the ability to promptly isolate the LPG supply in the event of a loss of containment.

2.5.5.1 Install an accessible, manual shutoff valve outside where LPG piping enters a main building and at each gas-consuming unit to permit access in the event of fire at the unit.

2.5.5.2 Conspicuously mark the location and the gas service controlled on each manual valve intended for emergency shutdown.

2.5.5.3 Provide internal excess flow valves on all vapor and liquid withdrawal connections at the tank, except the relief valve and fill connections, with the following features:

A. Establish and document the design flow rate at which the excess flow valve should close (i.e., when the flow exceeds the normal transfer flow rate by a predetermined amount that accounts for normal flow fluctuations).

B. Ensure the installed valve closure rating matches the design rating.

C. Provide excess flow valves with a pressure equalization bypass that does not exceed a No. 54 drill size opening (0.055 in. or 1.4 mm diameter).

D. If excess-flow valves are less than ½ in (DN 13) pipe size, provide a bypass that limits vapor flow to 10 scf/hr (4.7 L/min) at 100 psig (690 kPag).

E. Limit the orifice of tank liquid level and pressure gauges to a No. 54 drill-size hole (0.055 in. or 1.4 mm diameter) or install excess flow valves on the gauge connections.

Note: Excess flow valves will not activate if the release flow rate is less than the design closing flow rate, which may be substantial.

2.5.5.4 Provide a backflow check valve on the tank fill connection as follows:

A. Preferably internal to the tank or,

B. If outside the tank, design so an external impact will not shear off vital parts and prevent operation.

C. Use in-line spring-loaded or weight-loaded backflow check valves that close when the flow is stopped or reversed.

2.5.5.5 Install internal automatic emergency isolation valves on fill and withdrawal openings of LPG storage tanks as follows:

A. All roof-top tanks

B. Aboveground tanks greater than 4000 gal (15 m^3) water capacity

2.5.5.5.1 Provide all of the following activation means for the internal valves:

A. Thermal detector located within 5 ft (1.5 m) of the valve. The thermal detector may be plastic tubing supplying the pneumatic pressure needed to keep the valve open.

B. Water flow in the water spray or deluge protection system (if provided).

C. Failure of the operating electrical or pneumatic supply.

D. Remote manual emergency isolation controls in all the following locations:

1. LPG storage tank

2. Unloading station

3. Vaporizer

4. One or more locations at least 100 ft (30 m) beyond the unloading and storage areas and accessible in case of an LPG emergency.

5. Control room, boiler room or other constantly attended location

2.5.5.5.2 Use emergency isolation valves with the following features:

A. Close in the direction of liquid flow from the storage tank.

B. Capable of closing against a pressure of at least 150% of the design rating.

C. Rated for the temperature and pressure encountered.

D. Close within 5 seconds after actuation.

E. Require manual reset.

2.5.5.5.3 Install extra-heavy piping (e.g., Schedule 80 seamless steel) between each emergency isolation valve at the tank and the first manual shutoff valve.

2.5.5.6 Provide emergency isolation on truck and railcar unloading station piping as follows:

A. Provide an automatic shut-off valve in the fixed liquid fill piping at the bulkhead connection. A backflow check valve alone is sufficient.

B. Locate the automatic shutoff or the backflow check valve on the liquid line as close as possible to the unloading connection.

C. Provide an automatic shutoff valve in the vapor line.

D. Arrange automatic shutoffs at the unloading station in accordance with Section 2.5.5.5.

2.5.5.7 Provide LPG vaporizers with interlocks to alarm and shut down the vaporizer in the event of critical upset conditions, such as high water bath temperature, low water bath level, and high LPG liquid level.

2.5.5.8 Provide automatic shutdown of LPG transfer pumps on manual or automatic activation of the emergency isolation system.

2.5.5.9 When LPG installations are located in FM 50-year through 500-year earthquake zones (as defined in Data Sheet 1-2, *Earthquakes),* provide seismic-actuated automatic shutoffs on the piping connections to isolate the LPG tank. Arrange the shutoffs in accordance with OS 1-11, *Fire Following Earthquake.*

2.5.5.10 Post detailed operating instructions, including a sequence of emergency isolation valve operations.

2.5.6 Corrosion Control

2.5.6.1 Provide external corrosion protection for underground piping and tanks as determined necessary by a qualified corrosion specialist in accordance with recognized corrosion protection standards, such as NACE Standard Practice SP0169-2007.

2.5.6.2 Protect underground tanks with coating and cathodic protection as follows:

A. Coating recommended by the corrosion expert and applied in accordance with the manufacturer's instructions.

B. Prior to burial, visually inspect the tank coating for damage. Repair any damaged areas as recommended by the coating manufacturer.

C. Cathodic protection by means of sacrificial anode or impressed current anode.

D. Uncover the tank and conduct an inspection of all external surfaces for corrosion at least every 10 years or as determined appropriate by a corrosion expert.

2.5.6.3 Protect buried steel pipe against corrosion by shop- or field-applied coating and by cathodic protection.

2.5.6.4 Avoid connections that create galvanic corrosion, such as copper to steel piping. Where such connections are unavoidable, provide corrosion protection.

2.5.6.5 Provide weather-resistant coating on aboveground piping and equipment.

2.5.7 Equipment Commissioning and Documentation

2.5.7.1 Prior to startup of new or modified installations, implement a commissioning protocol to ensure documented compliance with the requirements of applicable pressure vessel and piping codes and the following:

A. Inspect and test all piping and equipment in accordance with the applicable code requirements and equipment manufacturer's instructions.

B. Conduct cleaning, purging, and pressure testing in accordance with Section 2.6.5.

E. Conduct a functional test of all emergency isolation and excess flow valves.

F. Conduct a functional test of the safety interlocks on vaporizers according to the manufacturer's instructions.

G. Verify that as-built equipment, piping, and instrumentation drawings are complete and accurate.

2.5.7.2 Document the detailed equipment specifications, including materials of construction, applicable pressure vessel and piping codes, and process and instrumentation diagrams for new installations, and also for modifications to existing installations.

2.5.7.3 Keep all original equipment commissioning documentation, including purchase specifications, "as-built" drawings and photographs, on file and readily accessible to authorized site personnel.

2.6 Operation and Maintenance

2.6.1 General

2.6.1.1 Allow only qualified employees and/or contractors to supervise and perform all operation and maintenance duties for LPG storage installations.

2.6.1.2 Obtain and implement the supplier's or manufacturer's written operating and maintenance procedures for each equipment item, including tanks, pumps, compressors, vaporizers, tank heaters, and mixers.

2.6.1.3 Maintain documented operating procedures for unloading stations, tanks, pumps, compressors, vaporizers, and mixers, including for the following operations:

A. Normal startup and shutdown

B. Supervision during normal operation

C. Emergency shutdown and isolation

2.6.1.4 Establish documented preventive maintenance procedures for the tank, unloading station, pumps, compressors, vaporizers, and mixers, following industry and equipment manufacturers' guidelines as well as local code requirements.

2.6.1.5 Conduct regular recorded maintenance and inspection of LPG tanks, piping, pumps, compressors, mixers, vaporizers, and unloading stations according to industry guidelines, manufacturer's instructions, and local codes, including the following:

A. Conduct visual monthly recorded inspections of general conditions to identify any evidence of leaks, overfilling, corrosion, damage to equipment, abnormal conditions, etc.

B. Conduct "fitness for service" inspections for pressure vessels at minimum 10-year intervals, or sooner if there is reason to suspect an unsafe condition.

C. Have a pressure vessel inspector perform an external inspection of aboveground tanks at intervals not greater than 3 years, or per local code if shorter intervals are required.

2.6.1.6 Take prompt corrective action to address the causes of breakdown, overfilling, leakage, corrosion, substantial changes in cathodic protection requirements, and any abnormal conditions.

2.6.2 Unloading Operations

2.6.2.1 Establish and document the maximum allowable filling limit for each tank.

2.6.2.2 Do not allow storage tanks to be filled in excess of the maximum allowable filling limit.

2.6.2.3 Keep a copy of the filling procedure in a location accessible to responsible attendants.

2.6.2.4 Ensure at least one qualified attendant remains at the transfer area from the time connections are made until they are disconnected and shutoff valves are closed.

2.6.2.5 Prior to each unloading, conduct a recorded visual inspection to ensure proper safeguards are present, including the following:

A. The delivery vehicle brakes are set and wheels are blocked.

B. The delivery vehicle meets the requirements of applicable regulations and is in satisfactory condition.

C. Where remote emergency isolation devices are required on the delivery vehicle per local or national regulations, the devices are present and functional.

D. Transfer hoses and connecting couplings are properly rated, do not leak and are in satisfactory condition.

E. The level and pressure gauges on the tank(s) to be filled are in satisfactory condition.

F. Ignition sources are controlled in accordance with Section 2.9.

G. Emergency isolation system for the tank and unloading connections is marked and functional.

2.6.3 Corrosion Control

2.6.3.1 Conduct a periodic visual inspection for signs of corrosion on aboveground tanks and piping. Where corrosion is found, take appropriate steps to clean and repaint or recoat any corroded surfaces.

2.6.3.2 Where tanks are protected with fireproofing, conduct regular inspections to identify corrosion under the fireproofing material.

2.6.3.3 Establish a documented corrosion monitoring and control plan for all underground LPG piping and storage tanks, under the supervision of a corrosion specialist.

2.6.3.3.1 Ensure cathodic protection is maintained, inspected, and tested at regular intervals as determined by the corrosion specialist.

2.6.3.4 Maintain inspection and test records on site and keep them available for review.

2.6.4 Safeguard Device Performance Testing

2.6.4.1 Ensure all testing is conducted by authorized personnel who are trained to follow a test procedure designed by the manufacturer and/or individuals with appropriate technical expertise in LPG systems.

2.6.4.2 Obtain and implement the manufacturer's written procedures for calibration and functional testing of the safety interlocks on each equipment item, including tanks, compressors, vaporizers and tank heaters. Test at least annually, or more frequently if recommended by the manufacturer.

2.6.4.3 Test the performance of all manual and automatic emergency isolation valves and actuators annually, or more frequently if recommended by the device manufacturer or if experience warrants it.

2.6.4.4 Test excess-flow valves in accordance with manufacturer's recommendations.

2.6.4.5 Test pressure relief valves on storage tanks as follows:

A. Test at no longer than 5-year intervals, or more frequently if recommended by the device manufacturer or if warranted based on visual observations of valve condition, operating experience, or testing history.

B. Use accepted procedures, test equipment, and trained, qualified personnel (see Data Sheet 12-43).

C. Where depressurizing the tank is required, ensure the tank is purged and inerted prior to removal of the device.

D. If valves are reconditioned, use a qualified repair organization and ensure all the requirements of the valve manufacturer and local codes are met.

2.6.4.5 Test and calibrate vapor detectors, where installed, in accordance with Data sheet 5-49, *Gas and Vapor Detector and Analysis Systems.*

2.6.5 Pipe Cleaning, Testing, Purging and Leak Checking

2.6.5.1 Ensure that cleaning, pressure testing, purging, and leak checking are conducted only by authorized personnel who are trained for and familiar with the equipment and test procedure.

2.6.5.2 Develop documented procedures for cleaning, pressure testing, purging, and leak checking of all LPG piping.

Note: An acceptable methodology for developing these procedures is given in NFPA 56, *Standard for Fire and Explosion Prevention during Cleaning and Purging of Flammable Gas Piping Systems.*

2.6.5.3 Prior to placing new or modified piping into service, clean the interior using air, inert gas, steam, or water. Do not use LPG or other flammable gas. Do not use oxygen.

2.6.5.4 Conduct pressure testing prior to introducing LPG into new or modified piping, as follows:

A. Use hydrostatic methods or pneumatic testing in accordance with the requirements of the piping design code.

Note: ASME B31.3 requires hydrostatic testing at no less than 1.5 times the design pressure, or pneumatic testing at no less than 1.1 times the design pressure. See code for additional test requirements.

B. Do not use LPG as the pressure testing medium for systems operating at greater than ½ psi (3.5 kPa). Never use oxygen. Use compressed air or other nonflammable medium if pneumatic test methods are applied.

C. Do not expose valves to excessive pressure or use a single valve to isolate the tested component when under test pressure.

D. Establish test conditions and pass/fail criteria based on local code requirements.

E. Ensure the system can hold the test pressure for at least the following duration:

1. 10 minutes for systems less than 10 ft^3 (0.28 m^3) in volume.

2. One half hour per 500 ft^3 (14 m^3) of internal pipe volume.

F. Locate leak sources with a gas detector or noncorrosive leak detection fluid.

G. Do not use the sense of smell or an open flame to locate leak sources.

2.6.5.5 Conduct purging with inert gas to remove air prior to introducing LPG into a new, modified, or repaired piping system as follows:

A. Vent the purge discharge to a safe outdoor location.

B. Equip the vent line with a readily accessible isolation valve.

C. Monitor the discharge gases using an oxygen indicator to determine when the purge end point is reached. The limiting oxygen concentration for propane is 9% for nitrogen inerting and 11% for carbon dioxide, (see Data sheet 7-59, *Inerting and Purging Vessels and Equipment).*

D. When introducing LPG vapor into the inerted pipe, continuously monitor the LPG vapor concentration until 90% LPG by volume is detected.

2.6.5.6 Conduct purging with inert gas to remove LPG from piping systems being taken out of service for removal, repairs, or modifications, as follows:

A. Ensure the point of discharge of the purge gas is outdoors and well away from potential sources of ignition, building openings, and equipment air intakes.

B. After depressurizing the piping, purge the residual LPG in the pipe with inert gas.

C. During discharge, continuously monitor the release with a combustible gas indicator until the purge end point is reached, which is the percentage of LPG below which no mixture with air will be flammable (for example, 9% propane in carbon dioxide or 5% propane in nitrogen; see NFPA 56, Annex B).

2.6.5.7 Conduct a startup “leak check” to confirm liquid and vapor piping do not leak at normal operating pressure when LPG is first introduced to a new system or to a system that has been previously shut down or idled:

A. Conduct the leak check at normal system operating pressure according to a procedure developed per Recommendations 2.6.5.1 and 2.6.5.2 above.

B. Just prior to the leak check, conduct a visual inspection to confirm all open fittings or ends have been closed, and that valves at unused outlets are closed and the outlets are plugged or capped.

C. Typical test duration during which the pressure reading should remain stable is from 3 to 5 minutes.

D. If leaks are indicated, close the supply and make necessary repairs, then retest.

2.6.6 Standby System Maintenance

2.6.6.1 Establish documented operating and maintenance procedures for standby LPG systems, including response to upsets during startup and shutdown.

2.6.6.1.1 If a contractor is relied upon for startup and shutdown, verify the contractor is using documented and adequate procedures.

2.6.6.2 Conduct a leak check per 2.6.5.7 on the LPG liquid and vapor piping systems during startup of a standby system that has been idled.

2.6.6.3 Inspect and test all equipment (mixers, vaporizers, pumps, regulators, fans, switches, etc.) prior to starting a standby system that has been idled.

2.7 Training

2.7.1 Employee Training

2.7.1.1 Create a training program for employees who have access to the LPG installation, including operators, emergency responders, and maintenance and security personnel. Include at least the following subjects in the training program:

A. The hazards created by LPG storage and use

B. The proper operation and shutdown of equipment under normal and emergency procedures

C. The location of all local and remote shutoff stations

2.7.1.2 Provide periodic refresher programs in addition to the initial training.

2.7.2 Contractor Training

2.7.2.1 Ensure contractor personnel have adequate training in LPG hazards and the performance of their assigned duties in supplying or maintaining the LPG installation.

2.7.2.2 Train contractor personnel to follow facility procedures for notification and response to LPG emergencies.

2.8 Human Factors

2.8.1 Property Conservation

2.8.1.1 Address LPG hazards and prevention of accidental releases as part of a documented property conservation program in accordance with DS 9-7, *Property Conservation,* including the following measures:

- Prepare a written policy.
- Establish supervisory authority and responsibility.
- Organize to handle emergencies.
- Educate and train.
- Audit and update regularly.

2.8.2 Emergency Response and Pre-Incident Plan

2.8.2.1 Establish an emergency response plan for accidental releases in LPG storage installations that includes the following measures:

- Refer to Data Sheet 10-1, *Pre-Incident Planning,* for general guidelines on establishing and maintaining an emergency response plan.
- Reliable activation of the emergency isolation system.
- The availability of provided fire protection features.
- LPG fires are only extinguished after the source of the release has been shut off.

2.8.2.2 Familiarize the facility's emergency response team members and the local fire service with the location of LPG equipment as well as the emergency response plan.

2.8.2.3 Conduct annual emergency response drills to reinforce the employee and contractor training program and to familiarize the fire service with the site layout.

2.8.3 Supervision of Loss Prevention Programs

2.8.3.1 Keep loss prevention documentation current and readily accessible at the plant for review and use in management of change, loss prevention audits, hazards assessments, and emergency response.

2.8.3.2 Ensure LPG loss prevention programs are supervised by employees trained in LPG handling and emergency response procedures.

2.8.4 Supervision of LPG Contractors

The term “LPG contractor” refers to outside firms and their employees who deliver LPG to the site and/or install, maintain, inspect, and test LPG storage, piping, and LPG-fired equipment.

2.8.4.1 Develop and implement a program to supervise contractors in accordance with the recommendations in Data Sheet 10-4, *Contractor Management,* including but not limited to the following:

A. Draft a formal policy statement on LPG contractor supervision, along with procedures for selecting, inducting, and supervising contractors.

B. Assign an employee to be accountable for ensuring the policy and procedures are followed, audited regularly, and updated as necessary.

C. Post the policy and ensure the information is communicated to all employees and contractors.

2.8.4.2 Prior to the selection of an LPG contractor, document all aspects of the work the contractor is expected to complete.

2.8.4.3 Ensure the contract specifies the services or work expected from the contractor, as well as the codes and standards the contractor must comply with in performing the work.

2.8.4.4 Identify any equipment and activities that will remain the responsibility of the facility, and how facility and contractor personnel will interface.

2.8.4.5 Review completed work records to ensure contract requirements are met.

2.9 Ignition Source Control

2.9.1 Hot Work

2.9.1.1 Do not allow hot work on or around LPG installations. Relocate any work to a nonhazardous location.

2.9.1.2 When relocation is not possible, use a documented permit system in accordance with Data sheet 10-3, *Hot Work Management,* to strictly control all hot work operations.

2.9.1.3 Issue temporary hot work permits only after conducting a thorough review of all proposed work. Document the procedure and identify the hazards in the area, as well as all precautions needed to prevent fire or explosion. If all of the requirements cannot be met, do not issue the permit and do not perform the work.

2.9.1.4 Physically manage the authorized work in the LPG area using a documented hot work permit system that specifically evaluates the fire hazards involved.

2.9.2 Hazardous Area Electrical Equipment

2.9.2.1 Design electrical installations to comply with the recommendations in Data Sheet 5-1, *Electrical Equipment in Hazardous (Classified) Locations,* and the applicable electrical codes.

2.9.2.2 Provide motors, switches, wiring, and other electrical equipment rated for hazardous electrical areas at storage tanks, unloading stations, gas-diluting equipment, pumps, compressors, vaporizers other than direct-fired, cylinder filling, and buildings containing vaporizers, gas-diluting, control, and regulating equipment.

2.9.2.3 Provide electrical equipment suitable for Class I, Division 1 or Zone 1 locations under the following conditions:

A. Within 5 ft (1.5 m) in all directions from any connection that is regularly made and disconnected or any point where excessive release of liquid or gas may occur (e.g., loading or unloading stations). Consider variations in the spotting of tank cars and tank vehicles at unloading stations and their relation to the point of connection.

B. Within 5 ft (1.5 m) in all directions, except in the discharge path, from the point of discharge of relief valves and tank gauge vent openings. Do not locate electrical equipment in an LPG discharge path.

C. In pits located beneath or containing LPG or liquid valves, pumps, compressors, regulators, or similar equipment.

2.9.2.4 Provide Division 2 or Zone 2 rating for outdoor equipment beyond 5 ft (1.5 m) and within 15 ft (4.6 m) in any direction from any connection that is regularly made and disconnected or any point where excessive release of liquid or gas may occur.

2.9.2.5 Provide Class I, Division 2 or Zone 2 rated electrical equipment for ventilated buildings housing vaporizers, gas-diluting equipment, controls, and regulating equipment.

2.9.2.6 Where vaporizer enclosures are heated, provide steam or hot water medium or an FM Approved electric heater rated for Class 1, Div 1 or Zone 1 installations.

2.9.3 Electrostatic Safeguards

2.9.3.1 Provide electrical grounding and bonding of LPG tanks and delivery tankers in accordance with Data Sheet 5-8, *Static Electricity.*

2.9.3.2 Ensure continuity of bonding and grounding for pipes, fittings, and hoses.

2.10 LPG Storage in Refrigerated and Large, Pressurized Containers

Apply this section to refrigerated and large, pressurized storage containers (100,000 gal [380 m^3] or greater individual capacity).

2.10.1 Location and Construction

Note: Spacing recommended in this section will help reduce exposures in the event of relatively small releases of LPG from storage containers. These distances are not sufficient for protection against fire and explosion associated with large release incidents, such as broken connections or piping failures.

2.10.1.1 Locate aboveground LPG storage tanks well away from main buildings and process structures as follows:

A. Provide separation distances per Table 4, subject to site availability.

Table 4. Separation Distance Between LPG Tanks and Main Buildings and Process Structures

Tank Capacity		*Minimum Separation*	
gal	m^3	ft	m
>100,000 to 200,000	>380 to 760	200	61
>200,000 to 1,000,000	>760 to 3800	300	91
>1,000,000	>3800	400	120

B. If the distances recommended in Part A are not feasible due to site constraints, provide as much separation as possible, but at least 100 ft (30 m).

2.10.1.2 Provide separation between adjacent LPG tanks in accordance with API 2510 or the applicable local code, whichever is greater.

2.10.1.3 Design drainage and impoundment for control of accidental releases from pressurized and refrigerated storage in accordance with API 2510 or other applicable standard.

2.10.1.4 Provide minimum separation distance between the shell of an LPG storage tank and the edge of a spill containment area for ignitable liquid storage in accordance with Section 2.2.1.5. and 2.2.1.5.1.

2.10.1.5 Where tanks are exposed to flooding, anchor them securely to prevent flotation.

2.10.1.6 Where tanks are located in FM 50-year to 500-year seismic zones, adhere to the recommendations in Section 2.2.4.

2.10.2 Fire Protection

Provide fire protection for LPG storage containers and loading/unloading stations in accordance with the following:

2.10.2.1 Install fire hydrants so each tank and loading/unloading station can be reached from at least two directions by at least three hose or nozzle streams.

2.10.2.2 Locate hydrants within 200 ft (60 m) of the protected tank.

2.10.2.3 In addition to hydrants and fire hoses, provide fixed protection for LPG tanks using automatic water spray with the capability of remote manual activation from the control room.

2.10.2.4 Provide water spray protection as follows:

A. Automatic discharge over the full surface of the protected vessel using a 0.30 gpm/ft^2 (12 mm/min) application rate.

B. Design water spray piping in accordance with Data Sheet 4-1N.

C. Use FM Approved water spray equipment.

2.10.2.5 Provide a dedicated reliable water supply capable of the following simultaneous water flow demands:

A. The design application rate (0.30 gpm/ft^2) over the tank of origin and all tanks less than one half tank diameter

B. An additional 750 gpm for hose streams (fixed monitors or mobile apparatus)

C. A minimum duration of 4-hours

2.10.3 Equipment and Process Controls

2.10.3.1 Design tanks, pressure relief valves, and piping in accordance with applicable codes.

2.10.3.2 Provide an excess flow valve installed on the first bolted connection or within the vessel.

2.10.3.3 Provide emergency isolation valves on liquid and vapor lines, other than connections to pressure relief devices, with the following features:

A. Activated automatically by fire detection

B. Also activated manually at pull stations in the loading/unloading and storage areas

C. Remote manual activation at pull station(s), preferably in the control room, but at least accessible during fire emergencies

D. Fire-rated valves on each outlet line below the maximum liquid level, preferably on the first bolted connection

E. Arranged per Section 2.5.5.5 above

2.10.3.4 Provide liquid-level gauges and two independent high-liquid-level alarms that signal the control room and field operators responsible for control of the filling operation.

2.10.4 Management of Process Safety

2.10.4.1 Establish programs to manage the safety of LPG tanks based on guidance in Data Sheet 7-43.

2.10.5 Emergency Response and Pre-Incident Plan

2.10.5.1 Establish an emergency response plan covering equipment, personnel, isolation, etc. for all LPG storage vessels per 2.8.2 above.

2.10.5.2 Where protection is a based on manual water spray, deluge, or monitor nozzle actuations, establish response capability from an adequately staffed, onsite structural fire brigade that is available 24/7.

2.10.5.3 Conduct a full turn-out drill at least annually.

3.0 SUPPORT FOR RECOMMENDATIONS

Given the large number of existing fixed storage installations, the frequency of fires and explosions involving uncontrolled LPG releases is quite low. However, severe losses involving release from these installations continue to occur, typically due to failure to design, maintain, or operate in accordance with accepted LPG

codes and standards. The likelihood of a large release at any given location increases significantly when management and supervision of LPG loss prevention programs is neglected.

The primary goal of the recommendations in this data sheet is to prevent loss of containment through basic prevention safeguards such as corrosion control, preventive maintenance, and control of ignition sources. Mitigation measures such as space separation, emergency isolation systems, and emergency response planning are also recommended where accidental release of LPG will expose high-value property and production operations.

3.1 Management of Loss Prevention Programs

3.1.1 Property Conservation Policy

Loss prevention programs will only work effectively if corporate and local management demonstrate strong support, beginning with a written policy that clearly sets property conservation and loss prevention as priorities for employees at all levels.

3.1.2 Loss Prevention Supervision and Internal Audits

Outdoor LPG releases that result in fire and explosion damage to plant buildings can often be attributed to a breakdown in implementation of basic loss prevention programs. Effective loss prevention requires ongoing supervision and internal audits conducted by knowledgeable and well-trained employees.

3.2 Separation of Exposures (Fig. 6)

Fixed LPG storage represents an inherent risk of severe fire and explosion that warrants consideration during site selection for new installations. The distances recommended in Section 2.2.1.1 are intended to encourage the use of space separation between LPG tanks and main buildings as a damage-mitigating safeguard in site selection for new LPG installations. These distances are acceptable for FM purposes, but should not be considered “safe separation” for large, accidental releases of LPG (examples of which are given in Section 3.5 and Appendix C). The following general approach to site selection can be used in conjunction with Section 2.2.1.1:

Fig. 6. A 15,000 gal (58 m^3) LPG tank (FM SimZone)

A. Recognize that a large LPG release is relatively unlikely, but cannot be ruled out. Therefore, any LPG tank installation on the facility site represents an inherent risk of severe fire and explosion.

B. In order to mitigate potential damage, attempt to maximize separation between main buildings and LPG storage and unloading.

C. Where the site can accommodate it, consider separation distances on the order of 200 ft (60 m) or more, which may help mitigate the extent of fire and explosion damage, depending on the release scenario.

D. Where site availability is limited, at least provide the shorter distances recommended by this data sheet in Table 1. But, recognize that these distances and code requirements provide little or no damage-mitigation in event of a large release of LPG.

3.2.1 Minimum Separation Distances in LPG Codes

LPG codes typically allow a “minimum separation distance” of 50 ft (15 m) or less, which exposes a main building or other target to near field (severe) damage for large release scenarios described in Appendic C. Such minimum separation distances are based on the rationale that prevention safeguards render large releases unlikely events, so that potential fire and explosion consequences do not need to be mitigated for code purposes.

Given the inherent hazard of large releases and their potential severity, the approach taken in this data sheet is that evaluation of separation distance and potential exposures to high-value buildings and production operations is warranted during site selection for new LPG installations.

3.2.2 Unloading Station Exposure to Storage Tanks

Unloading stations are susceptible to accidental releases during transfer from rail cars or tanker trucks. Locating the unloading station sufficiently far away will help prevent the storage tank from becoming involved in the event of release and fire at the unloading station (see Figure 7). This separation will also help facilitate manual firefighting in the event of LPG release and fire during transfer activity.

3.2.3 Separation from Bulk Combustibles

Large fires involving stored ignitable liquids or other combustible material located in proximity to an LPG tank or unloading station (Figure 8) may release sufficient thermal radiation capable of causing pressure buildup and opening of the tank relief valve.

LPG discharge from tank relief valves, if ignited, can create a large torch fire. The intense, radiated heat may ignite other combustibles and delay effective use of hose streams by emergency responders. The exposure can be reduced by providing special protection over the tanks. Fireproofing can be provided for tanks where installation of water spray is not viable.

3.2.4 Special Protection

External fire exposure to aboveground tanks from combustible storage can be reduced by providing special protection as recommended in Sections 2.2.1.5 and 2.2.1.6.

The following types of special protection are commonly provided:

A. Water spray protection on the storage tank(s) and/or unloading tanker per Section 2.4.2 (see Figure 9)

B. FM Approved 2-hour hydrocarbon fire-rated insulation over the entire tank surface and piping up to 20 ft (6.1 m) away. Install, test, and maintain fireproofing in accordance with the manufacturer’s instructions and API 2218, *Fireproofing Practices in Petroleum and Petrochemical Processing Plants.*

C. Mound or bury the tank(s) in accordance with Section 2.2.1.14 and 2.2.1.15.

3.3 Equipment and Processes

3.3.1 Emergency Isolation System

Uncontrolled releases following mechanical failure or human error represent an inherent threat of fire and explosion for any LPG installation. An emergency isolation system capable of achieving prompt shutdown of flow is the key to preventing a loss, or at least limiting the extent of damage following accidental release. A proper emergency isolation system will provide several independent means of isolating the source of a release, as described below.

Fig. 7. LPG unloading station 50 ft (15 m) away from storage tank (FM SimZone)

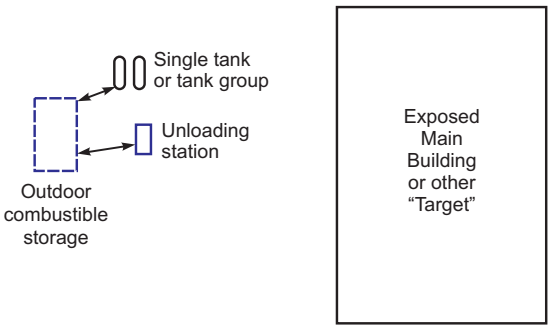

Fig. 8. Exposure distances from outdoor storage

Fig. 9. Water spray discharge on a 15,000 gal (58 m^3) LPG tank (FM SimZone)

3.3.1.1 Local and Remote Manual Isolation

Isolation valves actuated by a local manual pull or push button may be effective in limiting the duration of the release if operators are in the vicinity when a release occurs. Accessible remote pull stations are also needed to allow emergency responders to isolate the tank from a safe distance in case the release occurs when the installation is unattended. Figure 10 shows a typical remote shutoff station for manual closure of the internal valves on an LPG tank. This system uses nitrogen pressure to keep the isolation valves open during normal operation.

Fig. 10. Remote emergency shutoff 75 ft (23 m) from LPG tank (FM SimZone)

3.3.1.2 Excess Flow Valves

Excess flow valves are intended to automatically shut off the flow of LPG liquid or vapor due to releases caused by line breakage or other upset. The valve is closed by the differential pressure produced by a larger than normal flow rate through the valve. Excess flow valves are tested and rated to close when flow exceeds a predetermined rate for a given mounting position (vertically upward, horizontal, etc.). They must be installed in the correct direction. Valves are selected to close at flows between 150% and 200% of normal maximum flow. However, the excess flow valve will not actuate in releases at flow rates that are lower than the valve rating. Such releases may still be capable of significant fire and explosion damage if not shut down promptly.

Excess flow valves are recommended because they can be effective in achieving prompt shutdown of flow following a large break and sudden release of LPG. However, due to inherent limitations in their performance, they are considered a complementary safeguard to manual and automatic isolation.

3.3.1.3 Automatic Isolation

Automatic closing internal valves activated by back flow or thermal detection provide additional capability for emergency isolation in a fire situation where the manual isolation equipment malfunctions or is not activated. They are activated either electrically or by pneumatic systems with plastic tubing. Typically, the internal valve will also incorporate an excess flow isolation feature.

3.3.2 Pressure-Relief Device Testing

Failure of pressure-relief valves can create a variety of hazardous conditions. If they fail by leaking at pressures below the set pressure, or if they open and fail to properly reclose, the escaping LPG vapor may ignite as an external fire or deflagration if the vapor enter a building. Also, if valves fail to open at the set pressure, the vessel may be overpressurized. These failures are more likely to occur where environmental conditions are unfavorable.

All pressure-relief devices must be inspected, tested, and maintained at regular intervals to confirm they are in satisfactory condition (i.e., leak-free and ready to perform on demand). They also need to be replaced at the end of their useful service life, which depends on environmental conditions, operating experience, and valve design.

FM recommends pressure testing the valves at no more than 5-year intervals to ensure the proper setting.

3.4 Operation and Maintenance

Proper operation and maintenance of LPG equipment are key factors in preventing property loss due to accidental releases. Industry and FM loss experience has shown that even LPG systems designed and constructed according to the best codes and industry standards can cause major fire and explosion damage if not operated and maintained by well-trained personnel. Contributing factors in reported losses have included human error and maintenance failures such as:

- Unloading stations being left unattended during transfers
- Storage tanks being overfilled
- Corrosion control plans being allowed to lapse
- Improper repair of transfer hoses

Data Sheet 9-0, *Maintenance and Inspection,* Appendix C.1, provides guidance for evaluation of the quality of equipment maintenance programs.

3.4.1 Procedures and Records

Written procedures and work records provide the cornerstone for implementing safe operating and maintenance practices at LPG installations. Documentation of procedures and work activity also provides the basis for training new operators and maintenance personnel and conducting program audits.

3.4.2 Corrosion Control Plan

Devastating explosions have been experienced where corroded outdoor underground piping systems released LPG that subsequently entered industrial buildings where the vapor ignited as a deflagration; corrosion control is critical for maintaining the integrity of all underground metallic LPG piping and tanks. The protection may consist of a special coating or cathodic protection, as determined by evaluation of soil conditions by a qualified corrosion specialist. A corrosion control plan is needed to continuously monitor the installation over its life cycle to ensure corrosion protection is performing according to design.

3.5 Illustrative Losses

The following examples illustrate the potential severity of damage associated with large LPG releases.

3.5.1 Vapor Line Disconnected During Unloading (1983)

An 11,400 gal (43 m^3) tanker truck was transferring LPG into a 30,000 gal (114 m^3) storage tank at a chemical plant when the vapor return hose disconnected, due to a defective fitting or improper attachment. An excess flow valve was provided but failed to close. Propane vapor escaped from the tanker in the unloading station, which was located in a courtyard. The vapor entered the nearby boiler building where a deflagration occurred, causing extensive structural damage. Flames also propagated back to the tank truck where escaping LPG vapor continued to burn for three hours. An automatic water spray system over the unloading station activated and provided cooling for the tank truck.

3.5.2 Liquid Line Break at Storage Tank (1989)

An explosion occurred in a cylinder-filling system located next to two 18,000 gal (68 m^3) tanks. The explosion caused a break in a 1 in. diameter liquid line, resulting in an uncontrolled release. Fire ignited between the two tanks. Employees promptly notified the fire service, which responded in 5 minutes. A strong water supply, good emergency access, and effective use of monitor nozzles by the fire service helped prevent a BLEVE by keeping the tanks cool until all the fuel was consumed and the fire extinguished.

3.5.3 Pickup Truck Collides with LPG Tank (1992)

The driver of a landscaper's pickup truck lost control of his vehicle and struck a 1000 gal (3.8 m^3) LPG tank located 23 ft (7 m) from a warehouse building. The tank rolled against the wall of the warehouse. The tank filling and safety valves were broken off, allowing LPG vapor to escape from the tank. A jet fire ignited and spread inside the unsprinklered warehouse. The fire service arrived within 15 minutes and was able to apply hose streams to cool the tank, but the warehouse and contents were consumed by fire.

3.5.4 Storage Tank Rupture (1993)

An explosion and fire occurred in the outdoor storage yard at an industrial facility as a result of the rupture of a 15,000 gal (58 m^3) aboveground LPG storage tank. The 46 ft (14 m) long main section of the tank rocketed, struck a flatbed trailer located in its path, and finally landed on outdoor storage racks located about 350 ft (100 m) from the launch point (Appendic C, Figure A.2).

Fire and explosion damage was extensive for adjacent yard storage. Damage to the exposed main buildings and their contents was limited to minor overpressure effects on the exterior walls. Two favorable layout factors contributed to the mitigation of this loss: (1) Good space separation was provided between the tank and the main buildings; the closest being approximately 170 ft (52 m) from the tank, and (2) the tank's longitudinal axis was not "aimed" at any main buildings; otherwise, the large rocketing section would have impacted and caused extensive damage.

3.5.5 Liquid Release from a Corroded Pipe (2006)

The LPG installation supplying standby fuel for the boilers at a large metalworking facility was being readiness tested. A large release occurred through a rectangular-shaped hole, approximately 3/4 x 3/8 in. (2 cm x 1 cm) that was formed by corrosion in a 2½ in. (6.5 cm) diameter underground pipe supplying liquid LPG to the vaporizers.

The escaping LPG accumulated inside a courtyard where the vaporizer was located. Two warehouses, covering 46,000 ft^2 (4270 m^2), were totally destroyed by a deflagration following LPG entry. Blast waves from these deflagrations caused additional heavy damage to other main buildings. Multiple fatalities also resulted.

3.5.6 Offsite BLEVE and Vapor Cloud Explosion (2008)

A large LPG release from a tanker truck occurred at an LPG transfer yard, forming an outdoor vapor cloud that ignited and exploded. A subsequent fire resulted in a BLEVE of the tanker truck. Overpressure from the explosions damaged many surrounding residential, commercial, and public buildings, including two schools located about 1500 ft (450 m) away, where a rooftop ventilation unit was damaged, windows were broken, and ceiling tiles dislodged, resulting in extensive cleanup costs.

3.5.7 Other LPG Losses

The following loss examples illustrate additional large release incidents as reported by reliable public sources.

3.5.7.1 Hose Break and Tanker Truck BLEVE (2007)

A tanker truck operator arrived at an industrial plant to make a delivery and requested plant personnel to help repair a liquid transfer hose, which they did. The hose failed after being connected and pressurized by the truck's LPG pump. The automatic shutoff devices provided on the truck failed to stop the flow, allowing liquid LPG to escape adjacent to a main building. Flashing vapor ignited and burned under the tanker, which caused a BLEVE. The operator was killed. www.historylink.org

3.5.7.2 Severed Liquid Line (1996)

A single 18,000 gal LPG tank was located 85 feet from the nearest main barn at a poultry farm. The LPG release was caused by an all terrain vehicle that accidentally severed the aboveground liquid piping (3/4 in. diameter) that ran from the tank to the vaporizers. An excess flow valve was provided on the liquid line but did not close, resulting in the formation of a vapor cloud. The vapor cloud ignited and flames propagated back to the release point, where they continued to burn and impinge upon the tank until it failed due to a BLEVE (Appendix C, Figure A.1). Extensive property damage and multiple fatalities occurred. This incident was extensively investigated by the US Chemical Safety Board (CSB). A full technical report is available from the CSB website. www.csb.gov

3.5.7.3 Large Release from an LPG Tank (2007)

A 500 gal (1.9 m^3) water capacity fixed storage tank was located along the exterior rear wall of a general store. The tank was half full and being emptied of its contents by a contractor in preparation for removal. A defective liquid withdrawal valve stuck open allowing uncontrolled flow of flashing liquid LPG, which formed a flammable vapor cloud and reportedly entered the store through openings in the roof eaves. After approximately 25 minutes, a deflagration occurred inside the store, resulting in total destruction of the building (Figure 11) and adjacent emergency vehicles. Multiple fatalities occurred. This incident was extensively investigated by the US Chemical Safety Board (CSB). A full technical report is available from the CSB web site. The report also describes other similar incidents. www.csb.gov

3.5.7.4 Release from a Corroded Buried Vapor Line (2004)

A 1 in. diameter underground steel pipe conveying LPG vapor from a 1 ton (approximately 530 gal [2000 L]) outdoor LPG tank to a propane-fired industrial oven had corroded at the entry into the basement of a manufacturing building. Escaped vapor accumulated in the basement and ignited, resulting in an explosion that severely damaged the building and resulted in multiple fatalities and injuries. Source: The ICL Inquiry Report, July 2009. https://assets.publishing.service.gov.uk

Fig. 11. Remains of a deflagration at a convenience store (Source: US CSB)

4.0 REFERENCES

4.1 FM

Data Sheet 1-2, *Earthquakes*
Data Sheet 1-11, *Fire Following Earthquakes*
Data Sheet 1-40, *Flood*
Data Sheet 1-44 *Damage-Limiting Construction*
Data Sheet 4-1N, *Water Spray Fixed Systems*
Data Sheet 6-0, *Elements of Industrial Heating Equipment*
Data sheet 6-4, *Oil and Gas-Fired Single-Burner Boilers*
Data Sheet 6-5, *Oil or Gas-Fired Multiple-Burner Boilers*
Data Sheet 6-9, *Ovens and Dryers*
Data Sheet 7-39, *Material Handling Vehicles*
Data Sheet 7-43, *Process Safety*
Data sheet 7-49, *Emergency Venting of Vessels*
Data Sheet 7-50, *Compressed Gases in Portable Cylinders*
Data Sheet 7-54, *Natural Gas and Gas Piping*
Data Sheet 7-59 *Inerting and Purging Vessels and Equipment*
Data Sheet 7-77, *Testing Internal Combustion Engines and Accessories*
Data Sheet 9-0, *Inspection and Maintenance*
Data Sheet 10-1, *Pre-incident Planning*
Data Sheet 10-3, *Hot Work*

FM Approvals, *Approval Standard for Liquefied Petroleum Gas Vaporizers, Gas-Air Mixers and Vaporizer-Mixers,* Class Number 7151, 7156, and 7157, January 1990.

4.2 Others

Code of Practice for Hong Kong LPG Industry: Module 2, Underground Pipework. May 2003.

National Fire Protection Association (NFPA). *Standard for Fire of Explosion Prevention During Cleaning and Purging of Flammable Gas Piping Systems.* NFPA 56, 2014

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UKLPG. *Code of Practice 1: Bulk LPG Storage at Fixed Installations.* 2009.

US National Board Inspection Code, Part 2, Supplement 7.

US Federal Emergency Management Agency (FEMA). *Reducing the Risks of Nonstructural Earthquake Damage.* FEMA E-74.

APPENDIX A GLOSSARY OF TERMS

Automatic: An action that is designed to occur without human intervention.

Boiling Liquid Expanding Vapor Explosion (BLEVE): Failure by explosive rupture of a pressure vessel containing saturated liquid and vapor above the normal (atmospheric) boiling point of the liquid (see Appendix C).

Direct-Fired Vaporizer: A vaporizer in which heat is furnished by a flame that is directly applied to a heat exchange surface that is in contact with the LPG to be vaporized.

Electric Vaporizer: A vaporizer in which heat is generated electrically and transferred to the LPG either directly or indirectly through a heat exchanger.

FM Approved: References to “FM Approved” in this data sheet mean the products and services have satisfied the criteria for FM Approval. Refer to the *Approval Guide,* an online resource of FM Approvals, for a complete listing of products and services that are FM Approved.

Ignitable Liquid: Any liquid or liquid mixture that is capable of fueling a fire, including flammable liquids, combustible liquids, inflammable liquids, or any other term for a liquid that will burn. An ignitable liquid is one that has a fire point.

Indirect-Fired Vaporizer: A vaporizer in which heat is furnished by steam, hot water, or other heating transfer medium and is applied to a vaporizing chamber containing the LPG, and in which heating of the transfer medium is accomplished at a point remote from the vaporizer.

Leak Check (on LPG piping): An operation performed to verify that a piping system does not leak when LPG is first introduced into a new piping system or one that has been shut down for modification, maintenance, or standby purposes. Leak checks on LPG piping are typically performed using LPG as the test fluid.

Liquefied Petroleum Gas (LPG): Material composed predominantly of commercial propane and/or butane, propylene, butylene, isobutylene, butadiene and their mixtures.

Pressure test (on LPG piping): An operation performed prior to placing a new or modified LPG piping system into service, to confirm gas-tightness at design pressure or maximum allowable operating pressure (if greater than the design pressure). A pressure test is recommended to be performed using inert test fluids.

Waterbath Vaporizer: A vaporizer in which heat is furnished by a temperature-controlled bath of water, water-glycol combination, or other heated transfer medium into which a vaporizing chamber, tubing, pipe coils, or other heat exchange surface containing LPG to be vaporized is immersed.

APPENDIX B DOCUMENT REVISION HISTORY

October 2013. This data sheet has been rewritten and reformatted. The following are the key changes.

A. Recommendations pertinent to the following basic safeguards have been added:

- Corrosion control of underground piping and tanks
- Operating and maintenance procedures
- Supervision of contractors

- Training
- Automatic emergency isolation devices
- Emergency response

B. Recommendations for separation distances between main buildings and LPG installations have been revised.

C. Recommendations for providing seismic shut-offs on LPG installations in earthquake-prone locations have been moved to DS 1-11.

D. Damage-limiting construction is recommended for vaporizer buildings.

E. Recommendations are provided for leak checking of LPG piping systems.

F. Roof-top LPG tank installations are addressed.

January 2012. Terminology related to ignitable liquids has been revised to provide increased clarity and consistency with regard to FMI's loss prevention recommendations for ignitable liquid hazards.

January 2001. This revision of the document has been reorganized to provide a consistent format.

September 1998. Document reformatted.

October 1978. Technical revision.

APPENDIX C LPG BLEVE HAZARDS

Boiling liquid expanding vapor explosions (BLEVEs) occur when a pressurized vessel containing a superheated liquid rapidly breaks apart into two or more pieces, releasing significant "blast energy" as the contents flash from a liquid to a vapor state. Spectacular industrial and transportation BLEVE accidents reported in the media typically are BLEVEs involving LPG tanks, but any tank containing a superheated liquid, even water, is capable of a BLEVE causing great damage if the container ruptures in the manner described. In fact, the term "BLEVE" was first used in 1957 by FM (Factory Mutual at that time) engineers to characterize a pressure vessel explosion involving a watery, superheated liquid that was not capable of igniting [1,2].

A storage vessel can BLEVE due to weakening caused by corrosion or a weld defect at ambient temperatures ("cold BLEVE"), failure of pressure relief devices when the vessel is overpressurized, or due to thermal loads from external fire exposure. In the latter case, tank failure can occur after 10 to 30 minutes of fire exposure, even while the pressure relief valve is still functioning to maintain the tank pressure within design limits [3,4,5].

BLEVE accidents are known to occur in industrial and commercial installations as a result of large, outdoor releases of LPG from storage containers or connected piping. For example, large releases may occur when a transfer hose ruptures or becomes uncoupled at the tanker unloading station; a pipe connection to a storage tank fails; a pipe is severed by impact from a vehicle or other heavy object; a tank is overfilled; or as a result of improper maintenance actions. In addition, the emergency isolation system on the tank or delivery vehicle fails to stop the flow, resulting in a sustained uncontrolled release of LPG. Flammable vapor formed by the release can disperse over great distances and eventually reach an ignition source, resulting in an external fire; if that fire impinges on the storage tank or delivery vehicle, the container may rupture (BLEVE) violently.

An LPG BLEVE can produce a fireball several hundred feet (few hundred meters) in diameter, resulting in severe damage to surrounding buildings and equipment [6]. The size of the fireball depends on the amount of liquid and the pressure in the tank at the time of the rupture. In addition, the BLEVE can propel metal shards and burning or unburned LPG for hundreds of feet (meters). Portions of the tank may rocket over 500 yards (500 m), usually in the general direction of the tank's longitudinal axis, but any trajectory is possible. The rocketing sections may contain significant amounts of fuel that may spread fire to surrounding combustibles at the point of impact.

For example, Figure A.1 shows BLEVE and impact damage to a building that was located approximately 85 ft (26 m) away from the BLEVE of an 18,000 gal (68 m^3) LPG tank whose longitudinal axis was parallel to the building wall shown.

Figure A.2 shows the final landing position of the main body segment of a 15,000 gal (57 m^3) LPG tank that ruptured. The segment landed on outdoor storage racks located approximately 350 ft (110 m) from the original position, and approximately 30° off the direction of the tank's longitudinal axis.

Fig. A.1. Structural damage from BLEVE blast and fragment impact (Source: US CSB www.csb.gov)

Fig. A.2. Final position of ruptured LPG tank segment

Large releases are expected to happen at a low frequency for installations that are built, operated, and maintained in accordance with this data sheet, industry standards, and local codes. However, a severe fire and/or explosion scenario is inherently present at every location where LPG is stored onsite in fixed tanks.

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