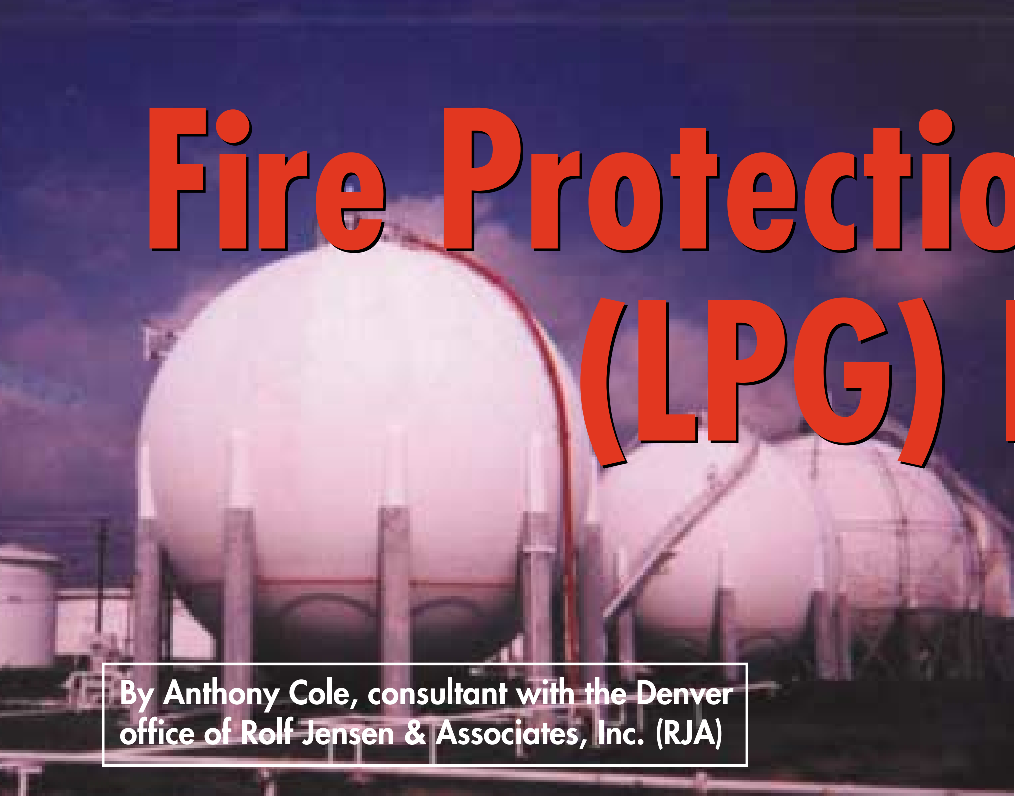
Fire Protection for Liq (LPG) Installati



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Pic courtesy of RJA

IN DEVELOPING FIRE PROTECTION METHODS and guidelines for liquefied petroleum gas (LPG) storage facilities, the chief concern is a massive failure of a vessel containing a full inventory of LPG. The probability of this type of failure occurring can be mitigated or at least controlled to a reasonable and tolerable figure with appropriately designed and operated facility. Since most LPG fires originate as smaller fires that become increasingly more dangerous, this article will focus on fire protection methods and guidelines in relation to small leaks and fires in LPG spheres. Of greater importance to the fire protection engineer is the more likely event of a leak from a pipe, valve, or other attached component leading to ignition, flash fire, pool fire, and eventually to a pressure fire at the source.

DEFINITION AND PROPERTIES

LPG was first discovered in the 1900s. The applications and uses of LPG, which range from cooking and refrigeration to transportation, heating, and power generation, make it an all-purpose, portable, and efficient energy source. LPG consists of light hydrocarbons (propane, butane, propylene, or a mixture) with a vapor pressure of more than 40 psi at 100°F. At standard temperature and pressure, LPG is in a gaseous state. LPG is liquefied by moderate changes in pressure (i.e. in a process vessel) or a drop in temperature below its atmospheric boiling point. The unique properties of LPG allow for it to be stored or transported in a liquid form and used in a vapor form. LPG vapors are heavier than air and tend to collect on the ground and in low spots. After LPG is released, it readily mixes with air and could form a flammable mixture. As a release occurs, there will be an area closest to the release that is above the flammable range, an intermediate area that may be in the flammable range, and areas that will be below the flammable range. Mixing, natural currents, and diffusion of LPG vapors affect the size and extent of these areas. If these processes continue, eventually the mixture is diluted to below the lower flammable limits (LFL).

Other characteristics of LPG include:

- LPG exerts a cooling effect as a result of vaporization due to releases at low pressure (as called autorefrigeration).
- The density of LPG is almost half that of water, therefore water will settle to the bottom in LPG.
- Very small quantities of liquid will yield large quantities of vapor.
- When vaporized, LPG leaves no residue.
- When LPG evaporates, the autorefrigeration effect condenses the surrounding air, causing ice to form. This is usually a good indication of a leak.
- LPG is odorless, therefore, agents such as ethyl mercaptan are added to commercial grades in most countries for better detection.

Properties of Two Common LPGs

PROPERTY	PROPANE	n-BUTANE
Specific Gravity	1.5	2.p
Vapor Pressure (at 60°F)	105 psia	26 psia
Boiling Point	−44°F	+31°F
Cubic feet of gas/gallon of LPG at 60°F	36.4 ft^3	31.8 ft^3
Lower flammable limit (LFL) % in air	2.0	1.5
Upper flammable limit (UFL) % in air	9.5	9.0
Gross Btu/ft^3 of gas at 60°F	2,516 Btu/ft^3	3,262 Btu/ft^3

Table 1 from 1996 edition of API 2510A

Tank Pressures for Two Common LPGs

LIQUID	QUANTITY	VAPOR VOLUME (gal.)	VAPOR VOLUME (ft^3)	VOLUME of GAS/AIR MIXTURE at LFL (ft^3)
Propane	1 gal.	270	36	1,680
n-Butane	1 gal.	230	32	1,630

Table 2 from 1996 edition of API 2510A

Vapor Volumes Obtained for Two Common LPGs

LIQUID TEMPERATURE	PROPANE	n-BUTANE
31°F	50 psig	0 psig
60°F	90 psig	11 psig
100°F	175 psig	37 psig
130°F	250 psig	65 psig
140°F	290 psig	80 psig

Table 3 from 1996 edition of API 2510A

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ons: The Basics

Pic courtesy of RJA

PRODUCTION AND OPERATIONS

LPG is derived from two main energy sources: natural gas processing and crude oil refining.

When natural gas wells are drilled into the earth, the gas released is a mixture of several components. For example, a typical natural gas mixture may be (90%) methane or "natural gas", while the remaining percentage of components (10%) is a mixture of propane (5%) and other gases such as butane and ethane (5%). From there the gas is shipped in tankers or via pipeline to secondary production facilities for further treatment and stabilization. From these facilities it is sent by bulk carrier or pipeline to various industrial plants and gas filling facilities or used for power generation.

LPG is also collected in the crude oil drilling and refining process. LPG that is trapped inside the crude oil is called associated gas. The associated gas is further divided at primary separation sites or Gas Oil Separation Plants (GOSP's), Central Processing Facilities (CPF's) for offshore installations or Drilling, Production, and Quarter's Platforms (DPQ's). At these facilities, the produced fluids and gases from the wells are separated into individual streams and sent on for further treatment.

At refineries, LPG is collected in the first phase of refinement or crude distillation. The crude oil is then run through a distillation column where a furnace heats it at high temperatures. During this process, vapors will rise to the top and heavier crude oil components will fall to the bottom. As the vapors rise through the tower, cooling and liquefying occurs on "bubble trays," aided by the introduction of naptha. Naptha is straight run gasoline and generally unsuitable for blending with premium gasolines. Therefore, it is used as a feedstock in various refining processes. These liberated gases are recovered to manufacture LPG.

In commercial applications, LPG is usually stored in large horizontal vessels called "bullets." These bullets can range in volume size from 150 to 50,000 gallons. In industrial applications, LPG is typically stored in large vessels that are sphere or spheroid shaped. These are the large "golf ball" shaped and oval vessels commonly seen at refineries and other similar occupancies. In this article, we will deal primarily with the protection of LPG spheres.

STANDARDS

Various sources of standards and codes exist for dealing with LPG facilities and proper fire protection. Some of these sources include:

- NFPA 54, *National Fuel Gas Code.*
- NFPA 58, *Liquefied Petroleum Gas Code.*
- NFPA 59, *Utility LP-Gas Plant Code.*
- American Petroleum Institute (API) 2510, *Design and Construction of LPG Installations.*
- American Petroleum Institute (API) 2510A, *Fire-Protection Considerations for the Design and Operation of Liquefied Petroleum Gas (LPG) Storage Facilities.*
- IP Code of Practice for LPG

Additional sources of information can be obtained from various organizations such as the British Standards Institute, the World LP Gas Association, The LP Gas Association, and industry producers and suppliers. For the purpose of this article, we will focus on some of the above-mentioned sources that are typically accepted as the industry standard.

FIRE PROTECTION DESIGN CONSIDERATIONS

In order to reduce the fire risk at LPG facilities, adherence to various design considerations and requirements such as layout, spacing, distance requirements for vessels, drainage, and containment control will help to limit the extent of fire damage. Additional considerations such as fireproofing, water draw systems, and relief systems are also important with respect to the integrity of the installation and the reduction of risk. These considerations address the various ways to prevent leaks or releases that may lead to a fire.

Equally as important to the prevention of a leak or release is properly designed, installed, and maintained fire protection systems. These systems attempt to minimize or limit the fire damage once a fire occurs. In the situation that a fire does occur, the levels of required fire protection are affected by several factors such as location and remoteness of the fire and the availability of water.

To determine if cooling water is required, the anticipated radiant heat flux from an adjacent tank, maximum tank shell temperatures if the vessel shell is not cooled, and other specific risk management guidelines must be analyzed. API 2510A contains a procedure to identify the point at which cooling water should be applied based on the size of the pool fire and the distance between the vessel and the center of the fire (Figure 1.) Additionally, an analysis of the relief valve parameters is necessary to maintain certain internal vessel pressures. Although computer models

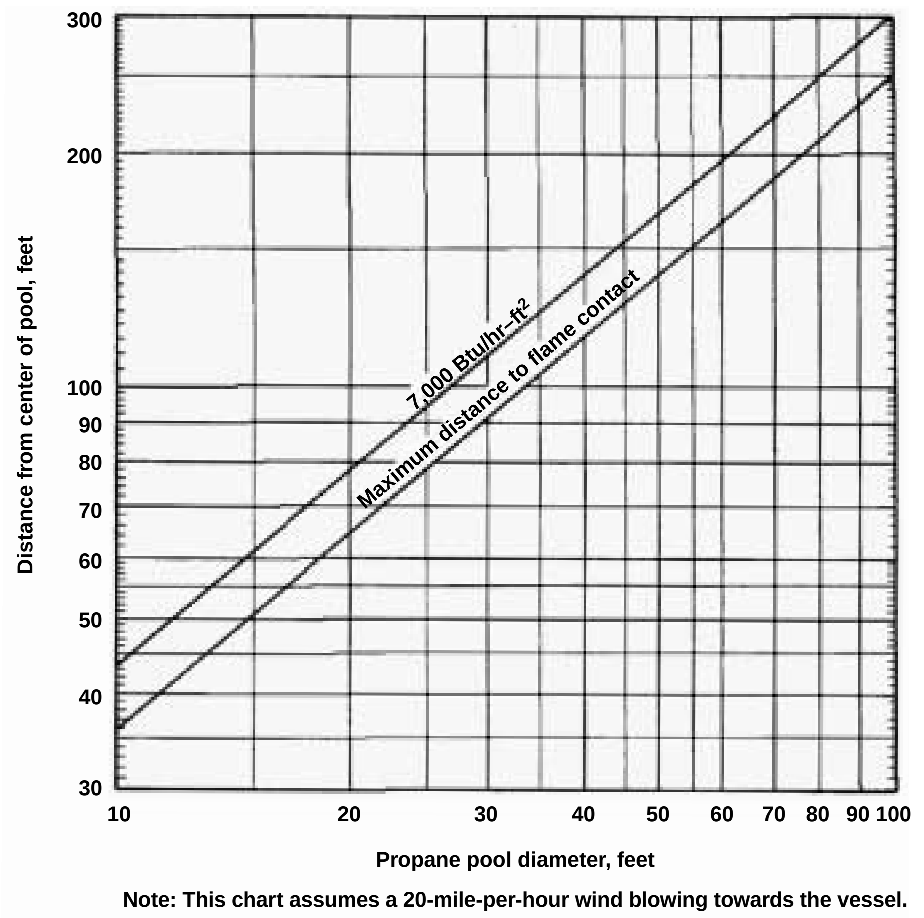

Figure 1. Pool Fire Radiant Heat Flux, from 1996 edition of API 2510A.

are available to more accurately anticipate the heat fluxes, this procedure helps to determine if a more detailed study is required.

Figure 1 considers the radiant heat flux from a pool fire, assuming a 20-mile-per-hour wind. To illustrate this procedure, first locate the diameter of the pool fire along the x-axis. Using an imaginary line from the designated point along the x-axis, locate the corresponding point of intersection on the 7,000 BTU/hr-ft^2 line. Next, extend an imaginary horizontal line to the y-axis. The corresponding point of intersection on the y-axis is the distance between the vessel and the pool fire at which cooling water must be applied. For example, if a pool fire is 30 feet in diameter, it is necessary to apply cooling water when the distance between the vessel and the center of the pool fire is approximately 120 feet.

In general, there are three primary methods that can be used to apply water for cooling or extinguishment to LPG vessels exposed to fire. The three methods are: water deluge, fixed monitors, and water spray. Additionally, portable equipment such as ground and trailer mounted monitors can be utilized, but should not be considered a primary means of water delivery. This is mainly due to the potentially extended set-up times, logistics, and requirement of human intervention that is not necessarily reliable.

The table below describes some of the advantages and disadvantages of the 3 primary water application methods and the use of portable equipment.

The first method involves the use of a water deluge system and some form of water distributor. This could include high-volume spray heads, perforated pipe or a distribution weir. An underflow or overflow weir is a form of distribution weir that allows water to be evenly distributed over the surface area of a sphere by water flowing up the piping network, over the top of the sphere, and out of the weir. This type of water distributor is commonly used but is prone to corrosion from standing water and clogging and requires increased preventative maintenance. Additionally, weirs may not be as effective on bullets and are often greatly affected by wind. The remaining components of this method are similar to other deluge installations. The typical deluge system contains a supply piping network, deluge valve and trim, and a branchline-piping network near the top of the sphere. Newer installations are usually activated automatically, whereas older installations are commonly activated manually. The decision as to which activation method to use requires evaluation of spacing, available protection, exposures, and other factors.

The principle behind the use of a deluge or weir system for LPG sphere protection is that the geometric shape of the sphere and gravity work together as an advantage. As water is applied to the top of the vessel, the shape of the sphere and the force of gravity facilitate the flow of the water as it covers the surface area of the vessel. This type of protection is very effective to facilitate an even distribution of water over the surface area. Caution should be exercised, however, because paint, corrosion, dust, and other environmental influences can cause changes in the surface of the sphere, resulting in uneven water distribution. Additionally, settling and other conditions inside the weir can also cause uneven water flow over the sphere's surface.

Fixed monitors, the second method of water application, permit the use of

Various Applications of Water for LPG Sphere Fires

Application Method	Advantages	Disadvantages
Water Deluge	1. Rapid activation 2. Can be automatic 3. Lack of plugging	1. Problems with wettability 2. Possible water spray supplement for legs 3. Effectiveness with jet fires
Fixed Monitors	1. Ease of activation 2. Can be automatic 3. Effective for jet fires	1. Exposure to operators 2. Wind 3. Large water demand 4. Monitors may be changed unknowingly
Water Spray	1. Rapid activation 2. Wettability and run down 3. Can be Automatic	1. VCE damage 2. Plugging 3. Effectiveness with jet fires
Portable Equipment	1. VCE damage not an issue 2. Specific application to area 3. Portability for multiple hazards	1. Prolong set-up times 2. Manual 3. Exposure to operators

Table 1 from 1996 edition of API 2510A

Pic courtesy of RJA

fixed hydrant mounted monitors or individual monitors connected to the fire main to apply water to the fire area. In this case, water application is accomplished by operators manually opening valves to allow the flow of water to the LPG sphere. This procedure exposes operators to high heat fluxes and places them dangerously close to vessels under fire conditions. It is important to carefully study the plant and vessel layout if this method is elected. Proper placement, location, and quantity of fixed monitors must be reviewed and field tested to ensure that proper application and even distribution of water to all parts of the vessel is accomplished. In some cases, remote activation and operation is suggested when proper spacing of monitors is not a possibility. Additionally, annual testing and preventative maintenance are necessary to ensure parameters have not changed and that coverage is still adequate.

The third method of application is the use of water spray systems. These are systems that are comprised of a piping network of spray nozzles that distribute water over the surface area of an LPG sphere. The spray nozzles are positioned to form a grid pattern which facilitates the complete coverage of the sphere's surface area. Larger orifices and piping should be considered to help reduce blockage due to scale and mussel build-up and other potential problems. It is also important to properly size the strainer to prevent blockage. Inspection of strainers should be part of the preventative maintenance program.

The last method available is the deployment of portable monitors and hoses. Although not one of the three primary methods of water application, preparations and planning for this type of application should not be forgotten.

When utilizing the four water application techniques discussed previously, a combination of techniques provides ample fire protection; a deluge or water spray system and portable monitors. A combination of a water deluge/distributor with a fixed water spray system with portable monitor back up from the fire department provides excellent coverage.

A water application rate for these fixed fire protection systems depends on the type of fire situation. When a vessel is exposed to only radiant heat without direct flame contact, a density of 0.1 gpm per square foot of vessel surface area is the minimum. If direct flame contact, or impingement, occurs, a density larger than 0.1 gpm, up to 0.25 gpm per square foot of vessel surface area is the minimum.

For fixed or portable monitors, 250 to 500 gpm is the minimum. However, field verification and flow testing is necessary to ensure adequate and proper coverage is provided. Placement of monitors must also be field verified against approved plans to ensure acceptable spacing and access.

Vapor, heat, or flame detectors mounted in the vicinity of a vessel can complete automatic activation of these systems. The use of vapor detection provides early detection and warning, but activation of water application systems must be confirmed through flame detection. Flame detection provides quick activation, but use caution when positioning these detectors to prevent false activation from sunlight. Consideration need also be given to the installation of UV/IR combination detectors to reduce the false indication rate. These devices require testing and preventative maintenance programs. An evaluation of the facility is necessary in order to determine the correct type and location of devices.

RESPONSE

Even with the proper installation of fixed fire protection system, the importance of emergency response to LPG fires cannot be disregarded. LPG fires can escalate quickly, and a lack of manual activities by the fire department can lead to vessel failure. As part of this response, an up-to-date and complete emergency response plan is an integral part. The plan should include:

- Hydrant layouts
- Hose lays and lengths
- Multiple response approaches (wind dependant)
- Vessel inventories
- Fixed protection information
- Scenarios for both un-ignited and ignited leaks

Other important factors include fire department capabilities and mutual aid agreements. Proper training and drills are also required to reduce the risk of injuries and promote a quicker and safer response to LPG events.

CONCLUSION

Since most LPG fires originate as smaller fires that become increasingly more dangerous, the use of the three primary methods to apply water in a quick manner can help reduce the risk of LPG vessel failure. The deployment of portable monitors and hoses, although not one of the three primary methods of water application, is an important back up to the primary methods. LPG fires can escalate quickly and a lack of manual suppression activities by the fire department can lead to vessel failure. It is necessary, however, to take control of the fuel source before attempting to suppress the fire. In any case, an emergency response plan, along with proper training and drills, is important to reduce the risk of injuries and promote a quicker and safer response.

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