Liquefied petroleum gas emergencies

By Colin Deiner, chief director, disaster management and fire brigade services, Western Cape Government

Responding to an LPG tanker on fire will always be a high-risk situation

Liquefied petroleum gas or 'LPG' as it's more commonly known, could present fire services with some of their most challenging incidents. The physical properties of LPG as well as the volumes in which it is transported, are the two biggest factors that will dictate the strategies and tactics of the responding incident commander. Understanding these properties and being able to recognise the type of storage vessels and type of hazard it is being exposed to ie fire or mechanical damage, is crucial in the survival of your responders and eventual successful management of the incident.

What is LPG?

Let's do a quick catch up on the physical properties of LPG. Liquefied petroleum gas is colourless, odourless and has anaesthetic properties. For this reason, LPG is usually odourised enabling detection by smell down to one fifth of the lower limit of flammability ie approximately 0,4 percent gas in air. LPG is stored as a liquid either at ambient temperature under its own vapour pressure or in a refrigerated condition at a lower pressure. Given that LPG vapour is heavier than air, it will flow along the ground and into drains, etc, sinking to low levels.

In still air conditions any accumulation of vapour will take some time to disperse. This means that a flammable mixture might become ignited some distance from the point of leakage with the flame travelling back to that point. Escaping gas can also be recognised by its cooling effect on the surrounding air, causing condensation and freezing of water vapour in the air, showing as frost at the point of leakage. Owing to its consequent lowering of temperatures, liquefied petroleum gas can cause severe frost burns to the skin.

What is propane and what is butane? Propane and butane are both forms of LPG but what does that mean and what are the similarities and differences between the two?

Propane, which comes from natural gas processing and oil refining, is a flammable hydrocarbon gas that is liquefied through pressurisation. It is commonly used for heating and cooking but can be used for a wide range of residential and commercial uses while butane is also a flammable hydrocarbon gas that comes from natural gas processing and oil refining. Butane on the other hand, is more commonly used as a fuel, propellant and refrigerant.

Propane and butane are both sourced in the same way and are members of the LPG family and while there are several similarities between the two gasses, propane produces more heat than butane and is more efficient in combustion. Butane has a characteristic that is also beneficial to the environment; it liquefies easily, making containment easy. The most important differences come down to the boiling point of the gasses. Propane has a boiling temperature of -42 degrees Celsius, whilst butane has a higher boiling point at -2 degrees Celsius.

Incidents involving LPG

There are many categories of incidents involving LPG for the purposes of this article I will limit it to the following two types of types: Incidents with ignition and incidents without ignition.

Incidents without fire (spills)
These incidents include accidental releases of gas due to damaged or faulty valves or tears/splits in the container. Although the amount of gas released from a damaged valve or vessel tear can be approximated, it is difficult to assess the distance or pace at which a gas cloud has propagated without purpose-designed software. Several computer simulation software could provide a good indication of the gas cloud propagation, however, there are several factors that will need to be considered along with the computer-generated model.

The models are designed to calculate the rate and volume of evaporation based on the following parameters:

- Ambient temperature
- Weather conditions
- Gradient and
- Surface area of the spill, including any obstructions such as walls or drains that could limit or increase the propagation of released gas.

Due to their varying boiling points, propane spills will boil rapidly and its temperature will drop well below zero while with butane any rapid boil quickly ceases and evaporation can be relatively slow.

With or without the benefit of software models, the on-scene incident commander must consider any physical features in the vicinity of the spillage as well as any potential source of ignition.

Incidents with ignition

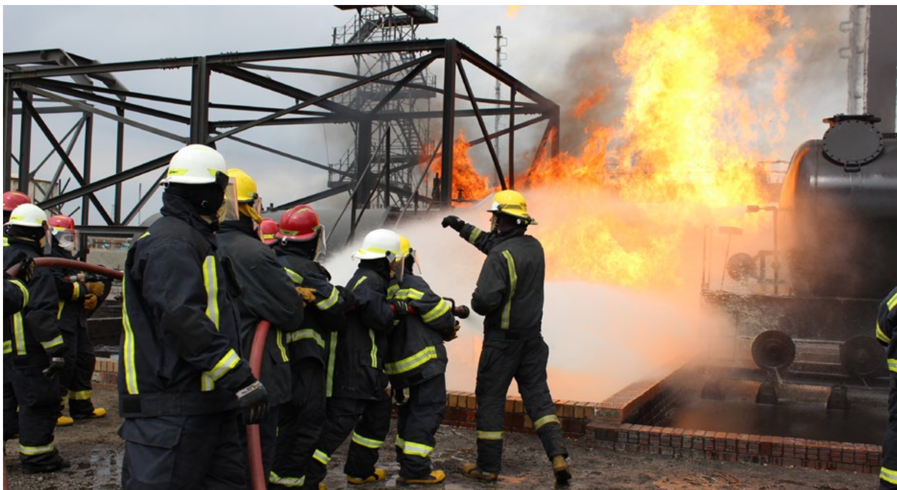
An incident where a large column of rapidly escaping LPG (within its flammable range) reaches an ignition source, will result in a high velocity and pressure fire accompanied by pressure and shock waves across the entire volume of the gas cloud, approximately 3 000 metres/second at a pressure of 20-30 atmospheres.

There are generally two types of fires emanating from an uncontrolled LPG release.

- Ignition could occur immediately after the incident has occurred resulting in an immediate ignition resulting a pressure-fed fire with a minimalised risk of explosion, depending on the integrity and proximity of the container. This type of fire could have the additional risk of starting secondary fires due to radiated heat igniting surrounding exposures.
- Flash fires occur when a fuel rich gas cloud finds an ignition source causing the flame to burn towards the released product (and its container). The size and velocity of the combustion will depend on the amount of released product, its density and propagation distance of the gas cloud. Here also there is a risk of secondary fires starting due to exposed surfaces of other flammable materials in the proximity of the combustion. The shock wave could either cause the flame to be snuffed out or lead to a fire at the point of release. Should the first eventuality take place, a real risk of secondary ignition will present if any secondary exposers are still burning. This type of incident is generally referred to as an unconfined vapour cloud explosion (UVCE).

A third type of incident type does not involve direct contact with the product but is caused by the heating of a vessel containing the liquefied gas by an external fire. The contents of the vessel are heated above their boiling point and the pressure in the vessel increases exponentially. The flames impinging on the surface of the vessel on or near the ullage space will cause the impacted wall to be weakened and may cause a catastrophic failure of the vessel. This is generally referred to as a boiling liquid expanding vapour explosion (BLEVE). As a result, the vessel ruptures propelling large pieces over considerable distances and leaving a trail of destruction in its wake.

This might be a good time to mention the safety systems on LPG storage vessels and road transport



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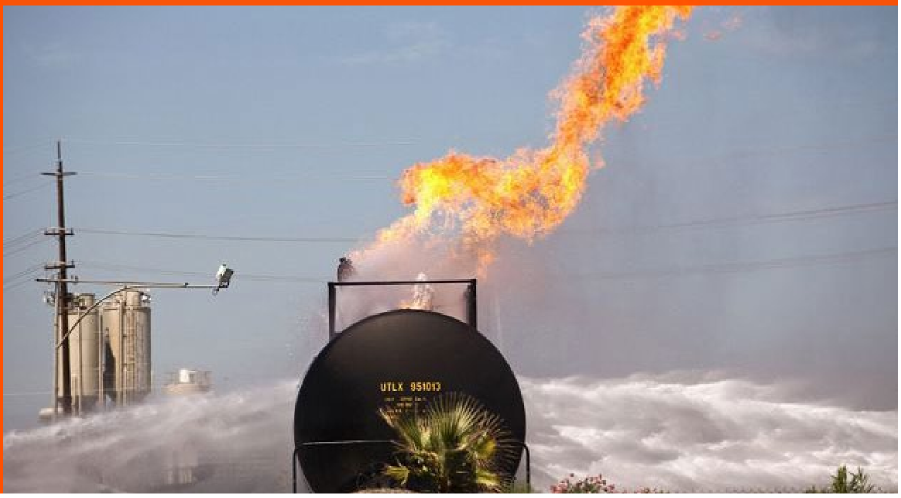


containers. Bulk LPG is generally stored in stationary storage containers and transported in LPG semi-trailers and custom designed LPG delivery vehicles commonly known as 'Bobtail trucks'. Storage methods will usually depend on the amount of gas stored and the industry it is being used for. Conventional refinery practice is to store LPG, such as butane and propane gas liquids under pressure in tanks or spheres.

Where large capacity LPG volumes of several thousand tons are stored, large, refrigerated storage vessels are placed either completely or partially below ground level. Bulk storage is usually found at the receiving terminals where the gas comes ashore from offshore fields or tankers. Bulk storage vessels for LPG range from small industrial users supplying gas for domestic use to major industrial users and refineries of 1 000 tons or higher. All these bulk vessels are designed for onsite re-filling.

Any storage facility must take into consideration the surrounding risks and the possibility that escaping LPG may migrate towards buildings, process plant, storage vessels or collect in natural depressions. The positioning of cylinders that may fail when involved in a fire must be considered. The direction in which they are aligned may impact the direction of travel of projectiles formed by the debris of the destroyed vessel.

Catchment areas for any liquid that might escape, must consider the propensity of the product to flow into low lying areas and the provision of low diversion walls will tend to ensure that the liquid will be directed to run away from tanks, pipelines and valves to a suitable area where it can be dealt with safely. Main shut off valves must also be placed in a position where they will not be compromised by a blast and where they will be accessible in an emergency.

Risks related to the road (and rail) transportation of LPG will be dependent on the location of the incident. An accidental gas release on a public road or in a built-up industrial could quickly find an ignition source and lead to multiple secondary fires. A road tanker incident with ignition in a similar area will have the risk of a BLEVE if not cooled down. The lack of a reliable water supply could be a major inhibiting factor here. A third situation could be a tanker involved in a rollover or suffering other mechanical damage to the vessel, which increases the pressure inside the vessel. Uprighting the vessel or exposing it to any movement may increase the pressure leading to a sudden rupture of the vessel. Pressure relief valves are designed to detect an increase in the internal pressure of the vessel and activate to relieve it to manageable parameters.

Managing LPG emergencies

Responding to an LPG tanker on fire will always be a high-risk situation. Ideally you don't want to extinguish a fire involving LPG. The gas cloud formed by the escaping unburned gas will propagate very quickly and any surrounding flames or heat sources could ignite it with catastrophic consequences. The main objective should be to isolate the source of the gas release thereby starving the fire of the fuel needed for it to continue burning.

If a cylinder has been exposed to direct flame impingement the possibility of a BLEVE will be ever present. There is no 'safe period' when a pressurised LPG container is subjected to heat. Pressure relief valves (PRV) on the cylinder are designed to open and vent the gas into the atmosphere in the event of an overpressure situation. Gas will escape through the PRV at a rapid rate, which will increase in proportion to the increase in the pressure inside the vessel. The placement of adequate water-cooling streams onto the vessel is critical in reducing the pressure inside the vessel and gaining control of the incident. Expect a boiling liquid expanding vapour explosion (BLEVE) at any time if adequate cooling has not been available or effectively done.

When the initial size up of a tanker involved in an incident is conducted, particular attention must be given to the condition of the PRV. It might have been damaged during the accident, which caused the valve mechanism to be jammed and while the responders are believing that the PRV has not yet activated and all is well, the internal pressure might already be critical.

The first responding unit must approach the incident from a safe distance and stage in an upwind direction. A pair of binoculars in the fire engine will assist the first-in incident commander to observe the incident from a safe distance where any immediate crew and public life risks can be determined and information can be gathered to assist in establishing an initial cordon around the potential hazard zone.

Try to set up cooling water streams onto the affected cylinders as soon as it is safely possible. This will minimise the possibility of vessel failure. Fire fighters should, however, take advantage of any available substantial shielding/cover and keep as low as possible to the ground. Ground monitors should always be a prime tool in such situations.

Flame contact anywhere on a vessel can lead to failure, however, the cylinder surface area above the level of the liquid is most dangerous as the internal gas will not conduct heat away as quickly as internal liquid.

Fire fighting considerations

Due to their comprehensive safety standards, bulk LPG incidents are rare occurrences. The most common LPG incidents that fire services will respond to would be smaller leaks that have ignited and these can be extinguished by using a dry agent and freeze sealing techniques. The technique of freeze sealing can be easily taught to first responders and entails using a roll of mutton cloth (or similar product) to wrap around the leak thereby causing the vapour surrounding the leak to freeze up between the cloth, thereby producing a temporary seal. The risk of suffering burns from super-cooled air is high and this will require full protective equipment to carry out.

A bulk LPG incident posing no risk to life could be dealt with by employing a defensive strategy whereby the vessel is allowed to burn out until the threat is neutralised. This can be a controversial decision by the incident commander but if it is, for example, a rail or road tanker rollover in an uninhabited area with very little knowledge of the integrity of the storage compartment or the PRVs, this might be the best way to go. A wide area evacuation of the area surrounding the burning vessel will be imperative. If it is necessary to evacuate people in the surrounding areas and this might take time, the employment of cooling streams must be considered.

An aggressive attack where crews will be employed to approach the fire in a controlled manner utilising fog to approach the source of the leak and then isolate it, must only be done after a thorough assessment of the risk to personnel and the feasibility of such a strategy has been done. The technique, more commonly known as flame bending, has been widely taught in petroleum oil and gas (POG) training programmes for almost 50 years and is reliant on several factors being present before it can be attempted. Sufficient cooling streams must be in place to ensure the integrity of the structure to be approached. Cooling will help prevent a possible tank rupture but also prevent any structures surrounding the vessel from collapsing due to the heat and weakening of its structural members.

A consistent and reliable water supply must be in place to support at least four hose teams for the entire duration of the operation. A burning gas release in a bulk storage facility may have also damaged nearby containers which could have resulted in running flammable liquid fires in the immediate vicinity of the burning gas leak. In such an event a continuous application of foam will be required.

It is not my intention to discuss three dimensional fires at length in this article. Safe to say that the decision to do this should be a carefully considered decision and, once the decision is made to do it, it must be done deliberately (don't deviate from your plan) and with maximum control by the team leader.

When approaching a fire at such close-range, care must be taken not to direct a water stream directly on to a burning gas stream. This could accidentally extinguish the fire and cause the unignited gas to escape uncontrolled to a point where it might again be ignited by a different source thereby engulfing the entire attack team in flame.

The use of attack teams is not only limited to valve isolation but can also be used to approach an area of high radiation heat to place water monitors or even rescue people near the fire.

A massive amount work has been done by the fire fighters from the various POG fire training schools in South Africa over many years. Here we must be particularly grateful to the guys at the Sasol Fire Training Centre in Secunda who have led the way in understanding and mastering these strategies.

Leaks without ignition

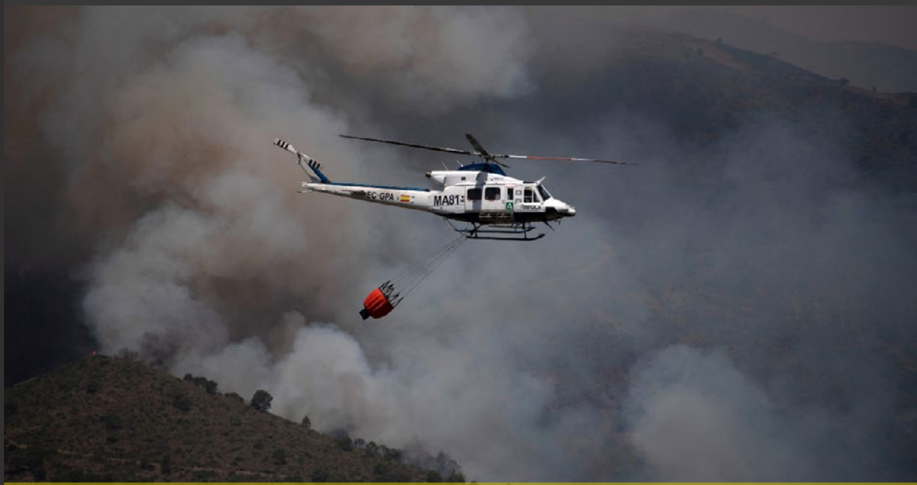
Earlier in this article I have mentioned the risk posed by an unignited leak. When responding to such an emergency, approach and stage your resources upwind and upgradient from the incident site. The incident commander's initial assessment must include the size of the leak, wind strength and direction and the potential for vapour cloud ignition. Any ignition sources must be removed and isolated.

Try to set up cooling water streams onto the affected cylinders as soon as it is safely possible

Command Corner: Communication with aircraft

By Chief Tim Murphy, US Forest Service Africa Disaster Management Technical Advisor

Chief Tim Murphy



Aviation communications should be clear, concise, short and to the point

Discuss the following information in terms of effective communication with aircraft. Involve the pilot(s) in this discussion.

- Establish an air-to-ground frequency on the incident and make sure everyone knows what it is.
- Avoid switching frequencies in the middle of an operational period.
- Discuss guard frequencies ie:
  - How they work
  - When to use them
  - What frequencies are established for aircraft in your area?
- Aviation communications should be clear, concise, short and to the point.
- Use standard terminology that can be understood by all people you are talking to. Do not use local slang.
- Know what you want to say before you key the microphone. Don't think and talk at same time.
- Before you key your microphone to talk, be sure to listen to ensure you don't cut into another transmission.
- Identify who you want to talk to by the call sign and identify yourself in every transmission.
- If the frequency gets congested, request another frequency. Upon receipt, ensure that all people who need to be on the new frequency transfer to that frequency.
- When giving ground descriptions, describe the location as if you are viewing the location from the direction an aircraft would be traveling. Use a common frame of reference for the sender and receiver.
- Use easily understandable directions, such as north, south, east, west, 2 o'clock, 9 o'clock, left 20 degrees, right 45 degrees, etc.
- When giving directions, always give them in relation to the pilot's perspective. "I'm at your 1 o'clock position."

Review Incident Response and Fireline Safety Pocket Guide pages 86 to 98.

Your priority will be to consider the need for evacuation of members of the public in the vicinity, vapour containment and dispersal using fog nozzles or monitors and other ground sprays to curtail the movement of vapour clouds and to reduce the gas concentration to below its lower explosive limit by the entrainment of air. The application of water to liquid spills will increase the rate of vaporisation.

Flammability detectors can also be used to determine the remaining areas of risk and the effectiveness of the mitigation methods being employed. Remember to also check for possible accumulations of gas at low levels, eg, in basements, drain and water courses.

Conclusion

Although I have spoken at length about the properties of LPG and the various risks it presents, I haven't elaborated much about incident location. We must appreciate that with mobile LPG containers (road, rail or portable) an LPG incident can happen virtually anywhere. It will not be possible to pre-plan for LPG leak or fire incidents at every location. It is therefore important to carefully evaluate the surrounding environment and consider which of the surrounding features may be particularly vulnerable or exasperate the incident. Ensure you are looking "inside-out" as well as "outside-in".