Shropshire
Fire and Rescue Service

# Brigade Order

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# Operations 14 Part 10
# Section 8

## Bulk Liquid Petroleum Gas – LPG

## Introduction

The purpose of this Section is to identify the chief risks likely to be encountered at incidents involving leakages of liquefied petroleum gas at bulk storage installations. It suggests the nature of operations which may need to be undertaken by the Fire and Rescue Service in such an event; and indicates the extent to which operations may usefully be pre-planned in consultation with management of the premises concerned.

Much of the guidance could be applied to small storage arrangements also, though these are not specifically included. It is not intended to detail standards of fire protection for LPG installations but mentions some of the safety measures which may be encountered that will assist in management of the fire fighting risks and the action which may be taken in an emergency.

## Characteristics of LPG

The term liquefied petroleum gas (LPG) refers to varieties of hydrocarbons derived from crude petroleum processes or from natural gas, being gases at normal temperature and pressure but which become liquid with either a moderate increase in pressure or a moderate drop in temperature, or both. (The term does not embrace such substances as methane which, though having certain of the same characteristics is lighter than air and therefore requires different treatment.)

These hydrocarbons include propane, propylene, butane, isobutane and butylene. The more readily liquefiable gases of this group are commercial propane and commercial butane, each of which may contain in varying amount several of the other hydrocarbons mentions.

The storage and transportation of large quantities of LPG in liquid form, is both convenient and economical. Liquefaction may be achieved in two ways:

- By the application of pressure in excess of the equilibrium vapour pressure; at normal temperature (15.6°C), 1 bar for commercial butane and 5 bar for commercial propane.

- By cooling to temperatures below the boiling point which for commercial butane is about – 1.1°C, for commercial propane - 40°C. When liquefied in this way the refrigerated LPG may be stored at pressure only slightly in excess of atmospheric, provided it is continually refrigerated.

Refrigerated storage is only economical when large quantities of approximately 2,000 tonnes or more are required to be stored at one location. The usual method of storage and transportation is as a liquid under pressure at ambient temperatures.

The density of the liquid is approximately half that of water.

Therefore, LPG if released, will tend to accumulate at low levels, hugging the contours of the ground, filling valleys, ditches and other low lying areas. In a comparatively still atmosphere, it will not disperse easily but can travel for long distances from the point of release. In this respect, it differs from methane which, being lighter than air tends to rise and disperse readily.

LPG becomes flammable when mixed with air in a concentration within the flammable range – for butane 1.9% to 8.5%, for propane 2.2% to 9.5% by volume; values for commercial butane and propane will not differ materially from the figures given here. 4.5 litres of butane when vaporised will produce around 1 cubic metre of gas at atmospheric pressure at 16°C; thus, at a 5% concentration in air, 20 cubic metres of flammable mixture would be formed.

Leaks of LPG are very likely to occur as vapour but if, at atmospheric temperature, there is a leakage from the liquid phase of a pressure container or from a pipe-line, an outflow of liquid butane can occur and there may be some delay in evaporation to the gas phase. An outflow of liquid propane is also possible but, owing to its lower boiling point, this would be more rapidly converted to gas. A leak at a flange or valve may often be detected by the presence of hoar frost due to the evaporation of the LPG causing a local reduction in temperature and the freezing of moisture in the surrounding air.

The pressure in a container is related directly to the composition of the particular variety of LPG and the liquid temperature. In all cases, a moderate rise in temperature greatly increases the pressure, for example, at 38°C commercial butane exerts a pressure up to 4.6 bar and at the same temperature commercial propane will exert a pressure up to 14 bar.

Liquid LPG has a relatively high co-efficient of expansion and, therefore, a container is filled to a limit which permits liquid expansion due to a normal rise in temperature without danger of over-stressing the container by hydraulic pressure.

LPG is odourless and non-toxic but has anaesthetic properties when inhaled in quantities for a long period. Inhalation in moderate concentrations produces nausea and headache. Heavy concentration in a pit or similar confined space may produce oxygen deficiency and cause asphyxiation. Such concentrations would present a serious risk of fire which might originate with explosive violence. To assist in detecting the presence of LPG a stanching agent is added (before sale) except where the intended use requires a gas free from odour as, for example, in the manufacture of aerosols. The odour produced is sufficiently strong to ensure that leaks can be detected well before the gas concentration approaches the lower limit of flammability.

## Bulk Storage Sites

The storage of LPG in large quantities occurs:

At refineries and other major installations and distributing depots of the oil industry

At producer and holder stations of the Gas Boards

At the premises of some large industrial users

It is normal to plan installations upon a site with due regard to fire exposures between containers (or group of containers) and buildings, other surrounding risks and boundaries. The contour of the ground, as it may affect the flow of heavier than air gases relative to roadways or other places where ignition might occur, is also a factor. Where several containers are required, alignment across rather than along the direction of the prevailing wind is usually adopted where site conditions allow. In the case of horizontal tanks, these may be positioned so that the tank ends, which are more susceptible to failure under excessive pressure, do not face towards buildings or plant.

## Containers

Containers may be cylindrical tanks, both vertical and horizontal, or spheres. The capacity of large containers is considerable; for example, spheres to accommodate quantities of the order of 3 – 5 million litres are not unusual within the oil industry and the capacity of a refrigerated tank may be many times greater. On most sites however, storage requirements are met by smaller containers.

Safety fittings normally include excess flow valves at container outlets and pressure relief devices (including, in the case of refrigerated tanks, vacuum breakers) fitted in the crown of a pressure variation due to a normal rise in the ambient temperature.

Containers for refrigerated storage are constructed with an outer cladding to protect and contain the insulating material, which may be of the order of one metre in thickness; the interspace may also contain inert gas.

High standards of construction and maintenance make it unlikely that a container would fail under normal conditions. Any major spillage is more likely to result from damage to or failure of a valve or flanged joint on a product pipe-line.

## Catchments

In order that any liquid spillage will be directed away from containers and from ancillary equipment such as pipe-lines and valves the ground beneath containers is usually sloped or channelled to a catchment area. At the same time, in order not to interfere with the dispersal of gas by natural ventilation, catchments are kept as shallow as possible consistent with a suitable degree of containment and the superficial space available for this purpose.

Main valves are positioned where they are most likely to be accessible in an emergency and they may also be remotely controlled.

## Facilities for the Cooling of Tanks

In the event of fire, the exposure of any container to the heat will be accompanied by an increase in the internal pressure which, unless steps are taken to cool the container, may lead to the opening of the pressure relief devices, the involvement of gas escaping from these positions, and a general deterioration in the fire situation resulting eventually in a BLEVE (Boiling Liquid Expanding Vapour Explosion)

Various types of automatic water spray installations are in use which apply cooling water to a container either through a piping system with a large number of heads distributed over the whole of the container surface or, alternatively, over the upper parts of a container so that a film of water spreads downwards. With the latter arrangement it is possible that some of the lower parts of a container will be imperfectly covered but the upper parts, most often including the gas phase which is more readily susceptible to damage by heat, will normally be effectively protected. Any water spray systems may also be designed for manually controlled hot weather cooling to reduce loss of produce due to an unduly high rate of vaporisation.

On some storage sties, fixed ground monitors are provided as an alternative to or as a supplement for water spray installations.

The need for further water supplies, for Fire Service use, is mentioned later in this Order.

## Accidents at Bulk LPG Installations

The kind of accidental occurrence for which provision has to be made is the leakage of LPG either as a spillage of the liquid – with vaporisation dependent upon the particular variety of LPG and the ambient temperature – or as an escape of gas. In either event, there is the serious risk that fire or explosion will occur, not necessarily at the initial stage but inevitably if the escape is not arrested and the gas safely dispersed before it reaches a source of ignition. In all cases the first consideration is to stop the outflow of product, if possible by the closure of valves and, if ignition has occurred, to afford immediate protection to the tanks and all surrounding risks.

Pre-planning between the Fire and Rescue Service and the management concerned, instruction of the staff of the premises, Fire Service familiarity with the topography of the site and exercises in which the site staff and the Fire and Rescue Service train together are vitally important. These matters are dealt with later.

At the actual time of an occurrence, the appropriate technicians of the premises should, whenever possible, be on hand to advise fire officers what emergency measures are possible. Such technicians should also be fully consulted regarding action to be taken by the Fire and Rescue Service. It is against this background of pre-planning and close co-operation that the following consideration of certain courses of action is set out.

## Leakage of LGP With Ignition

A small quantity of liquid butane or propane of small surface area will burn with a reasonably lazy flame and for a comparatively long time, not increasing the surrounding temperature sufficiently to increase greatly the rate of vaporisation. The larger the area of fire, the less readily can heat be dissipated and the more intense the fire becomes.

A fire associated with a leakage of LPG should not be extinguished until the outflow has been stopped, or as part of a precisely timed operation to enable operatives to go forward and immediately stop the flow. If the fire were extinguished in other circumstances, the large volume of inflammable atmosphere would form and the unpredictability of the movement of a gas cloud would be extremely hazardous.

A large area of burning liquid may however, be reduced by the use of foam gently applied from the edges in order to avoid disturbance of the liquid and consequent increase in the rate of burning. Care should be taken to leave sufficient points of burning to avoid the risk of a serious flash over.

Notwithstanding the early protection afforded by any automatic water spray installations, an incident involving a major spillage of LPG or in which an LPG leak cannot be immediately arrested, will almost certainly necessitate additional use of water for cooling operations as soon as fire fighting personnel and mobile equipment reach the scene.

In the application of water spray from portable branches, particular attention should be given to any parts of a container surface or supporting structure not effectively covered by the fixed installations and especially any dry areas which may be above the level of liquid within a container. Any nearby product pipe-lines and installations structures should be included. In the case of refrigerated storage containers, cooling to preserve the structural integrity of external shells is equally important; external shells enclosing the legs of spheres may be particularly vulnerable.

The utmost discretion must be exercised in the use of water on a fire involving LPG in liquid form since the effect is to increase the rate of vaporisation and intensify the fire. The application of a jet of water would raise a cloud of burning gas and liberate such heat as to be extremely dangerous for persons nearby.

Water should not normally be applied to a stop valve or a safety valve at which LPG is leaking, or to the associated piping nearby; to do so may render the valve inoperative due to freezing.

Where liquid is burning beneath a container, the use of water spray to cover both the fire and the underside of the container may prevent direct impingement of flame upon the vessel and assist in burning off the liquid.

**If, due to continuing exposure to heat, the stage is reached at which pressure relief devices open, cooling operations should be massively increased in an endeavour to lower the pressure, but if nevertheless the discharge of gas that is on fire becomes markedly more noisy, this must be taken to indicate a dangerous rise in pressure. It will then be imperative to withdraw all personnel from the vicinity without delay and to this, end the early use of ground or trailer monitors and branch holders will reduce the need for manpower in hazardous situations.**

An extremely hazardous situation would arise if the contents of an LPG container became exhausted during a fire. With the loss of internal pressure and the admission of air, an explosive mixture would occur within the container and if flame should enter a **violent** explosion will ensue. This condition is known as Boiling Liquid Expanding Vapour Explosion (BLEVE). If the escape of LPG is from outlets near the base of a container, this risk can be prevented where the installation includes facilities to enable the bottom part of a container to be charged with water.

When LPG is burning only at the point of escape, the fire will go out as soon as the outflow is stopped and any small remainder of the product has been consumed. In the case of a large spillage however, the quantity of liquid remaining after the flow has ceased may be sufficient to sustain burning for some time and, in these circumstances, the protection of any surrounding risks must continue while the LPG is either allowed to burn off or possibly assisted to do so by judicious use of water spray.

## Leakage of LGP Without Ignition

The essential difference which characterises a serious leakage of LPG **without** ignition is the continuing process of vaporisation to form a gas cloud of unpredictable extent and behaviour which may be ignited by any source in its path.

The gas itself is not visible except in heavy concentrations but the vicinity of a liquid leak may be discerned because the fall in temperature will condense moisture in the air and be seen as a deposit or a white fog. Neither of these manifestations must be assumed to indicate the limits of a gas cloud which, in fact, is liable to be much more extensive. The most effective means for determining the approximate limits of risk is by means of an explosimeter. Such devices are normally available at major oil installations and storage site owners.

In any escape of LPG which has not ignited, emergency operations must be directed to shutting off the leak at source and, in the meantime, taking all possible steps to prevent ignition and to disperse the gas safely. At some major oil installations quantities of gas oil are available and may be used to absorb a spillage of liquid and so reduce the rate of vaporisation and the likelihood of flammable atmosphere reaching a source of ignition. The use of large jets of water on fog setting and directed into the air can be used to disperse small leaks.

It may be that a sudden escape of LPG could be ignited within moments of its occurring and so avoid the formation of a dangerous volume of flammable mixture but any such action would need to be taken at an extremely early stage and on the decision of the plant management. At any later stage the gas should not be ignited and therefore such a course is unlikely to arise in the presence of the Fire and Rescue Service. A considerable gas cloud may have formed by the time of the Fire Service's arrival.

Fire and Rescue Service and other emergency personnel should approach from up wind, all vehicles being left outside the area. **Only in very exceptional circumstances should persons enter the gas cloud**; not withstanding the taking of precautions, the risk of a chance ignition may be considerable and the heat due to ignition of a gas cloud is extremely severe.

The direction and force of the wind at the time will have a large influence upon the movement of the gas and the distance within which its concentration may be reduced below the lower level of flammability. Therefore, whilst all potential sources of ignition in the vicinity should be removed without delay, the most urgent consideration may need to be given to those which are downwind of the leakage. So long as any doubt exists as to the actual limits of the danger zone, precautionary measures should be applied over a move extensive area than is likely to be affected.

Within this area of precautions, all vehicles and other engines should be stopped, electrical equipment should be switched off, fires should be extinguished and the use of other kinds of heating appliances should cease. Telephones or radio equipment should not be used unless flame-proof. According to the proximity of other premises, roads and other transport routes, it may be necessary to bring movement to a standstill, prohibit smoking and evacuate the area. Steps must be taken to prevent persons from unwittingly entering the danger zone. Special consideration should be given to the possibility of gas accumulating at low levels, including basements where ventilation may be poor, or following the course of ditches and similar channels.

If any irremovable ignition source lies in the path of a gas cloud, it may be possible to divert the gas by interposing a dense curtain of water spray. The massive use of water sprays may also be adopted for the more general direction of the gas and to assist in dispersing it but it may not be possible to discern the extent to which such measures are effective. Persons engaged in these or any operations should remain outside the danger zone, if necessary after lashing branches in position.

The most likely occasion for any person to enter the area of a gas cloud would be as a result of the decision to attempt to stop the leak. Such a decision would normally be taken by the management or senior staff of the premises in consultation with Fire Officers. In these circumstances, the operatives making the attempt should be given the utmost possible protection, including heavy coverage by water spray or fog from the moment of their entering the area. If necessary, the branch crews providing this coverage should in turn be similarly protected. In the rare circumstances when personnel may have occasion to work within the area of a as cloud, breathing apparatus should be worn.

Once the leak has been stopped, an interval of time must be allowed to elapse for the ultimate dispersal of the gas before normal movement within the area can be resumed. Tests for gas should be made in any basements, pits or low lying parts where additional ventilation may be necessary.

## Pre-Planning and Training

Preceding paragraphs on accidents involving bulk quantities of LPG deal with the main contingencies in broad terms only. The success of operations at the time of the accident may largely depend upon the adequacy of fire planning and training directly related to each of the premises concerned. This necessitates much more than good layout and a sufficiency of equipment for fire fighting and cooling operations, important though these are.

Both the staff of the premises and members of the Fire and Rescue Service should have a clear understanding of the potential hazards and in any given circumstances, know what action must be taken at the onset and thereafter.

The arrival of the Fire and Rescue Service should be merely one phase in the carrying out of a carefully prepared and well rehearsed combined operation, leading to the eventual restoration of safe conditions with the least practicable damage. The closest possible co-operation between management and Fire Officers is essential in pre-planning of this Order.

It is necessary to balance the quantity and type of fire protection equipment against the facilities for its being brought into use at each stage. For example, if the number of staff who may be available at the time of an emergency is small, automatic installations and good communications will be the more important. Again, if the estimated peak rate of water usage is not immediately sufficient, the supplies which are available should be reasonably sufficient to contain the situation during the mobilising of further supplies from more distant sources.

Considerations of this kind are familiar to fire officers and it is not the purpose of this Order to suggest fire protection standards; however, it may be remarked that for fixed water spray installations on containers, a discharge rate of 9 litres per minute per square metre of surface area is widely accepted. Therefore when assessing the total need of water, an allowance of this order may be made for each protected container which could be directly exposed to heat from a fire, the requirements for the application of water by other means being additional.

Once the details of a satisfactory emergency plan have been agreed, all persons liable to be concerned should be instructed and trained in its application. Fire Officers and crews must be made familiar with the premises at risk and the facilities available, and should have a general understanding of the normal working of the installation or plant and any special measures of control which may be possible. Company staff should have regular training to enable them to play the roles required of them with assurance and efficiency. Both fire crews and installation personnel should be brought together in combined training and exercises so that their operations may be closely integrated and mutual confidence be established.

## LGP Tankers

In the event of a tanker being involved in an accident or overturned upon the road – especially in a built up area – the situation is liable to be complicated by damage to the tanker and by the exposure of nearby property and the public to risk. One consequence of a tanker being overturned may be to bring pressure relief valves, which are normally in the gas phase of the tank, below the liquid level so that liquid will be discharged through these valves if the tank becomes heated. In all circumstances where fire occurs, cooling should be undertaken to prevent a dangerous build up of pressure.

If the burning at a point of leakage should be accidentally extinguisher, it should be instantly relit by means of a remotely held flame. Provision for this purpose should be made before the necessity arises.

Where LPG escapes from a road tanker without fire, vehicular traffic should at once be halted and all persons be excluded from the vicinity. Large jets, on fog setting and pointed into the air should be used to try to disperse any gas. Urgent measures need to be taken to eliminate sources of ignition around the site, special attention being given to basements. The occupants of all buildings within the danger area should, if possible, be evacuated and others less immediately threatened, should be warned.