



HAL
open science

Safety provisions and LPG

Marc Caumont, Sylvie Ponthieu

► **To cite this version:**

Marc Caumont, Sylvie Ponthieu. Safety provisions and LPG. 15. Hazards Symposium "The Process its Safety and the Environment", Apr 2000, Manchester, United Kingdom. ineris-00972199

HAL Id: ineris-00972199

<https://ineris.hal.science/ineris-00972199>

Submitted on 3 Apr 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

SAFETY PROVISIONS AND LPG

Marc CAUMONT and Sylvie PONTHEIU

Institut National de l'Environnement Industriel et des Risques,
Parc Technologique ALATA, BP 2, 60550 Verneuil-en-Halatte, France

The safety of an industrial site depends in particular on the characteristics of the safety devices employed and the equipment installed.

In France, the safety evaluation of an installation is carried out, in particular, through hazard analysis. However, the absence of objective criteria for safety device evaluation makes the task difficult. Different pieces of equipment that assure the same function don't necessarily have the same safety level.

Consequently, INERIS undertook a study including:

- an outline of the various practices based on an inventory of French regulation and a comparison with regulations applied in other European countries,
- an accidentology allowing one to focus on some important safety devices,
- a description of the various devices that can be encountered on a L.P.G site, accompanied by a collection of descriptive boards of safety devices used with L.P.G.,
- a presentation of the concept of devices that are "Important For Safety", with definitions of commonly-used terms,
- a presentation of some approaches for taking into account safety devices in the evaluation of the risks or specific methods used for the evaluation of a L.P.G. site.

Keywords : L.P.G., safety device

INTRODUCTION

In 1997 there were 95 establishments in France storing at least 300 cubic metres (m³) of LPG (exclusively butane and propane) not including the underground storage sites.

Some 90% of these 95 sites were created between 1956 and 1975.

These sites have over 300,000 m³ of storage capacity made up as follows :

- . Mounded tanks : 23,600 m³ (10 sites),
- . Above ground spherical tanks : 220,000 m³ (68 sites),
- . Cylindrical tanks : 27,000 m³ (49 sites),
- . Cryogenic tanks : 60,000 m³ (3 tanks on a single site).

Four operators account for 54 of these sites ; chemical firms and refineries operate 15 of them. The remaining 26 sites are where LPG is used as a utility for heating plants, industrial furnaces, and so on, for a variety of activities.

There are at least about 182 spheres (100 containing butane and 82 propane), 200 horizontal tanks and 2 vertical cryogenic tanks (35,000 and 20,000 m³). The capacity of the spheres varies from 300 to 5,000 m³. Mounded tanks include horizontal tanks some of which have substantial capacity (3,000 m³) and spheres (from 1,000 to 3,500 m³). In France there are also 23 industrial sites (essentially in the chemical industry) storing products similar to LPG (for example, butadiene) with tank capacities ranging from 80 to 9,000 m³.

In the current situation of technological change INERIS is undertaking a study for the French Ministry of Environment (MATE) in the following five areas :

- A description of the different types of industrial facilities in France using LPG, specifying the different industrial practices involved,
- An inventory of the principal current regulatory requirements in different European countries (notably the UK, the Netherlands, Belgium and Italy) and a comparison with French requirements,
- The feedback of experience based upon an analysis of industrial accidents involving LPG,
- Identifying systems which are important to safety,
- An evaluation of the consequences of various accident scenarios according to the safety systems present on the installation.

This study is still in progress. Hereafter some extracts of the sections covering an overview of French LPG sites, the comparison of regulations and the feedback of experience are briefly presented.

OVERVIEW OF FRENCH INDUSTRIAL SITES UTILISING LPG

The French sites utilising LPG can be subdivided into 7 main categories :

- Refineries (producing and storing LPG and distributing it to “buffer” and/or operating sites) ;
- “Buffer” sites (receiving and storing LPG and distributing it to operating sites) ;
- Operating sites (receiving and storing LPG and distributing to clients and to “local depots”) consisting of :
 - ❖ filling centres (distributing LPG in bulk, “packaging” and distributing cylinders) ;
 - ❖ intermediate depots (distributing only bulk LPG) ;
- So-called “local depots” (receiving and storing LPG and distributing it in bulk to clients), which are similar to the intermediate depots but store smaller quantities (storage capacity < 120 m³).
- Industrial sites employing LPG as a utility for an industrial process (for example, heating plants, industrial furnaces, and so on).
- Chemical sites employing LPG as a raw material.
- The cosmetic industry employing LPG as a propellant gas (aerosols).

In the following we shall disregard industrial sites employing LPG as a raw material, utility or propellant gas. Some characteristics of the different types of French industrial site where activities are entirely or partly focused on LPG are given in the following table :

Type of site	Type of location	Type of tank	LPG entry	LPG despatch	Remarks	Site workforce
Refinery	Large industrial complex	Spheres (>10) horizontal tanks (>10)	- (Internal)	Pipe Ships Wagons Trucks	Despatches frequently made by independent sites	>100 (firemen on the site)
"Buffer" site	Large industrial complex	Spheres Refrigerated tanks Underground cavities	Pipe Ship	Wagons Trucks	Entry by truck very rare.	>20
Filling centre	Industrial zone or suburban zone	Spheres (<10) Horizontal tanks (<10)	Pipe Wagons Trucks	Trucks	For packaged LPG, the cylinders are despatched by truck.	About 20
Intermediate depot	Industrial zone or suburban zone	Spheres (1 or 2) Horizontal tanks (<4)	Wagons Trucks	Trucks		Of the order of 2
Local depot	Suburban zone	1 horizontal tank (volume < 120 m ³)	Trucks	Trucks		-

Overview of French LPG sites

This table illustrates the general trends for the various industrial configurations that exist. Of course, there are exceptions, notably concerning the number and type of storage tanks.

TANK EQUIPMENT

For the tanks themselves, French regulations require to mound them (for capacity greater than 500 m³). This makes it possible to reduce safety distances for major accident scenarios. Quite a number of the existing spheres have been "mounded" by being covered with "TEXSOL" (special blend of sand and synthetic fibres). Use of this technique has allowed continued use of sites that were threatened by housing developments. More than a dozen industrial sites have used this technique for protecting their spheres.

Apart from the safety fundamentals – proper pressure vessel design, provision for hydraulic and seismic loading, and so on – the strategies applied with respect to tank auxiliaries have the following objectives :

- . to limit any spread of product,
- . to protect the tanks against any thermal effects,
- . to a lesser degree, to protect the tanks from impact missiles.

The safe state for tanks is attained by remote controlled safety valves on each connections that close automatically if gas or a flame is detected on site. In addition, the liquid outlet connections are fitted with internal remote controlled safety valves (usually hydraulically operated). Bunds are the rule around above ground tanks.

Thermal and mechanical protection is attained by adding one metre of earth or an equivalent thickness of TEXSOL (60 centimetres). For above ground tanks, protection against thermal effects is provided by a spray system (10 litres/m².min).

Regarding the protection against missile impact, mounded tanks (under earth or TEXSOL). are inherently safe. Above ground tanks - most French LPG tanks are of this type - do not meet this safety objective apart from a few rare exceptions (when tanks are protected by a concrete wall or dome)

INVENTORY AND COMPARISON OF LPG REGULATIONS

GENERAL

The different regulations or “reference documents” specific to LPG facilities were summarised for five countries : the Netherlands, the United Kingdom, Italy, Belgium and France.

Of the five countries considered, only Belgium⁽¹⁾, Italy⁽²⁾ and France⁽³⁾ have specific regulations for LPG facilities. The respective sources are given in chapter refernces.

In the Netherlands, the directive “LPG distribution depots”⁽⁴⁾ serves as the basis for defining the regulatory requirements governing the issue and renewal of licences for operating such installations.

In the United Kingdom, two reference documents⁽⁵⁾ may be used, one from the Health & Safety Executive, and the other from the British Institute of Petroleum. However these two documents provide guidance and do not have the force of law.

It may be noted that general or particular legislation not specific to LPG facilities may contain requirements that also apply to such facilities. Such legislation is disregarded in this study.

Our inventory was drawn up using, first, the above documents and, secondly, information obtained from industry and government representatives in the countries concerned.

Notwithstanding this, the inventory should not be regarded as exhaustive.

Apart from the classification of products, the main items dealt with in these regulations are :

- . Rules for the location of tanks
 - ❖ Distances from establishment boundaries
 - ❖ Distances between tanks
- . Protection of water
- . Firefighting measures
- . Gas detection
- . Control valves
- . Relief valves
- . Level measurements
- . Pressure measurements
- . Temperature measurements

As an example, the following table summarises the situation as to the regulatory requirements for safety valves on liquid outlets from tanks.

	1 st valve	2 nd valve	Comments
France	Motorised, inside the tank	Motorised	Fail safe
Netherlands (recommended)	Manual, as close to tank as possible, 1 st flange welded	Motorised, as close as possible to 1st valve	Fail safe
United Kingdom (recommended)	Motorised, or excess flow valve, or non-return valve	Motorised, if 1 st valve manual	Fire safe
Belgium	Motorised non-return valve	-	Fail safe
Italy	Liquid outlet : manual Liquid outlet: manual	Excess flow valve Non-return valve	Fire safe Valves designed for P > 40 bar

Summary of regulatory requirements for valves on liquid outlets

This comparison reveals appreciable differences in approach between the different countries considered. In France for example, internal valves are required on liquid outlets while the other countries considered have opted for safety devices outside the tank.

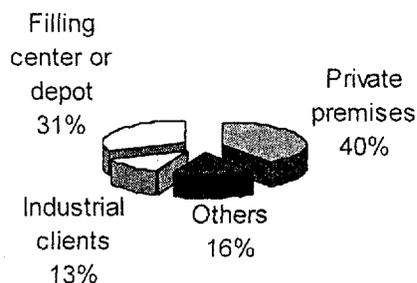
LPG ACCIDENTS

Accidents are unfortunately a prime consideration from the safety standpoint, whether in terms of prevention, protection or control. The accident analysis performed is based mainly on information available in the "ARIA" database⁽⁶⁾. It was done for each zone of activity – for example storage, transfer (loading/unloading), cylinder filling, etc., and also for each type of phenomenon : BLEVE (Boiling Liquid Expanding Vapour Explosion), explosion and fire. The following summary refers only to the analysis of accidents occurring during LPG transfer operations involving tanker trucks or wagons.

REVIEW OF ACCIDENTS OCCURRING DURING LPG LOADING OR UNLOADING

Statistical analysis

The statistical analysis of LPG accidents occurring during loading or unloading covers a sample of 33 events, most of the data being taken from the ARIA database. These events took place in the period 1951 to 1998. Although the sample is on the small side, we shall try to deduce the main trends. A breakdown of where the accidents took place is shown below.



Distribution of accidents by type of location

It will be seen that the processes of unloading LPG on private premises and industrial sites (in bulk) alone account for over half (53%) of the events listed. In both these circumstances, transfer is practically always done using equipment carried on the tanker trucks (pumps, hoses on reels, etc.). It should be borne in mind that a truck serving private clients (capacity limited to 6 or 9 tonnes) fills up at the filling centre or *dépot* and then delivers supplies to an average of 10 clients. The number of unloading operations by these trucks at private premises far exceeds the number of their loading operations at LPG centres.

Ten accident events are listed in connection with operations at these LPG centres. The two earliest events (Port Newmark in 1951 and Brinkley in 1957) shown in the "others" category could probably be included with them.

No particular analysis of the geographical location of the accidents was done since those reported by the different sources are strongly influenced by the availability of information. In fact the proportion of the accidents taking place in Europe and North America is very high compared with other parts of the world. Here it is interesting to note that countries, like Russia, apparently had very few accidents. As a result the list is not exhaustive since a number of accidents probably took place with no report being published either by the media or the international organisations.

As to the time distribution of the events, the number of cases reported appears to rise steadily as time passes : 50% of the accidents have been in the last 10 years. This observation is probably related to the growth of safety policies and the enhanced media attention for accidents and incidents that impose a wider circulation of information.

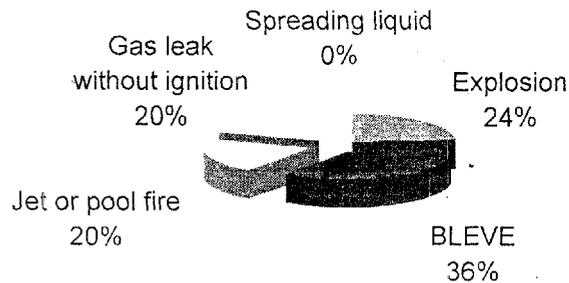
Phenomena observed

These have been classified into five categories :

Phenomenon
1. Liquid spreading on the ground
2. Gas phase leak without ignition
3. Jet (or pool) fire
4. Gas or vapour explosion
5. BLEVE of a tank

Phenomena used as a basis for classifying accidents

It is worth noting that phenomena 1 and 2 can be precursors of 3 or 4, while the flare (or pool) fire can be the precursor of 5 (a BLEVE). In other words, a leak of flammable product (whether liquefied or not) may ignite well after it spreads. The following figure shows the different phenomena involved. The phenomenon shown in the following classification is the most significant one noted during the accident (for a leak followed by a fire, this type of accident is placed in the fire category).



Distribution of events by observed phenomena

Thus it can be seen that the main phenomenon characterising accidents during LPG transfer operations is a leak followed by ignition of the cloud formed, which in most cases (60%) leads to the effect of overpressure (24%) or a fireball (BLEVE : 36%). However ignition didn't occurred in 20% of the cases reported.

The two phenomena of fire and explosion (including BLEVE), which of course regularly occur together, account for more than two thirds of the accidents (80%).

For the cases listed it will be seen that a leak is usually accompanied by the formation of a cloud that drifts with the prevailing wind. The ignition of this cloud at a distance (possibly at a considerable distance) is followed by a "flame return" that can cause fire under the road or rail tanker or tankers or its immediate vicinity.

The known BLEVEs listed in the literature result, in all the cases listed above, from a fire heating the tank, leading to an increase in pressure and mechanical failure. This phenomenon therefore affects ordinary above ground tanks, i.e., those where the shell has little or no protection from thermal effects. Among the accidents listed, inadequate means of protection are regularly identified as decisive in the development of an accident sequence towards a BLEVE.

Explosions of flammable gases are the result of a gas leak followed by ignition of the cloud if this is wholly or partly enclosed in a confined space. A large number of experiments have shown that the ignition of a gas cloud in free space, in the case of LPG, does not generate significant overpressure that is harmful to the environment. This is confirmed by accident reports. Indeed this condition of partial containment is probably the reason why most explosions of combustible gas (with the appearance of overpressure effects) concern production units, where there is usually a high density of equipment (with seals, valves, etc.) in a small volume, or leaks on customer's premises, for example when the cloud has entered a dwelling. Of course in these cases the explosion of the cloud could cause damage and leaks to the other tanks or mobile tankers (the domino effect).

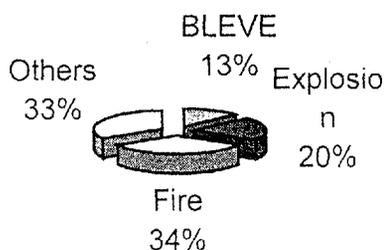
Finally we may note that only one of the listed events mentions an incident that did not give rise to a leak and that no report mentions the presence of LPG in the liquid phase on the ground.

The severity of accidents

This was evaluated simply by dividing the accidents into two categories :

- . Accidents not resulting in casualties.
- . Accidents resulting in casualties.

Some 55% of the accidents did not result in casualties. In 15 of the listed cases there were casualties (injury or death) and the phenomena responsible are shown in the figure below.



Causes of injury or death

Fire (excluding fireballs) is the main cause of casualties with 5 accidents. The victims were people present in the gas cloud when it ignited. The "other" category (5 cases) mainly contains accidents for which there is no information as to the cause of casualties (4 cases) and, in the 5th case, the operator had a fall following a leakage of LPG.

These 15 accidents were responsible for a total of 236 victims with 26 deaths and 210 injured. It is worth pointing out that two events resulting in a BLEVE alone accounted for 14 deaths and 144 injured.

However accidents occurring at LPG loading or unloading points do not always lead to loss of life. Thus on 1 April 1990 an accident occurred in an LPG filling centre at SYDNEY (Australia) during a process where the product was being transferred from a road tanker to a storage tank. A fire started and led to a BLEVE in a cylindrical 50 tonne LPG tank and a tanker truck. About 10,000 people were evacuated and the neighbouring airport temporarily closed, but there were no victims.

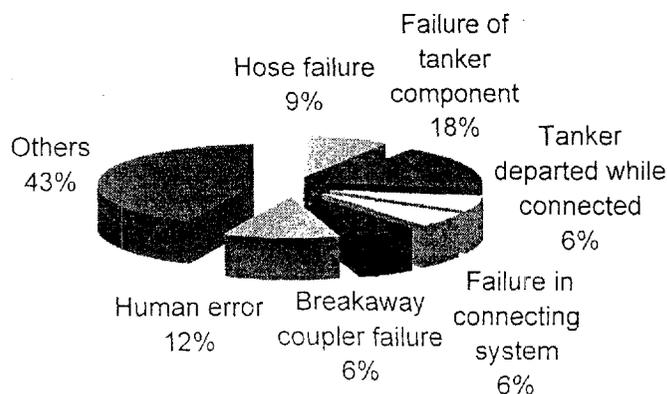
The causes of accidents

As to the causes and circumstances of the 33 accidents listed, we identified the following seven causes set out in the table :

1. Hose failure
2. Failure of mobile tanker component
3. Failure of connecting system
4. Failure in break away coupler
5. Truck departed while connected
6. Human error
7. Other causes

Types of causes-circumstances considered

Any accident, even if it affects a whole area, is usually caused by a particular action or system. In the present case therefore, we looked into the nature of the causes and separated the main groups of causes-circumstances occurring. Their distribution is shown in the following figure.



Breakdown by type of cause-circumstance

The classification is based upon the precursor event. Lots of causes are identified. However the relatively large number of accidents (6 cases) involving the failure of systems on road or rail tankers will be noted. Hose failures account for 6% of cases (2 events) as do the failures of connecting systems or a breakaway coupler, or leaks resulting from the road tanker's leaving while still connected to the fixed installations. As regards failures of connecting systems, it is worth noting that the two events reported concern the operations of filling clients' tanks for which the connecting systems are much smaller (1¼") than those used on LPG sites (2" and 3").

Human error, which could also have been identified as a major cause in the case of tankers departing when still connected, covers two types of error in this classification :

- Opening the wrong line, allowing product to discharge to atmosphere (2 accidents in Germany).
- Operator error leading to the bursting of a hose, for example the accident at Divonnes-les-Bains or the discharge of product when liquid was being taken from a client's tank (the accident at Mouans-Sartoux).

Feedback of experience

In view of the small number of accidents listed, and taking into consideration the variety of possible scenarios, we must point out that the preventive, protective or control measures referred to in this paragraph are not the only ones taken at loading or unloading facilities on French LPG sites.

The accidents listed are usually characterised :

- by a leak either from the road or rail tanker or from the fixed installation,
- by the ignition of the cloud, often outside the site,
- by the means of control, notably spray systems, frequently inoperative either through their design or as a result of damage when the accident sequence began.

From these facts it is clear that the objectives as regards measures of prevention, protection and control should be :

- to employ high quality and reliable systems,
- to minimise any accidental releases of product,
- to cool tanks to prevent their bursting in the event of ignition.

The measures described below are guided by these objectives.

For the fixed installation

Hoses

A few accidents have occurred on site during the transfer of liquefied gases. A good number of these involved hoses, a technique no longer employed on French LPG sites except for one or two where they are used for the gas phase. For both loading and unloading operations on LPG sites, articulated metal arms are the rule both for road and rail tankers.

Each transfer arm is usually fitted with two automatic isolating devices and the transfer zones are under continuous surveillance for gas leaks or heat sources. These aspects are described below.

It will be noted that hoses are still used for the operations of loading and unloading liquefied toxic gases such as ammonia, chlorine, and so on.

One-way valves

These are useful only when tanker trucks or wagons are being unloaded. In these circumstances the one-way valve can substantially limit the quantities of product discharged to the atmosphere from the fixed installations. This passive system has the advantage of a short response time but serves no purpose in the case of fire or increased temperature. To be effective, it should be fitted as close as possible to the base of the arm, just before or after the motorised valve at that point.

Breakaway coupler

The causes of accidents include the unexpected movement of the road or rail tanker during loading or unloading. Whatever the cause of the movement of the tanker whose product is being transferred, the presence of breakaway coupler ensures that the mechanically weak point of the system consisting of the road or rail tanker, its pipework, the articulated arm and the fixed installation, lies between two automatic isolating valves.

The breakaway coupler should have the following two characteristics :

- . It should create a weak point in the transfer arm that will fail under abnormal stress.
- . An automatically closing isolating valve is positioned at both sides of this weak point.

This arrangement can limit the amount of LPG discharged to the atmosphere, if the valve is open, to a few hundred grammes.

It will be noted that two accidents arising from malfunctions of such breakaway coupler are listed in this study. They occurred before the system has been modified.

Gas and fire detectors

Product transfer systems should be located in areas where there is continuous detection of :

- . gas
- . flame
- . heat

It is of course extremely difficult to determine the best detection positions particularly for flames and gas.

Gas detection

Gases are usually detected using sensors with two alarm concentration levels : 20% and 50% of the Lower Flammable Limit for the gases, and which generally lead to :

- . 20% LFL : audible and visible alarm,
- . 50% LFL : audible and visible alarm, with the site setup in safe condition by closing the motorised safety valves at the base of the arms and all motorised safety valves of all types on the site, *and possibly automatic spraying of the installations.*

Flame detection

This can involve flame detectors (of the infrared or other type). Detection of flames by a sensor should, besides raising an alarm, at least put the site in a safe condition and possibly initiate automatic spraying of the installations.

Detection of heat

Due consideration should be given to the potential ignition of a flammable gas cloud, as indicated by the accidents listed in this study. To limit the consequences of such an event each motorised valve at the base of the arm (and indeed all the motorised valves on the site) should be placed in a safe position automatically in the event of any rise in temperature in their immediate vicinity. If the valves are operated pneumatically, this objective can be achieved by introducing a compressed air supply pipe which, over the last few metres before the actuator, is made of a meltable material. Then any substantial rise in temperature (about 80°C) in the vicinity of the valve will melt its supply pipe and lead to the automatic closure of the motorised valve.

For mobile tankers

Railway tankers

Rail tankers have two nozzles at the bottom of the tank, one for the liquid phase and one for the gas phase (fitted with an extension tube opening into the gas phase). Each nozzle has :

- . a stop valve, inside the tanker, which can only be opened and kept open by pulling on the operating lever ; this is done by introducing a hook secured to the valve operating lever (or to the extension cable) and to the rail track, in order to maintain a continuous pull on the valve operating lever ;
- . a manual valve.

Removal of the hook, for any reason, leads to the automatic closure of the stop valve under the effect of the closure springs it contains.

Three types of hook may be encountered :

- . mechanical,
- . pneumatic,
- . electromagnetic.

The hooks, whether of mechanical or other design, are automatically released if the rail tanker should be accidentally moved, causing the automatic closure of the valves at the bottom of the rail tanker. However the motorised hooks (pneumatic or electromagnetic) have the advantage that they can be operated by gas or fire detectors and by pressing an emergency stop button, which means that the placing of the rail tankers being loaded or unloaded in a safe condition can be incorporated in the general process of placing the site in a safe condition.

Mechanical hooks on the other hand, if a leak should occur without wagon movement, can only be operated by a cable some 30 metres in length (usually) and on condition that the cable is not in the gas cloud.

Finally, we should mention an original technique which, instead of fixing up the hook on the rail, employs a pneumatic hook-retaining bar, a technique that has been systematically applied to sites. The system consists of a bar parallel to the rail and near to it, held in this position by being clamped axially by a pneumatic jack. The hook is then secured to this bar rather than to the rail.

Any detection of gas, flames or heat (by the meltable pipe supplying compressed air to the jack that retains the bar) or actuation of one of the emergency stop buttons on the site, releases the hook retaining bar, thus causing the automatic and instantaneous closure of the valve or valves at the bottom of the rail tanker or wagons.

Where the hooks are motorised or attached to a bar retained in position pneumatically, it is no longer necessary to use a chain or cable to remotely operate the hook.

Some of the advantages of motorised hooks are the following :

- . They have been proven on a number of sites.
- . These systems are integrated into the site safety scheme, since they operate automatically if gas or flame is detected or an emergency stop actuated.
- . They are fail safe devices, since in the event of an anomaly they take up a safe position.
- . These devices are easily tested.

Tanker trucks

Every nozzle (liquid or gas) on road tankers (small and large bulk carriers) is fitted with an internal safety valve usually operated hydraulically. These valves close automatically in case of fire thanks to the presence of a fuse plug. However the closure of these safety devices cannot be integrated into the automatic site safety scheme. This aspect deserves close attention.

Cooling systems on mobile tankers

Faulty operation or weaknesses of cooling systems in installation are often blamed when scenarios develop catastrophically (into a BLEVE). LPG loading and unloading units are not usually fitted with fixed spray systems. Only those sites where fixed tanks have been mounded are usually fitted with such systems, the embankment of fixed tanks (on existing sites) releasing substantial amounts of firefighting water. Both rail and road tankers are very frequently fitted with a sunscreen. Small tanker trucks (that fill up at LPG sites) are provided with a rear locker containing the different components to be protected. Rail tankers are fitted with skirts at the bottom where the tanker is secured to the chassis. The effectiveness of fixed spray systems could therefore be significantly and adversely affected by these arrangements. Accordingly spray systems should combine fixed installations (headers) and judiciously located fire hydrants so as to be able to spray all the road or rail tankers involved as well as local areas not cooled by the fixed installations.

In order to help the cooling of rail tankers, it is preferable not to place two trains side by side because in that case effective spraying of the arms (between the two trains) and the wagon nozzles is extremely difficult if not practically impossible.

The time taken to start up fixed systems (fixed headers) should be as short as possible. Automatic spraying, initiated by the gas or flame detection systems (at the very least) would probably ensure effectiveness.

LESSONS

Except in the two cases of accidents concerning failure of the breakaway coupler, one can note that the installations blamed in the accident reports were not usually fitted with the safety systems described above.

In concluding this chapter on the feedback of experience concerning LPG loading and unloading operations, it may be noted that in the absence of satisfactory safety arrangements on these installations, two main phenomena may occur :

- explosion or ignition of a gas cloud following the accidental release of LPG to the atmosphere .
- a BLEVE in a mobile tanker.

CONCLUSION

This study is intended to provide the French Ministry of Environment with a reference base regarding regulatory trends in a few neighbouring countries concerning the best industrial practice. It may also provide guidance for developing French regulations for LPG.

References

(1) - Belgium

“Arrêté royal concernant les dépôts, en réservoirs fixes non réfrigérés, de gaz propane et de gaz butane liquéfiés commerciaux ou leurs mélanges” - 21 October 1968

(2) - Italy

Approvazione della regola tecnica di prevenzione incendi per la progettazione, la costruzione, l'installazione e l'esercizio dei depositi di G.P.L. in serbatoi fissi di capacità complessiva superiore a 5 m³ e/o in recipienti mobili di capacità complessiva superiore a 5.000 kg”
Ministerial Decree of 13 October 1994 (Ministry of the Interior) -

(3) - France

- “ Arrêté du 9 novembre 1972, règles d'aménagement et d'exploitation des dépôts d'hydrocarbures liquéfiés” - - Ministère de l'industrie
- “Arrêté du 09 novembre 1989, relatif aux conditions d'éloignement auxquelles est subordonnée la délivrance de l'autorisation des nouveaux réservoirs de gaz combustibles liquéfiés” - Ministère de l'Aménagement du Territoire et de l'Environnement
- “Arrêté ministériel du 10 mai 1993 (Ministère de l'Aménagement du Territoire et de l'Environnement), relatif au stockage de gaz inflammables liquéfiés sous pression” - Ministère de l'Aménagement du Territoire et de l'Environnement

(4) - The Netherlands

“LPG distribution depots (Butane, propane, and their mixtures thereof)” Directive issued by the Committee on the Prevention of Disasters due to Hazardous Materials (CPR) – 1994

(5) - United Kingdom

- “The storage of LPG at fixed installations, brochure SHG 34 (1987)” - Health & Safety Executive – UK
- “Liquefied Petroleum Gas – part 9 (February 1987)” - British Institute of Petroleum – UK

(6) - ARIA

database of the French Ministry of Environment – Direction de la Prévention des Pollutions et des Risques – Service de l'Environnement Industriel – Bureau d'Analyse des Risques et Pollutions Industrielles