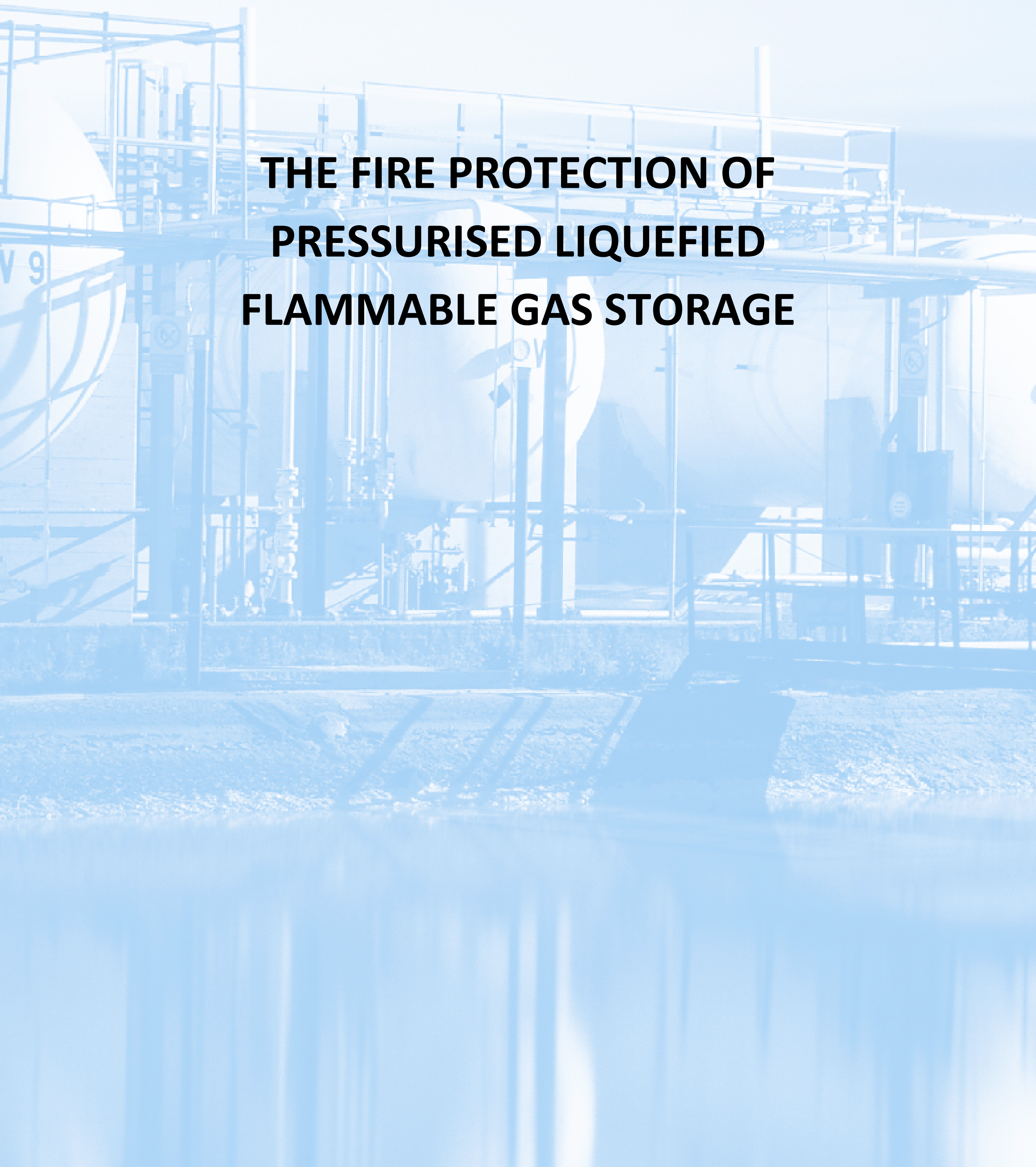
CONFIDENTIAL TO MEMBERS OF EPSC Report No 22

# THE FIRE PROTECTION OF PRESSURISED LIQUEFIED FLAMMABLE GAS STORAGE



# THE FIRE PROTECTION OF PRESSURISED LIQUEFIED FLAMMABLE GAS STORAGE

Report prepared by Hedley Jenkins for the EPSC Fire Protection of Flammable Gas Storage and the Prevention of BLEVEs Contact Group



Any enquires about this report, or other EPSC matters, should be addressed to Mr Lee Allford, Manager - EPSC Operations.

# The European Process Safety Centre

## Objectives

1. **Information**
   To provide advice on how to access safety information and whom to consult, what process safety databases exist and what information on current acceptable practices is available.

2. **Research and Development**
   To collect European research and development (R&D) needs and activities in the safety and loss prevention field, to inform members accordingly, to act as a catalyst in stimulating the required R&D and to provide independent advice to funding agencies priorities. “R&D” here includes experimental research and the development and review of models, techniques and software.

3. **Legislation and Regulations**
   To provide technical and scientific background information in connection with European safety legislation and regulations, e.g. to legislative bodies and competent authorities

4. **Education and Training**
   To provide a single source of information on training materials for:

   (a) the teaching of safety and loss prevention at undergraduate level; and
   (b) courses and materials for training and continuing education at all levels of the workforce

## Benefits of Membership

- Improved cross-European co-ordination on safety standards
- Identification of areas where manuals and guidelines could be produced
- Improved co-ordination of safety R&D and handling of complex technical research programmes
- Stimulation of R&D in areas where there are gaps in knowledge
- Transfer of knowledge from elsewhere to Europe and between European countries
- Technical input to legislators and standard makers to ensure more realistic legislation
- Sharing and dissemination of information on safety technology and accident prevention
- Access to information from a single source

# Contents

# The Fire Protection of Pressurised Liquefied Flammable Gas Storage

## The European Process Safety Centre


### Summary

Liquefied Flammable Gases, including LPG, are stored in large pressurised vessels throughout Europe and the rest of the world. Whilst the overall safety record of such installations is good the fire induced failure of a large vessel typically results in widespread damage and fatalities. Due to differences in experience of operators/designers and the development of a number of different national codes a range of different protection strategies has been developed.

This report reviews alternatives by reference to the results of a workshop of experts from EPSC Companies, held in April 2000, which considered a case study featuring a challenging LPG storage situation.

The EPSC study shows common elements amongst all those contributing to the study as well as areas of difference. The solutions included active (water spray and deluge) and passive (mounded and insulated) protection. (It should be noted that whilst two of the experts proposed mounded storage, none advocated buried storage.)

No single optimum arrangement can be identified since this must depend on the size of the storage and its location.

This report has been prepared to enable those designing and operating such installations to identify 'Good practice' design features.

# 1. Introduction

In 1998 EPSC conducted a brief survey of its members on practices for the fire protection of vessels containing more than 3 tonnes of pressurised LPG (commercial butane, propane and mixtures) (ref.1). The survey, to which 21 organisations responded, comprised a ten element questionnaire.

The responses showed a common recognition of the hazards but a wide diversity of approaches to the management of these hazards (see Appendix 1). To some extent this diversity reflects the multiplicity of published codes and regulations for LPG storage. These code, regulation and guideline differences, most of which relate to the principles of containment design, have already been thoroughly reviewed by JRC (ref.2). However the questionnaire responses also evidenced substantial differences in basic protection strategy, particularly in relation to BLEVE prevention. It was suggested that a meeting of practising designers and operators of pressurised LPG storage systems might help to rationalise thoughts on this issue.

Accordingly, in April 2000, EPSC convened a seminar the primary objective of which was to consider BLEVE protection strategy. This seminar utilised a case study as a basis for discussion. Seven of Europe's largest and most widely respected operators and designers of bulk LPG storage facilities participated. This report summarises the conclusions of this meeting referencing the case study "features listings" completed by each of the participating organisations.

The elimination of the BLEVE hazards associated with the pressurised storage of LPG's is technically possible. However the techniques employed can introduce other technical problems and hazards. Any protection strategy must therefore be tailored to the circumstances of the installation concerned.

The requirements of in-house LPG storage specific codes of practice traditionally reflected these concerns. However many organisations now handling LPGs do not possess such codes. There are industry and national codes of practice relating to LPG storage but the extent to which they acknowledge BLEVE risks is generally uncertain. This report is intended to assist those reviewing existing installations or developing proposals for new installations to consider BLEVE protection.

The report relates directly to the EPSC seminar case study. The case study is for two LPG storage installations typical of those encountered in practice. Participants were asked to assume that there were no local regulatory requirements. They completed a questionnaire accordingly and discussed their proposed mitigation strategies during the seminar. The report records the responses to the questionnaire and summarises the outcome of the seminar discussions on a topic by topic basis.

Whilst this report and the seminar focussed on the storage of flammable hydrocarbon "LPG's" many of the conclusions apply to the storage of other liquefied flammable gases stored under pressure, see section 14.

*Note – This report does not consider the 'Cavern' and 'Fully Refrigerated' storage of LPGs. No direct reference is made to the 'Semi-refrigerated' storage of lower boiling point LPGs but much of the content of the report applies equally to this storage option.*

## 2. Pressurised LPG Storage Fire Concerns

The pressure in a pressurised LPG storage installation is just sufficient to maintain the bulk of its contents in the liquid phase at ambient temperature, i.e. its operating pressure is the vapour pressure of the material concerned at ambient temperature.

The temperature of the contained liquid will rise if the shell of the vessel below the liquid surface is exposed to fire and the pressure in the vessel will increase accordingly. Pressurised LPG storage installations are generally fitted with relief valves rated for this condition. When the pressure increases sufficiently to cause the relief valve to lift the pressure in the vessel will stabilise and the temperature of the liquid contents will hold constant at a value that can be tolerated by the vessel shell.

If the surface of the vessel above the liquid is exposed to fire the area of the shell concerned has no equivalent opportunity for latent heat cooling. Its temperature will therefore increase and it will weaken until it eventually fails. If the released gas is flammable it will ignite and this will very quickly precipitate overall failure of the vessel. The resulting potentially very destructive fireball is termed a BLEVE (Boiling Liquid Expanding Vapour Explosion).

The initial fire may either be a pool fire or a jet fire. The jet fire may derive from an adjacent facility or the LPG installation itself.

Apart from physical separation there are two conventional approaches to BLEVE prevention:

- The application of 'passive' protection systems, 'mounding' or 'burying'
- Water cooling of the vessel shell

The first approach is classed as 'inherently safer' but monitoring of the condition of the installation to ensure its ongoing integrity is problematical. A failure of containment could result in a massive release of LPG at low level and result in a fireball or vapour cloud explosion. Water cooling is satisfactory only if it is initiated quickly and its coverage is comprehensive.

## 3. April 2000 LPG Storage Seminar Case Study

The case study relates to the preliminary design for a new free-standing manufacturing plant on a greenfield site. The plant has two pressurised LPG storage installations:

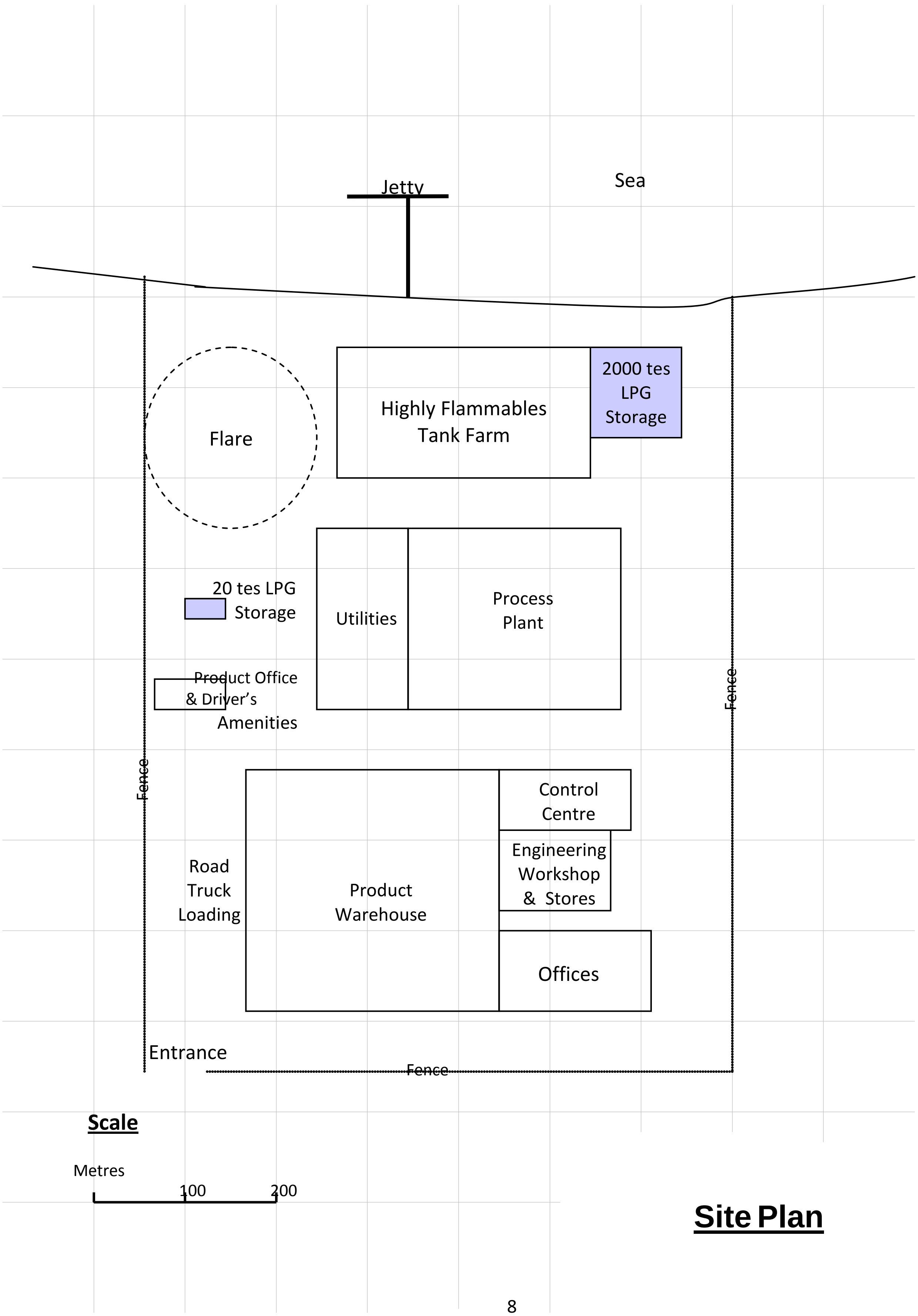
- One of 2,000 tonnes capacity from which material in the liquid phase is transferred to the process unit as a feedstock. The material is a highly flammable but non-toxic material (v.p. 1 to 2 barg at 20OC). It is delivered by sea over the jetty in 1,500 tes parcels
- The second of 20 tonnes capacity from which material in the vapour phase passes into a 'secure' fuel gas system serving the boiler and flare pilots. This material is conventional propane/butane fuel LPG (v.p. 2.5 to 9 barg at $20^{O}$C). It is delivered in 10 tes capacity road tankers to a hose connection adjacent to the storage facility

This arrangement is typical for a single plant site where a feedstock is an LPG and where there is no refinery or chemical complex in the vicinity which might act as a source of fuel gas. At 2000 tonnes capacity there is a major cost incentive to opt for a single sphere rather than multiple horizontal drums to store the feedstock. 20 tes capacity is larger than readily available 'standard' LPG fuel storage units.

The plant site is on a flat coastal plane in a non-OECD country. The climate is temperate continental. A preliminary Site Plan and an outline Local Area Plan are provided (pages 6 & 7).

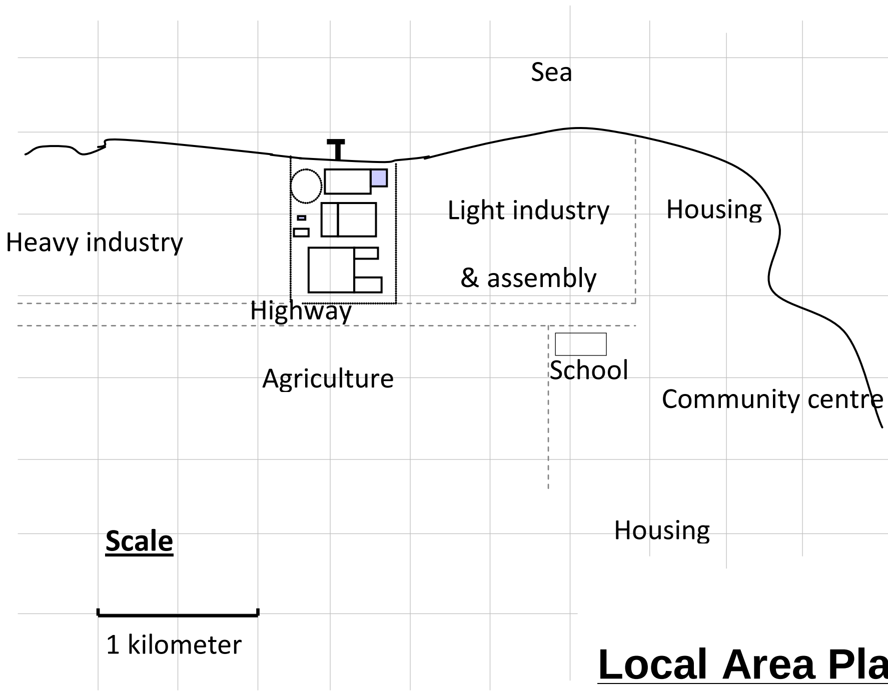
There are no local regulations specifically relating to the design of pressurised LPG storage installations.

Each participant considered a questionnaire in advance of the seminar and summarised their selected fire mitigation strategy in a presentation to the remainder of the participants at the outset of the seminar. The seminar concluded with an open discussion on those topics for which the presentations evidenced a diversity of approach. The following sections comprise a summary review of the various topic areas and a tabulated summary of the associated questionnaire responses. The reproduced comments extracted from the completed questionnaires have not been edited.



Sea
Jetty
Flare
Highly Flammables Tank Farm
2000 tes LPG Storage
20 tes LPG Storage
Utilities
Process Plant
Product Office & Driver's Amenities
Fence
Control Centre
Engineering Workshop & Stores
Road Truck Loading
Product Warehouse
Offices
Entrance
Fence
Fence
Scale
Metres
100
200


## Site Plan




## Local Area Plan

# 4. Vessel Selection

The owner of a facility will generally require the vessel to be specified and designed to minimise costs consistent with the satisfaction of corporate safety standards or risk criteria. The selection of pressurised rather than refrigerated LPG receipt and storage typifies this policy approach.

**Vessel Selection - 2,000 tes unit**

A single carbon steel single walled vessel is likely to be the lowest cost option. However the mounding or burying of a single sphere of this capacity is impracticable. The use of multiple vessels provides operational and maintenance flexibility and potentially allows inventory segregation in an emergency.

**Vessel Selection - 20 tes unit**

A single carbon steel single walled horizontal cylindrical vessel is the lowest cost option regardless of the setting of the vessel.

**Vessel Type - 2,000 tes unit**

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Single horizontal drum (single wall) | | | | | | | | |
| • Multiple horizontal drums (single wall) | | ☑ | ☑ | ☑ | | | | (2) 5 x 250$m^3$ BUT single sphere is an acceptable alternative<br>(3) 3 x 670 tes.<br>(4) 2 x 1000 tes. Single wall only applicable for materials when are not harmful to ground water |
| • Sphere | ☑ | ☑ | | | ☑ | ☑ | ☑ | (5) 2 x 1000 tes. Typical to provide operational flexibility |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(4) No company guideline but recommended practice for new projects. We avoid publishing company guidelines which do not correspond with older, existing plants which cannot be modified. There is always a safety review specific to the installation concerned. Good experience with existing plants.

(5) Operational & economic considerations.

**Vessel Type – 20 tes unit**

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Single horizontal drum (single wall) | ☑ | ☑ | ☑ | ☑ | ☑ | | ☑ | |
| • Multiple horizontal drums (single wall) | | | | | | ☑ | | (1) 26 tes standard vessel.<br>(4) Single wall only applicable for materials which are not harmful to ground water |
| • Sphere | | | | | | | | (5) 2 x 1000 tes. Typical to provide operational flexibility |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(4) No company guideline but recommended practice for new projects. We avoid publishing company guidelines which do not correspond with older, existing plants which cannot be modified. There is always a safety review specific to the installation concerned. Good experience with existing plants.

(5) Operational & economic considerations.

## 5. Primary Fire Protection Principles

**Mounding** constitutes inherent fire protection. However the hidden elements of the facility can rapidly fail in the event of a shortcoming in the corrosion prevention system (generally coating and cathodic protection). Accordingly great care must be taken in the initial mounding and any subsequent remounding to avoid damaging the corrosion protection outer linings because ongoing confirmation of LPG containment integrity is inherently problematical. Periodic internal inspection of the vessel is a generally accepted requirement but provides little information on the condition of the external surfaces. Adequate supporting of all equipment within the mound is essential because settlement can also cause a loss of containment. Periodic or continuous sampling of the atmosphere within the mound is sometimes employed to detect leaks but the design of a comprehensive sampling system is problematical and the monitoring results are typically difficult to interpret. Therefore the periodic exposure and visual inspection of the outside of the shell is generally required. The headworks of a mounded installation are of course as vulnerable as the equivalent features of any other arrangement.

**Burying** is an option if the soil conditions are suitable and the site is well above the water table. However the additional problems associated with ongoing containment integrity verification are generally considered to require that the buried vessel is double walled. (It should be noted that none of the organisations contributing to the EPSC study advocated buried storage.)

Open aspect above ground vessels and their associated equipment may have either active or passive primary fire protection.

**Passive protection** can take the form of a fire resistant insulant or an intumescent. In either case there is generally some doubt about its ability to withstand jet fire impingement. Furthermore most passive systems deteriorate with time and their effectiveness diminishes accordingly. It can also create ideal sites for corrosion of the hidden underlying containment surface. Nevertheless passive systems are generally low cost and, unlike active systems, require no action to render them effective in the event of a fire.

**Semi mounding** is a compromise arrangement whereby the bulk of the containment is inherently protected and the relatively vulnerable active end of the vessel and associated facilities are provided with above ground active or passive protection.

**Active protection** requires the application of water to cool and prevent the weakening of containment. The external surfaces of an installation with active protection are visible so any external corrosion is readily seen. However the active system must be initiated quickly and it must cool all those surfaces directly affected by the fire if it is to be effective. This is particularly difficult on the underside of vessels exposed to a local pool fire. Furthermore an active system will prevent jet fire failure only if it provides for a very high rate of water application to the flame impingement area. This is rarely feasible.

**Primary Fire Protection Principles - 2,000 tes unit**

A buried 2,000 tes LPG storage facility comprising a series of double walled buried vessels, even if it were a practical possibility on a low lying coastal plain, would generally be regarded as being prohibitively expensive.

It is doubtful if a single vessel of 2000 tes capacity could be mounded or semi-mounded. A multi-vessel mounded or semi-mounded facility is likely to be more costly than the single above ground vessel alternative.

For an installation in a remote location it will be necessary to ensure that the site has access to the necessary technical expertise and resources for safe operation.

- In the case of passive protection this will be the specialist resources necessary to monitor the integrity of the storage
- In the case of active protection this will be the availability, within a short period of time, of a well-equipped and trained fire brigade

**Primary Fire Protection Principles - 20 tes unit**

The hazard potential of the 20 tes facility is substantially less than that of the 2,000 tes facility but safety considerations are broadly similar.  A site fire brigade would typically have the capability and competence to back-up the primary fire protection system on a unit of this size.  Therefore there is little incentive to consider options other than above ground active protection in this instance.

## Primary fire protection principles - 2,000 tes unit

| | Selection | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Underground (buried)<br><br>Vessel shell condition verification:<br>– Periodic dig out and visual inspection<br>– Periodic vessel entry and NDT | | | | | | | | (2) Not recommended. No underground storage of LPG type of materials |
| • Mounded | | | ☑ | ☑ | | | | (2) Not recommended but several in acquisition and joint ventures which are Periodic dig out & visual inspection and Periodic vessel entry and NDT. As by local or governmental authority defined. |
| Vessel shell condition verification: | | | | | | | | |
| – Periodic dig out & visual inspection | | | ☑ | ☑ | | | | |
| – Periodic vessel entry and NDT | | | | | | | | |
| – Other | | | ☑ | | | | | (3) Coating of external vessel shell with appropriate bituminous materials and cathodic protection to avoid corrosion. |
| • Semi-mounded (single 'open end')<br>'Covered' shell condition verification:<br>– Periodic dig out & visual inspection<br>– Periodic vessel entry and NDT<br>– Other<br>'Open end' primary fire protection:<br>– Active<br>– Passive<br>Vessel shell condition verification:<br>– Periodic strip & visual inspection | | | | | | | | (2) Not recommended but Several in acquisition and joint ventures which are Periodic dig out & visual inspection and Periodic vessel entry and NDT (covered shell) . As by local or governmental authority defined and Deluge or monitor gun for open end. |

## Primary fire protection principles - 2,000 tes unit - continued

| | Selection | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Above ground (open) | ☑ | ☑ | | | ☑ | ☑ | ☑ | |
| Primary fire protection: | | | | | | | | |
| – Active | ☑ | ☑ | | | ☑ | ☑ | ☑ | |
| – Passive | | | | | | | | |
| Vessel shell condition verification: | | | | | | | | |
| – Periodic strip & visual inspection | ☑ | | | | | | ☑ | (1) Periodic inspections due to TRB 801 No. 25, external 2 years internal 10 years. |
| – Other | | | | | | | | |
| • Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(1) & (2) Company standard practice or guideline

(3) Italian Ministerial Decree: “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 5000 m3., Dated 13 October 1994

(5) Results from QRA

(6) Based on API 2510 plus extra additions

## Primary fire protection principles - 20 tes unit

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Underground (buried)<br><br>Vessel shell condition verification:<br>– Periodic dig out and visual inspection<br>– Periodic vessel entry and NDT | | | | | | | | (2) Not recommended. No underground storage of LPG type of materials |
| • Mounded<br>Vessel shell condition verification: | | | | ☑ | | | | |
| – Periodic dig out & visual inspection | | | | ☑ | | | | (4) For smaller vessels dig out is acceptable |
| – Periodic vessel entry and NDT<br>– Other | | | | | | | | |
| • Semi-mounded (single 'open end')<br>'Covered' shell condition verification: | | | | | | | | (4) Acceptable alternative to fully mounded. |
| – Periodic dig out & visual inspection<br>– Periodic vessel entry and NDT<br>– Other | | | | | | | | (4) For smaller vessels dig out is acceptable |
| 'Open end' primary fire protection:<br>– Active<br>– Passive | | | | | | | | (4) Removable, with metallic cladding |
| Vessel shell condition verification:<br>– Periodic strip & visual inspection | | | | | | | | (4) If semi-mounded option utilised |
| • Above ground (open) | ☑ | | ☑ | | ☑ | ☑ | ☑ | (3) Mounded vessel is preferred also for this duty, however above ground has been chosen for comparative purpose |
| Primary fire protection:<br>– Active | ☑ | | | | ☑ | ☑ | ☑ | |
| – Passive | | | ☑ | | | | | (4) Bigger mounded vessels should have no nozzles at the bottom, but they need an additional smaller (1-2 m3) vessel above ground as suction pond for the booster pump. This small vessel needs also |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Vessel shell condition verification:<br>– Periodic strip & visual inspection<br>– Other | ☑ | | | | | | ☑ | some fire protection. Normally it should get a fire proof insulation. It depends on the local arrangement whether a shower for both, that means for the pumps and for the suction vessels may be practicable.<br>(5) Passive protection provided on legs/saddle<br><br>(1) Periodic inspections due to TRB 801 No. 25, external 2 years internal 10 years<br>(3) Radiography |
| • Other | | | ☑ | | | | | |

Basis of selection (numeral indicates participant concerned)

(1) & (2) Company standard practice or guideline
(3) Italian Ministerial Decree: “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 5000 m3., Dated 13 October 1994
(5) Results from QRA
(6) Based on API 2510 plus extra additions

# 6. Location

Separation distances must be sufficient to ensure that the risk of an incident on an adjacent facility initiating an incident on the LPG storage facility and that the risk of an incident on the LPG storage facility threatening its neighbours are both tolerable.

Unless it is buried or fully mounded any LPG storage installation has the potential to BLEVE. It is not feasible to consider separation as a means of protecting adjacent units from the consequences of a BLEVE. Precautions must be taken to reduce the risk of BLEVEs to a level which is tolerable acknowledging that a BLEVE would result in major damage to adjacent facilities and fatalities if anyone was in the vicinity.

The provision of comprehensive reliable fire detection facilities coupled with well rehearsed procedures can provide for the safe evacuation of all site personnel who might otherwise be affected by a BLEVE. However the rapid evacuation of persons beyond the boundary fence is generally impossible. A combination of separation and enhanced building construction can ensure the wellbeing of those who are required to remain in a control centre.

Jet fire (or 'torch flame') impingement on the LPG storage vessel is the greatest concern because few active or passive primary protection systems are effective in these circumstances. The length of a jet fire flame is a function of the source pressure and the size of the leak orifice. The sudden failure of an all-welded pipeline or the holing of a coded vessel is very unlikely but the guillotine fracture of a vessel connection is generally regarded as possible. Accordingly an above ground LPG storage facility, whether it has active or passive primary protection (see section 5), should generally be located beyond the range of any jet fire associated with a sheered connection on an adjacent unit.

An above ground LPG storage facility is equally vulnerable to a jet fire emanating from a failure of its own associated systems. Therefore these systems must be located, orientated and protected in a manner which will ensure that the risk of them being the source of a jet fire is tolerable. The magnitude of the maximum credible initial leak is generally assumed to be a function of pipe size. Accordingly an LPG storage system's separation distances are typically dependent on the size of its outlet line.

A pool fire is a concern if the radiation intensity on any element of the LPG storage installation which may not be liquid filled could cause weakening of the containment. The radiation intensity of a pool fire is a function of its surface area. Therefore the extent of any adjacent drainage areas and storage bunds which might be subject to the spillage of flammable materials must be determined. The ground area directly associated with an above ground LPG storage unit is generally drained to a 'burn-off pit' where an LPG spill, if it ignites, will not threaten the storage unit itself or adjacent facilities (see section 11).

Vehicles constitute a source of ignition, so roads and vehicle loading/unloading points must be located at a sufficient distance from possible LPG leak points to prevent the ignition of leaks. The admission of other sources to the vicinity of an LPG storage unit will typically be prohibited by procedure but such control is rarely possible beyond the site boundary fence.

**Location – 2,000 tes unit**

Details of the bunding arrangements in the adjacent highly flammables tank farm are not provided so it is impossible to establish if its separation is adequate.

The LPG storage plot is only some 60 metres from the boundary fence beyond which there are likely to be high concentrations of people involved in the designated 'light industry & assembly operations' operations. Risk assessment will probably suggest that 60 metres separation is insufficient for a 2,000 tes above ground LPG storage unit.

**Location – 20 tes unit**

The only nearby vulnerable feature is the 'product office & drivers amenities'. The 60 metres separation is probably adequate if an appropriate evacuation procedure is established or measures are taken to ensure that the adjacent buildings can withstand the incident thermal radiation.

The location of the road truck unloading point is not specified but an adequate separation distance between this facility and the storage unit is clearly essential.

**Location (See proposed site plan & local area plan) 2,000 tes unit** (Assuming that the Primary Fire
Protection Principles applied are as previously advised – see page 13)

Separation distance between the storage vessel(s) and: (insert 'ok' if the case study plan depicted separation distances are satisfactory)

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| - Flammables storage | | | | Ok | | Ok | Ok | (1) 30 metres min.<br>(2) Separated from flammables storage.<br>(3) 40 – 60 metres<br>(4) Mandatory distances have to be covered, see guidelines.<br>(5) Use consequence model to establish sufficient separation to prevent escalation from incident in the flammables tank farm<br>(6) Separation road in between required<br>(7) To be confirmed with simulation of scenarios |
| - Other LPG stogage | | | | Ok | Ok | Ok | ok | (1) 30 metres min.<br>(2) Minimum ¼ of the sum of the diameter of the tanks.<br>(3) 3 times vessel diameter. 25 metres min<br>(4) Mandatory distances have to be covered, see guidelines |
| - Flare | | | Ok | Ok | Ok | Ok | Ok | (1) 50 metres.<br>(2) Depends on the capacity of the flare and the heat capacity at maximum<br>(4) Mandatory distances have to be covered, see guidelines (and API 521) |
| - Process plant | | | Ok | Ok | | Ok | Ok | (1) 50 metres.<br>(2) 46 – 76 metres.<br>(4) Mandatory distances have to be covered, see guidelines<br>(5) Depends on process plant. Need to consider potential interactions eg explosion damage, presence of fired heaters, etc |
| - Control centre | | | Ok | Ok | Ok | Ok | ok | (1) 20 metres.<br>(3) 61 metres. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (4) Mandatory distances have to be covered , see guidelines.<br>(7) To be strengthened according to simulation of scenarios. |
| - Offices | | | Ok | | Ok | Ok | Ok | (1) 50 metres<br>(3) 91 metres<br>(4) Location of offices (“for the unessential people”) should have a distance of more than 200m to any major LPG processing equipment. |
| - Product office and driver’s amenities | | | Ok | | Ok | Ok | Ok | (1) 50 metres.<br>(2) 61 - 91 metres.<br>(4) Recommended distance to filling stations, where hoses may be opened ca. 50 m. No hot work nearby, details have to be discussed with respect to frequency of filling procedures.<br>(6) Provided the office is equipped with an automatic evacuation alarm. |
| - Site fence | | | Ok | | | | Ok | (1) 50 metres.<br>(2) Not defined.<br>(4) This depends mainly on local regulations and on the type of plants at the other side of the fence.<br>(5) Depends on what is on the other side of the fence.<br>(6) Too close. 90 metres min..<br>(7) To be confirmed with simulation of scenarios. |

Basis of selection (*numeral indicates participant concerned*)

TRB 801 No. 25, appendix - Safety distances are depending on maximum pipe diameter and type of storage (group A – D )

(2) Governmental defined. CPR-9.

(3) ILA.AF.REV.009, “Safety Review for Plant Layout”, Rev .0, August 1996.

(4) No company guideline but recommended practice for new projects. We avoid publishing company guidelines which do not correspond with older, existing plants which cannot be modified. There is always a safety review specific to the installation concerned. Good experience with existing plants.

(5) Operational & economic considerations.

(6) Consequence and risk assessments.

**Location (See proposed site plan & local area plan) 20 tes unit** (Assuming that the Primary Fire Protection Principles applied are as previously advised – see page 13)

Separation distance between the storage vessel(s) and: (insert 'ok' if the case study plan depicted separation distances are satisfactory)

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| - Flammables storage | | | Ok | Ok | | | Ok | (1) 30 metres min<br>(3) 25 metres min<br>(4) Mandatory distances have to be covered, see guidelines<br>(7) To be confirmed with simulation of scenarios |
| - Other LPG stogage | | | | Ok | Ok | | ok | (1) 30 metres min..<br>(3) It depends on the capacity of the other LPG storage. However 15 metres min.<br>(4) Mandatory distances have to be covered, see guidelines. |
| - Flare | | | Ok | Ok | Ok | | Ok | (1) 30 metres.<br>(5) Use consequence model to establish that credible leak (e.g. flange leak) could not be ignited by flare, particularly if ground flare.<br>(4) Mandatory distances have to be covered, see guidelines (and API 521). |
| - Process plant | | | Ok | Ok | | | Ok | (1) 30 metres.<br>(4) Mandatory distances have to be covered, see guidelines.<br>(5) Depends on process plant. Need to consider potential interactions, e.g. explosion damage, presence of fired heaters etc. |
| - Control centre | | | Ok | Ok | Ok | | ok | (1) 20 metres<br>(4) Mandatory distances have to be covered , see guidelines.<br>(7) To be strengthened according to simulation of scenarios. |
| - Offices | | | Ok | Ok | Ok | | Ok | (1) 30 metres |
| - Product office& driver's amenities | | | Ok | Ok | | | Ok | (1) 30 metres.<br>(4) Recommended distance to filling stations, where hoses may be opened ca. 50 m. No hot work nearby, details have to be discussed with respect to frequency of filling procedures. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (5) Use consequence model to establish whether the flammable cloud from a credible release would be able to enter the building |
| - Site fence | | | Ok | | | | ok | (1) 30 metres.<br>(4) This depends mainly on local regulations and on the type of plants at the other side of the fence.<br>(5) Depends on what is on the other side of the fence.<br>(7) To be confirmed with simulation of scenarios. |

Basis of selection (*numeral indicates participant concerned*)

(1) TRB801 No. 25, appendix - Safety distances are depending on maximum pipe diameter and type of storage (group A –D)

(3) ILA.AF.REV.009, "Safety Review for Plant Layout", Rev .0, August 1996.

(4) No company guideline but recommended practice for new projects. We avoid publishing company guidelines which do not correspond with older, existing plants which cannot be modified. There is always a safety review specific to the installation concerned. Good experience with existing plants.

(5) Operational & economic considerations.

# 7. Primary Fire/BLEVE Protection

Some means of preventing weakening on exposure to fire must be applied to all exposed gas phase LPG containment surfaces and any steelwork supports. It may be active, in which case sufficient water to remove all the heat must be applied very quickly to the surface concerned, or it may be a passive fire resistant insulant. The extent of the surfaces requiring protection is of course much reduced if the installation is buried or mounded.

In principle the primary protection system is effective from the outset of an incident. Its effectiveness typically diminishes but the secondary protection system is established, or the fire is extinguished, before the primary protection system ceases to provide adequate protection.

Passive protection systems generally take the form of either a cementitious or intumescent coating. Both suffer from long term deterioration. Water penetration of a cementitious coating severely diminishes its insulation properties. The ability of intumescent coatings to intumescent deteriorates with age. Physical damage to either can lead to invisible and rapid corrosion of the underlying LPG container. The stripping and replacement of passive protection is a difficult, time-consuming and expensive task.

Active systems and their water supply arrangements, whatever their form, must be sufficiently robust to ensure that prior damage and initial fire and explosion damage does not compromise their effectiveness.

Two types of active protection are in general use – deluge and spray. Deluge systems are simple and reliable but their ability to provide even and effective coverage, particularly on the underside of vessels is questionable. The design of an effective distributor is typically compromised by the multiplicity of connections at the head of the storage vessel. Spray systems provide better coverage but they must be sufficiently robust to ensure that they are not damaged by the initial release. Furthermore their nozzles are prone to blockage and they require frequent testing and, if necessary, nozzle replacement.

The early and reliable detection of the fire is essential if an active protection system is to be effective. Water application may be initiated automatically by fusible plugs, fire detection systems, flammable gas detection systems or by a manual switch in the control centre. It is necessary to select the optimum combination of these systems to suit the form, scale and circumstances of the installation concerned. It should acknowledged that any combination of these systems is fallible (see section 13).

The continuity of the fire water supply must be maintained until the fire is extinguished. In most situations it is assumed that a competent fire brigade will establish a back-up supply within two hours so the inventory of designated site firewater reserve is fixed at two hours design application rate. In situations where there might be a problem the inventory is typically increased to four hours.

The collapse of LPG vessel supports would inevitably precipitate a major incident. The active protection of supports, particularly on large spheres, is problematical. For this reason the supports are generally either concrete clad or are provided with a cementitious coating.

**Primary protection – 2,000 tes unit**

Until recently most pressurised LPG installations of this size comprised one or more spheres with deluge or spray active primary protection. Legislation in a number of countries now demands the burial or mounding of LPG storage installations. For both of these options the confirmation of ongoing mechanical integrity presents additional technical problems and creates additional hazards (there was no consensus amongst the participants in this study on the relative merits of open aspect or mounded storage but none of the participants advocated buried storage).

**Primary protection – 20 tes unit**

Units of this size are typically horizontal drums with spray active primary protection.

**Primary fire/BLEVE protection 2,000 tes unit** – Completed only if an ‘above ground’ or ‘semi-mounded’ option is selected above

If ‘Active’ is selected above:

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Active (water) – system type | | | | | | | | |
| - Sprinkler | | | | | | | | |
| - Top deluge | ☑ | ☑ | | | | | | (2) Top & bottom |
| - Sprays / spray rings | | | | ☑ | ☑ | ☑ | ☑ | (4) Sprays for pump station |
| - Fixed monitor(s) | | | | | | | | (4) Fixed monitors for pump stations with big pipes connecting numerous tanks |
| - Mobile monitors (locally stored & activated) | | | | | | | | |
| - Mobile monitors (site fire brigade) | | ☑ | | | | | | 4) Normally this is not a question of the storage alone, but of the total site. |
| - Mobile monitors (public service or mutual help fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (locally stored & activated) | | ☑ | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (site fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (public service or mutual help fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Other | | | | | | | | |
| • Active (water) – application rate | | | | | | | | |
| - 100 $l/m^2$/hour or similar | | | | | | | | |
| - 10 $l/m^2$/min or similar | ☑ | ☑ | | | ☑ | ☑ | ☑ | (1) 600 $l/m^2$/h.<br>(2) 10 – 20 $l/m^2$/min. |
| - Other | | | | | | | | |
| • Active (water) – reserve (select one for each duty) | | | | | | | | |
| - 2 hours | ☑ | | | | ☑ | | | (5) More may be necessary if fire of more than 2 hours duration credible in flammables tank farm. |
| - 4 hours | | ☑ | | ☑ | | ☑ | ☑ | (4) After 4 hours eventually switch over to sea water, depending on the location |
| - Other | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| • System initiation | | | | | | | | |
| - Heat sensor | | ☑ | | | | | | |
| - Flame sensor | ☑ | | | | | | | |
| - Fusible plug | | ☑ | | | | ☑ | ☑ | |
| - Switch in control centre | ☑ | ☑ | | ☑ | ☑ | ☑ | | (4) Different types of detectors are used |
| - Switch local to storage facility | ☑ | ☑ | | | ☑ | ☑ | | |
| - Valve(s) local to storage facility | | | | | | | | |
| - Other | | ☑ | | | | | | (2) By gas detection |

**Primary fire/BLEVE protection 2,000 tes unit**

If 'Passive' is selected above:

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Passive – insulant | | | | ☑ | | | | (4) Even if the main vessel is mounded and therefore protected against fire, the other equipment, which belongs to the storage vessel, has to be kept cool during a fire. Details have to be discussed in a safety review for bigger pipes near the storage, not for pipes on pipe racks. |
| - Intumescent coating | | ☑ | | | | | ☑ | (2) For main bearing construction. |
| - Sprayed foam | | | | | | | | |
| - Block foam | | | | | | | | |
| - Other | | | | | | | | |
| • Passive – covering on insulant | | | | | | | | |
| - SS sheeting | | | | | | | | |
| - Resin coating | | | | | | | | |
| - Other | | | | | | | | |
| • Passive Passive – vapour barrier | | | | | | | | |
| - None | | | | | | | | |
| - Mastic coating | | | | | | | | |
| - Resin coating | | | | | | | | |
| - Polymer coating | | | | | | | | |
| - Other | | | | | | | | |
| • Passive – extent of application) | | | | | | | | |
| - All exposed surface of vessel | | | | | | | | |
| - Underside of vessel only | | | | | | | | |
| - Piping and valves | | | | | | | | |
| - Firewall (state location) | | | | | | | | |
| - Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(1) & (2) Company standard practice or guideline

(2) TRB 801 No. 25 Ba

(5) NFPA Guides & risk assessment

**Primary fire/BLEVE protection 20 tes unit** – Completed only if an 'above ground' or 'semi-mounded' option is selected above

If 'Active' is selected above:

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Active (water) – system type | | | | | | | | |
| - Sprinkler | | | | | | ☑ | | |
| - Top deluge | ☑ | | | | | | | (2) Top & bottom |
| - Sprays / spray rings | | | | ☑ | ☑ | | ☑ | (4) Sprays for pump station |
| - Fixed monitor(s) | | | | | | | | |
| - Mobile monitors (locally stored & activated) | | | | | | | | |
| - Mobile monitors (site fire brigade) | | | | | | | | 4) Normally this is not a question of the storage alone, but of the total site. |
| - Mobile monitors (public service or mutual help fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (locally stored & activated) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (site fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Hose on hydrant (public service or mutual help fire brigade) | | | | | | | | (4) Normally this is not a question of the storage alone, but of the total site. |
| - Other | | | | | | | | |
| • Active (water) – application rate | | | | | | | | |
| - 100 $l/m^2$/hour or similar | | | | | | | | |
| - 10 $l/m^2$/min or similar | ☑ | | | | ☑ | ☑ | ☑ | (3) 600 $l/m^2/h$ |
| - Other | | | | | | | | |
| • Active (water) – reserve (select one for each duty) | | | | | | | | |
| - 2 hours | ☑ | | | | ☑ | | | |
| - 4 hours | | | | | | | | (4) After 4 hours eventually switch over to sea water, depending on the location |
| | | | | ☑ | | | ☑ | |
| - Other | | | | | | | | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|
| • System initiation | | | | | | | | |
| - Heat sensor | | | | | | | | |
| - Flame sensor | ☑ | | | | | | | |
| - Fusible plug | | | | | | ☑ | ☑ | |
| - Switch in control centre | ☑ | | | ☑ | ☑ | ☑ | | (4) Different types of detectors are used |
| - Switch local to storage facility | ☑ | | | | ☑ | ☑ | | |
| - Valve(s) local to storage facility | | | | | | | | |
| - Other | | ☑ | | | | | | (1) Pressure sensor |

**Primary fire/BLEVE protection 20 tes unit**

If 'Passive' is selected above:

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Passive – insulant | | | ☑ | ☑ | | | | (4) Even if the main vessel is mounded and therefore protected against fire, the other equipment, which belongs to the storage vessel, has to be kept cool during a fire. Details have to be discussed in a safety review for bigger pipes near the storage, not for pipes on pipe racks. |
| - Intumescent coating | | | | | | | ☑ | |
| - Sprayed foam | | | | | | | | |
| - Block foam | | | ☑ | | | | | (3) Cementitious Type (as alternative) |
| - Other | | | | | | | | |
| • Passive – covering on insulant | | | | | | | | |
| - SS sheeting | | | ☑ | | | | | |
| - Resin coating | | | | | | | | |
| - Other | | | | | | | | |
| • Passive Passive – vapour barrier | | | | | | | | |
| - None | | | ☑ | | | | | |
| - Mastic coating | | | | | | | | |
| - Resin coating | | | | | | | | |
| - Polymer coating | | | | | | | | |
| - Other | | | | | | | | |
| • Passive – extent of application) | | | | | | | | |
| - All exposed surface of vessel | | | ☑ | | | | | |
| - Underside of vessel only | | | | | | | | |
| - Piping and valves | | | | | | | | |
| - Firewall (state location) | | | | | | | | |
| - Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(1) & (3) Company standard practice or guideline.
(5) NFPA Guides & risk assessment.

# 8. Secondary Fire/BLEVE Protection

Primary protection systems, whether active or passive, are generally only capable of providing adequate protection to those areas subject to direct flame impingement for a very limited period typically twenty minutes. Moreover, for active systems, the water initially applied to the full area of containment is far more effective if redeployed to the area of containment and the associated features directly affected by the fire as quickly as possible.

Secondary systems typically involve fire brigade intervention. The brigade commander is required to assess the situation and, unless the fire can be quickly extinguished, provide for the long term application of cooling water to those elements of the LPG storage system necessary to sustain its integrity. This adjustment must be achieved quickly in a very stressful situation without diminishing the effectiveness of the primary system during the period when the new arrangements are being established. The brigade must be equipped and trained accordingly.

The risks to those setting up secondary protection during a fire on an LPG storage installation are very great unless they take suitable precautions. It is essential that the fire brigade concerned is properly equipped and has received situation specific specialist training.

**Secondary protection – 2,000 tes unit**

The fire brigade must have monitors which in all foreseeable fire situations are capable of being directed to apply water to any of the exposed surfaces of the LPG storage system. For a single sphere storage installation this will typically require good all round access and mobile high head monitors supplied from hydrants via mobile booster pumps.

**Secondary protection – 20 tes unit**

Requirements are generally satisfied without the need for any special brigade equipment.

## Secondary fire/BLEVE protection 2,000 tes unit

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • None | | | | | | | | |
| • Firewall | | ☑ | | | | ☑ | | (6) Pump area if identified by risk assessment |
| • Sprinkler | ☑ | | | | | | | |
| • Top deluge | | | | | | | | |
| • Sprays /spray rings | | | | ☑ | | | ☑ | (4) Even if the main vessel is mounded and therefore protected against fire, the other equipment, which belongs to the storage vessel, has to be kept cool during a fire. Details have to be discussed in a safety review. For pumps, loading or filling stations. |
| • Fixed monitor(s) | | | | | | ☑ | | |
| • Water flood | | | ☑ | | | | | (3) Depending on 1st valve/pipe connection (if welded or not). |
| • Mobile monitors (locally stored & activated) | | | | | ☑ | | | |
| • Mobile monitors (site fire brigade) | ☑ | ☑ | | | | ☑ | | |
| • Mobile monitors (public service or mutual help fire brigade) | | | | | ☑ | | | |
| • Hose on hydrant (locally stored & activated) | ☑ | | | | ☑ | | | |
| • Hose on hydrant (site fire brigade) | | | | | | | | |
| • Hose on hydrant (public service or mutual help fire brigade) | | | | | | | | |
| • Other | | | ☑ | | | | | (3) Water sprays/Fixed monitors to protect critical areas (Truck unloading & Pumping) |
| Water application rate (select one for each duty) | | | | | | | | |
| - 100 $l/m^2$/hour or similar | | | | | | | | |
| - 10 $l/m^2$/min or similar | ☑ | ☑ | ☑ | | ☑ | ☑ | ☑ | (1) 600 $l/m^2$/<br>(2) 10 – 20 $l/m^2$/min<br>(3) On the critical areas (Truck unloading and Pumping)<br>(4) Water shield to keep tank trucks cool |
| - Other (specify) | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| System initiation | | | | | | | | |
| - Heat sensor | | | | | | | | |
| - Flame sensor | | | | | | | | |
| - Fusible plug | | | | | | ☑ | | |
| - Switch in control centre | ☑ | | ☑ | | | ☑ | ☑ | (3) Activated after Fire alarm confirmation |
| - Switch local to storage facility | ☑ | | | ☑ | | ☑ | | (4) To be discussed, normally multiple push buttons |
| - Valve(s) local to storage facility | | | | ☑ | | | | (4) To be discussed, normally multiple push buttons |
| - Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(5) NFPA Guides & risk assessment.

## Secondary fire/BLEVE protection 20 tes unit

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • None | | | | | | | | |
| • Firewall | | | | | | ☑ | | (6) Pump area if identified by risk assessment |
| • Sprinkler | | | | | | ☑ | | |
| • Top deluge | | | | | | | | |
| • Sprays /spray rings | | | | ☑ | | | ☑ | (4) Even if the main vessel is mounded and therefore protected against fire, the other equipment, which belongs to the storage vessel, has to be kept cool during a fire. Details have to be discussed in a safety review. For pumps, loading or filling stations |
| • Fixed monitor(s) | | | ☑ | | | | | |
| • Water flood | | | ☑ | | | | | (3) Depending on 1st valve/pipe connection (if welded or not). |
| • Mobile monitors (locally stored & activated) | | | | | ☑ | | | |
| • Mobile monitors (site fire brigade) | ☑ | | | | | ☑ | | |
| • Mobile monitors (public service or mutual help fire brigade) | | | | | ☑ | | | |
| • Hose on hydrant (locally stored & activated) | | | | | ☑ | | | |
| • Hose on hydrant (site fire brigade) | | | | | | | | |
| • Hose on hydrant (public service or mutual help fire brigade) | | | | | | | | |
| • Other | | | ☑ | | | | | (3) Water sprays/Fixed monitors to protect critical areas (Truck unloading & Pumping) |
| Water application rate (select one for each duty) | | | | | | | | |
| - 100 l/m$^2$/hour or similar | | | | | | | | |
| - 10 l/m$^2$/min or similar | | | ☑ | | ☑ | ☑ | ☑ | (3) On the critical areas (Truck unloading and Pumping) |
| - Other (specify) | | | | | | | | (4) Water shield to keep tank trucks cool |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| System initiation | | | | | | | | |
| - Heat sensor | | | | | | | | |
| - Flame sensor | | | | | | | | |
| - Fusible plug | | | | | | ☑ | | |
| - Switch in control centre | | | ☑ | | | ☑ | ☑ | (3) Activated after Fire alarm confirmation |
| - Switch local to storage facility | | | | ☑ | | ☑ | | (4) To be discussed, normally multiple push buttons |
| - Valve(s) local to storage facility | | | | ☑ | | | | (4) To be discussed, normally multiple push buttons |
| - Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

3) Company standard practice

(5) NFPA Guides & risk assessment

# 9. Overpressure Protection

Fire situation overpressure protection is not an issue for buried or mounded installations. Above ground installations are generally equipped with relief valves rated for a fire situation which assumes the liquid inventory is exposed to the fire. This relief provides no protection against the weakening of containment which will arise if the vapour filled sections are exposed to fire.

The extent it is appropriate to assume a credit for elevation, slope away ground surfaces and fire protection arrangements in the sizing of the relief device should be determined by a risk assessment which acknowledges the specific circumstances of the unit concerned. Accumulation allowances are generally determined by the vessel design code. These matters are exhaustively reviewed elsewhere (ref.2).

The material vented from the relief device must either be routed to a flare or discharged in a manner which, under all foreseeable weather conditions, will ensure that it is dispersed below its LFL before it contacts a source of ignition. LPG venting from a leaking or lifted relief valve is readily ignited by lightening. Thermal radiation from an ignited relief valve vent must not be allowed to weaken LPG containment.

**Overpressure protection – 2,000 tes unit**

Relief quantities are very sensitive to fire protection assumptions. There is generally a reluctance to claim high credits on a large and/or complex unit. due to concerns about the effectiveness of protection systems and the consequences of undersizing the relief devices in these circumstances.
The dispersion characteristics of LPG vented to atmosphere from a relief valve are poor.

The plant site described in the case study features a substantial process flare so the designer would undoubtedly consider routing the LPG storage relief vent to this flare in the first instance. However the back pressure may be excessive, the connection length is substantial, and measures to prevent liquid accumulation in the connection may be necessary.

Meaningful dispersion modelling of material vented in the proximity of a large vessel is problematical. Nevertheless there would typically be reluctance to provide a flare to handle the LPG storage vents were one not already available in the vicinity.

**Overpressure protection – 20 tes unit**

It is reasonable to expect that the protection measures on a well maintained and operated unit of this size will be effective. Acknowledgement of the protection measures in sizing the relief valve should enable the relief valve to be vented to atmosphere without fear of vent ignition.

The case study features nearby vehicle loading, utilities, an office, a flare and overfence activities all of which may constitute sources of ignition. Therefore the acceptability of the intended atmospheric vent arrangements should be confirmed with dispersion modelling.

Note – *Conventional overpressure protection arrangements cannot protect against a brittle fracture of the containment exposed to excessively low temperatures. These low temperatures might result from low ambient temperature or the evaporative cooling of a liquid phase release. The selected materials of construction must be capable of tolerating the local area minimum ambient temperature. The gas detection strategy applied must be capable of detecting all releases capable of causing evaporative cooling brittle fracture (see items 11 & 13).*

## Overpressure protection 2,000 tes unit

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • PSV(s) rated for the fire case assuming (if local regulations allow discretion): | | | | | | | | |
| • Fire is not a concern | ☑ | | ☑ | ☑ | | | | (1) PSV is rated for the gas volume displacement corresponding to the max. delivery of filling pump.<br>(3) PSV is installed on mounded vessels only if required by the Client Standard or local legislation.<br>(4) Following German guidelines (AD-Merkblaetter), fire is not a design basis, but for major vessels, especially in the process plant, we use API guidelines. |
| • 'x'% vessel surface is exposed to fire | | | | | ☑ | | | (5) 100% |
| • 'Underside' or 55% of vessel surface is exposed to fire | | ☑ | | | | ☑ | | |
| • Vessel surface <9m above grade is exposed to fire | | | | | | | ☑ | (7) API Recommended Practice 520. |
| • Active fire protection credit (specify factor) | | ☑ | | | | | | (2) According NFPA 30. |
| • Passive fire protection credit (specify factor) | | | ☑ | | | | | |
| • Other | | ☑ | | | | ☑ | | (2) Positively drain away from under the vessel.<br>(6) Jet fire is the major concern |
| • Allowable Accumulated Pressure in fire situation (select one for each duty) | | | | | | | | (4) German guidelines do not allow higher stress to material as 100%, the resulting relief valve size is not a problem for mounded vessels. |
| – 110% Design Pressure (or similar) | ☑ | | ☑ | | ☑ | | ☑ | (3) If PSV is provided for mounded vessels |
| – 115% Design Pressure (or similar) | | | | | | | | |
| – 120% Design Pressure (or similar) | | | | | ☑ | | | |
| • PSV(s) vent to: | | | | | | | | |
| – Atmosphere | | | | | | | ☑ | (4) PVS vents normally to flare, smaller relief valves may be allowed to vent directly to atmosphere, when the released material is "only" inflammable gas and when a distribution calculation shows, that there is no risk of a delayed ignition. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| – Flare | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | | (2) Preferred also for mounded vessel (if PSV is provided). |
| – Other | | | | | | | | (5) Flare used where available. Typically, a flare would not be provided specifically for this duty. |

Basis of selection (numeral indicates participant concerned)

(1) Druckbehälterverordnung, TRB 403, Pressure Eqipment Directive.

(2) & (3) Company standard practice or guideline.

(4) Safety Guidelines of German TAA ("Technischer Ausschuss Anlagensicherheit") which define the state of the art. Vents to atmosphere need to be accepted by the authorities (local requirements).

## Overpressure protection 20 tes unit

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • PSV(s) rated for the fire case assuming (if local regulations allow discretion): | | | | | | | | |
| • Fire is not a concern | ☑ | | | ☑ | | | | (3) PSV is rated for the gas volume displacement corresponding to the max. delivery of filling pump.<br>(3) PSV is installed on mounded vessels only if required by the Client Standard or local legislation.<br>(4) Following German guidelines (AD-Merkblaetter), fire is not a design basis, but for major vessels, especially in the process plant, we use API guidelines. |
| • 'x'% vessel surface is exposed to fire | | | | | ☑ | | | (5) 100%. |
| • 'Underside' or 55% of vessel surface is exposed to fire | | | | | | ☑ | | |
| • Vessel surface <9m above grade is exposed to fire | | | | | | | ☑ | (7) API Recommended Practice 520. |
| • Active fire protection credit (specify factor) | | | | | | | | |
| • Passive fire protection credit (specify factor) | | | ☑ | ☑ | | ☑ | | (3) Depending on F/P insulating characteristics (approx. 0.3 according to API RP-520).<br>(6) If passive fire protection is applied also (impact resistant material). |
| • Other | | | | | | ☑ | | (6) Jet fire is the major concern. |
| • Allowable Accumulated Pressure in fire situation (select one for each duty) | | | | | | | | (4) German guidelines do not allow higher stress to material as 100%, the resulting relief valve size is not a problem for mounded vessels. |
| – 110% Design Pressure (or similar) | ☑ | | ☑ | | ☑ | | ☑ | |
| – 115% Design Pressure (or similar) | | | | | | | | |
| – 120% Design Pressure (or similar) | | | | | ☑ | | | |
| • PSV(s) vent to:<br>– Atmosphere | ☑ | | | | | | ☑ | (4) PVS vents normally to flare, smaller relief valves may be allowed to vent directly to atmosphere, when the released material is "only" inflammable gas and when a distribution calculation shows, that there is no risk of a |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| – Flare | | | ☑ | ☑ | ☑ | ☑ | | delayed ignition.<br>(4) Preferred also for mounded vessel (if PSV is provided).<br>(5) Flare used where available. Typically, a flare would not be provided specifically for this duty. |
| – Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(1) Druckbehälterverordnung, TRB 403, Pressure Equipment Directive.

(3) Company standard practice.

(4) Safety Guidelines of German TAA (“Technischer Ausschuss Anlagensicherheit”) which define the state of the art. Vents to atmosphere need to be accepted by the authorities (local requirements).

# 10. Connections to Storage Vessel(s)

A leak of liquid LPG can quickly precipitate a major fire situation or, if it occurs as a result of a fire, the leak can substantially magnify the intensity of the fire.

Good practice requires minimisation of the number of connections which could release the liquid inventory if they failed. Those that are fitted generally incorporate firesafe valves located as close as possible to the source of the liquid. The firesafe valves are typically fitted with actuators which enable them to be closed from a remote location. In some circumstances provision is made for a fire detection system to automatically close the valves.

The pipework on all connections is typically of all-welded construction between the vessel and the first readily accessible valve to minimise the likelihood of non-isolatable leaks. Fill lines typically incorporate remote shut-off valves near the storage unit if there is no equivalent facility at the upstream supply point or if the configuration would allow the storage system's liquid inventory to flow back into the line in the event of it failing.

All connections to the storage vessel should be protected against fire in the vicinity of the installation.
Burying or mounding generally requires electrical continuity prevention joints on all connections.
These connections are potential 'weak' points. They must be robust, protected against physical damage and fireproofed.

**Connections – 2,000 tes unit**

Both the outlet and inlet connections on installations of this size are generally equipped with an isolation valve which is automatically closed by a signal from the fire detection system and can be switch closed from a remote location.

**Connections – 20 tes unit**

In this instance the LPG supplies a fuel gas system so a liquid outlet connection is probably unnecessary. If a liquid outlet connection were provided it would probably be equipped with an isolation valve which can be closed from a remote location. A single valve in the fill line located at the road truck offloading point would in any case probably be equipped with an isolation valve which can be closed from a remote location.

## Connections to storage vessel(s) 2,000 tes unit

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Top connections only | | | | ☑ | | | | |
| • No bottom connections | | | | ☑ | | | | |
| • Liquid outlet piping | | | | | | | | |
| - No flanges upstream of first valve | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (3) The part of liquid line under the mound is in a double pipe with the inner space filled with N2 and pressure sensors to monitor leaks.<br>(4) Generally the first valve should have a fire-proof insulation. |
| - Actuators fitted to first and/or second valve | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | (6) Preferred, otherwise flange to be fire proofed. |
| - Emergency closure switch in control centre | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | |
| - Emergency closure switch local to storage facility | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Normally locally and in control centre. |
| - Automatic closure on fire detector signal | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Normally locally and in control centre.<br>(2) Emergency Block Valve principle. |
| - Automatic closure on gas detector signal | ☑ | | ☑ | ☑ | | ☑ | ☑ | (4) Automatic trips work only when multiple alarms occur simultaneously. |
| - All valves are 'firesafe' | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ ☑ | ☑ | (4) Automatic trips work only when multiple alarms occur simultaneously.<br>(4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Passive fire protection | ☑ | ☑ | ☑ | ☑ | | ☑ | | (1) Jacket for the valves.<br>(4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Active fire protection | | ☑ | | ☑ | | ☑ | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Other protective features of note | ☑ | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | (1) Heating for valves due to freezing problems. |
| • Liquid fill piping | | | | | | | | |
| – No flanges downstream of last valve | ☑ | | ☑ | | | | ☑ | |
| – Actuators fitted to one or more valve(s) | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | |
| – Emergency closure switch in control centre | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Normally locally and in control centre. |
| – Emergency closure switch local to storage facility | ☑ | | ☑ | ☑ | ☑ | | ☑ | (4) Normally locally and in control centre. |
| – Automatic closure on fire detector signal | ☑ | ☑ | ☑ | ☑ | | | | (3) According to a Voting Logic.<br>(4) Automatic trips work only when multiple alarms occur simultaneously. |
| – Automatic closure on gas detector signal | ☑ | | ☑ | ☑ | | | | (3) According to a Voting Logic.<br>(4) Automatic trips work only when multiple alarms occur simultaneously. |
| • Liquid fill piping (continued) | | | | | | | | |
| - All valves are 'firesafe' | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Passive fire protection | | | ☑ | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Active fire protection | | | | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Other protective features of note | | | ☑ | | | ☑ | | (3) Fit pipe from top discharging above the max. liquid level.<br>(6) If dip tube installed then a wheephole in top to prevent siphon. |
| • All other pipe connections to the storage vessel(s) | | | | | | | | |
| – No flanges on vessel side of the<br>– first valve | ☑ | | | | ☑ | | ☑ | |
| – Actuators fitted to one or more<br>– valve(s) | ☑ | ☑ | ☑ | | ☑ | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| – Emergency closure switch in<br>– control centre | ☑ | ☑ | ☑ | | ☑ | | | |
| – Emergency closure switch<br>– local to storage facility | ☑ | | ☑ | | ☑ | | | |
| – Automatic closure on fire<br>– detector signal | | ☑ | | | | | | (2) As long as the valves are in service as an EBV. |
| – Automatic closure on gas<br>– detector signal | ☑ | | | | | | | |
| -All valves are 'firesafe' | ☑ | ☑ | | | ☑ | | ☑ | (2) As long as the valves are in service as an EBV |
| -Passive fire protection | | ☑ | | | | | | |
| -Active fire protection | | ☑ | | | | | | |
| -Other protective features of note | | | | | | ☑ | | (6) Restrictions in connections either: orifice, check valve or excess flow valve. |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(1) Company standard practice & TRB 801 No. 25, appendix.

(4) There are no written company standards. Hazards are evaluated for the individual case.

(5) LPGA codes.

## Connections to storage vessel(s) 20 tes unit

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Top connections only | | | ☑ | ☑ | | | | |
| • No bottom connections | | | ☑ | ☑ | | | | (4) Smaller vessels may have a bottom connection with fireproof insulation and a block valve |
| • Liquid outlet piping | | | | | | | | |
| - No flanges upstream of first valve | ☑ | | * | ☑ | ☑ | | ☑ | (3) Generally the first valve should have a fireproof insulation |
| - Actuators fitted to first and/or second valve | ☑ | | * | ☑ | ☑ | ☑ | ☑ | |
| - Emergency closure switch in control centre | ☑ | | * | ☑ | ☑ | ☑ | ☑ | (4) Normally locally <u>and</u> in control centre. |
| - Emergency closure switch local to storage facility | ☑ | | * | ☑ | ☑ | ☑ | ☑ | (4) Normally locally <u>and</u> in control centre. |
| - Automatic closure on fire detector signal | ☑ | | * | ☑ | | ☑ | ☑ | (4) Automatic trips work only when multiple alarms occur simultaneously. |
| - Automatic closure on gas detector signal | ☑ | | * | ☑ | | ☑ | ☑ | (4) Automatic trips work only when multiple alarms occur simultaneously. |
| - All valves are 'firesafe' | ☑ | | * | ☑ | ☑ | ☑ | ☑ | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Passive fire protection | | | * | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Active fire protection | | | * | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |

* It is assumed that the LPG is drawn off as vapour so no liquid outlet connection is provided

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| • Liquid fill piping | | | | | | | | |
| – No flanges downstream of last valve | ☑ | | ☑ | | ☑ | | | |
| – Actuators fitted to one or more valve(s) | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | |
| – Emergency closure switch in control centre | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Normally locally <u>and</u> in control centre. |
| – Emergency closure switch local to storage facility | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Normally locally <u>and</u> in control centre. |
| – Automatic closure on fire detector signal | ☑ | | ☑ | ☑ | ☑ | | ☑ | (4) Automatic trips work only when multiple alarms occur simultaneously. |
| – Automatic closure on gas detector signal | ☑ | | ☑ | ☑ | | | | (4) Automatic trips work only when multiple alarms occur simultaneously. |
| - All valves are ‘firesafe’ | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Passive fire protection | | | ☑ | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Active fire protection | | | | ☑ | | | | (4) Fire safe seats alone will not solve the problem. When bolts of valve flanges become weak due to the heat impact of an external fire, the gaskets will fail. Same arguments are valid for fail close spring loaded remote valves. |
| - Other protective features of note | | | ☑ | | | ☑ | | (3) Fit pipe from top discharging above the max. liquid level.<br>(6) If dip tube installed then a wheephole in top to prevent siphon. |
| • All other pipe connections to the storage vessel(s) | | | | | | | | |
| – No flanges on vessel side of the – first valve | ☑ | | | | ☑ | | ☑ | |
| – Actuators fitted to one or more – valve(s) | ☑ | | ☑ | | ☑ | | | |
| – Emergency closure switch in – control centre | ☑ | | ☑ | | ☑ | | | |
| – Automatic closure on fire | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| – detector signal<br>– Automatic closure on gas<br>– detector signal | ☑ | | | | | | | |
| -All valves are 'firesafe' | ☑ | | | | ☑ | | ☑ | (2&3) Company standard practice or guideline.<br>(1) Company standard practice & TRB 801 No. 25, appendix.<br>(3) Company standard practice.<br>(4) There are no written company standards. Hazards are evaluated for the individual case. |
| -Passive fire protection | | | | | | | | (5) LPGA codes |
| -Active fire protection | | | | | | | | |
| -Other protective features of note | | | | | | ☑ | | (6) Restrictions in connections either: orifice, check valve or excess flow valve. |

Basis of selection (*numeral indicates participant concerned*)

## 11. Leak Management

The possibility of a leak from an LPG storage installation and its associated transfer systems can never be entirely discounted regardless of the locational and engineering measures adopted in its design.

A proportion of any released liquid will flash immediately. The remainder will fall onto the ground surface below where it will flash until the surface cools below the LPG's Bubble Point.
The vapour release rate then reduces dramatically because it is dependent on heat transfer between the liquid surface and the surrounding atmosphere rather than heat pickup from a warm surface. The residual released liquid LPG lies as a quiescent pool with a flammable atmosphere immediately above its surface.

It is essential to adopt measures to avoid the ignition of spilled material which can affect the fundamental integrity of the LPG containment system. These measures typically provide for thechannelling of spilled LPG to a location where, if it does ignite, the consequent conflagration will threaten neither the LPG system or other equipment in the locality. The capacity of the holding arrangement and its configuration must acknowledge that firewater will be applied to the installation soon after the leak commences. The location of the holding facility must acknowledge that entry of this firewater will encourage evaporation of the accumulated spilled LPG.

A leak of liquid LPG will result in the evaporative cooling of surfaces in its vicinity. The release detection and monitoring strategy applied must provide for the early detection of a leak sufficient to cause brittle fracture of the containment (see item 13).

Many LPG storage units are equipped with a high pressure water flood connection enabling water to be introduced into the storage vessel in order to prevent the release of LPG in the event of a leak in the base of the vessel or a bottom connection.

The various LPG handling codes have sections dealing specifically with leak prevention and leak management at the LPG storage loading/offloading stations typically associated with LPG storage installations.

**Leak management – 2,000 tes unit**

The ground area below a large aboveground LPG storage installation and its associated facilities is typically provided with an impervious surface. This surface is sloped and drains to a collection pit where any accumulated LPG will, if ignited, burn harmlessly. The pit must be equipped so that, under normal conditions, it is maintained essentially empty, i.e. free of accumulated rain water. Connections to the site drainage system are generally via an underflow weir and valved interceptor pit. The volume of the holding facility will depend on assumptions regarding the rate of liquid LPG release, the rate of firewater application, prior rainwater accumulation, etc..

**Leak management – 20 tes unit**

In some circumstances a similar arrangement to that for the 2,000 tes installation is adopted. More typically the surface below the storage unit and its associated facilities is sloped to drain into the surrounding unsurfaced area from which spilled LPG is expected to harmlessly evaporate to atmosphere.

## Leak management 2,000 tes unit

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Impervious surface below vessel(s) | ☑ | ☑ | | ☑ | | ☑ | | (4) We must follow local guidelines. In Germany impervious surface is mandatory for pressurised gases which are harmful to groundwater. This is also valid for single wall mounded vessels (concrete pavement, controlled rain water drain). Alternative: Double wall, select the less expensive solution. |
| • Surface sloped to prevent accumulation under vessel(s) | ☑ | ☑ | | ☑ | | ☑ | | (4) For normal LPG sand bed with no retention.<br>(4) Mounded vessels have no free space under the vessels, but for pump arrangement you need some leak management of this kind. |
| • Impervious surface below vessel(s) | | ☑ | | ☑ | | | | (4) For normal LPG sand bed with no retention. |
| • Containment | | | | | | | | |
| - Bund with volume 'x'% of vessel volume (state 'x') | | ☑ | | | | | | (2) 100% plus half hour fire water flow. |
| - Shallow sill | | | | | | | | |
| - Area below vessel(s) free drains to remote basin | | ☑ | | ☑ | ☑ | ☑ | ☑ | (4) Mounded vessels have no free space under the vessels, but for pump arrangement you need some leak management of this kind. |
| - Volume of basin | | | | | | | | (2) 100% plus half hour fire water flow<br>(5) Based on credible leak<br>(6) Half volume |
| - No containment provision | | | | ☑ | | | | (4) For normal LPG sand bed with no retention. |
| - Other | | | ☑ | | | | | (3) Bunded area only in front (operating side) to mounded vessels where transferring pumps are located. |
| • Drainage | | | | | | | | |
| - Site drainage system can accept spilled LPG | | | | | | | | (2) To be decided upon leakage scenario.<br>(4) Sewer system has an area classification but is not designed to accept spilled LPG |
| -Area/basin normally isolated from site drainage system | ☑ | ☑ | | ☑ | | ☑ | | |
| -Arrangement incorporates water sealed interceptor | ☑ | ☑ | | ☑ | ☑ | ☑ | | (4) Underground pipes for normal rain water drain are permanently flooded with water. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| • Other leak management features | | | ☑ | | | ☑ | | (3) Water drainage from vessel bottom or along liquid bottom line in a closed system and with double valves arrangement. Water connection provided to fill vessel bottom and to suppress the LPG leakage.<br>(6) Gas detectors to be installed. |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(4) No written guidelines.

(5) LPGA codes.

## Leak management 20 tes unit

| | Selection | | | | | | | Comments (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| ▪ Impervious surface below vessel(s) | ☑ | | | ☑ | | ☑ | | (4) We must follow local guidelines. In Germany impervious surface is mandatory for pressurised gases which are harmful to groundwater. This is also valid for single wall mounded vessels (concrete pavement, controlled rain water drain). Alternative: Double wall, select the less expensive solution |
| ▪ Surface sloped to prevent accumulation under vessel(s) | ☑ | | ☑ | ☑ | | ☑ | | (4) We must follow local guidelines. In Germany impervious surface is mandatory for pressurised gases which are harmful to groundwater. This is also valid for single wall mounded vessels (concrete pavement, controlled rain water drain). Alternative: Double wall, select the less expensive solution.<br>(4) Mounded vessels have no free space under the vessels, but for pump arrangement you need some leak management of this kind. |
| ▪ Impervious surface below vessel(s) | | | | ☑ | | | | (4) We must follow local guidelines. In Germany impervious surface is mandatory for pressurised gases which are harmful to groundwater. This is also valid for single wall mounded vessels (concrete pavement, controlled rain water drain). Alternative: Double wall, select the less expensive solution. |
| ▪ Containment<br>• -Bund with volume ‘x’% of vessel volume (state ‘x’)<br>• -Shallow sill<br>• -Area below vessel(s) free drains to remote basin | | | | | | | | (4) Mounded vessels have no free space under the vessels, but for pump arrangement you need some leak management of this kind. |
| • -Volume of basin | | | | | | | | (6) Half volume. |
| • -No containment provision | | | ☑ | ☑ | | | ☑ | (3) Because no bottom connection (see entry for ‘outlet line’ in item 10)<br>(4) We must follow local guidelines. In Germany impervious surface is mandatory for pressurised gases which are harmful to groundwater. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| • -Other | | | | | | | | This is also valid for single wall mounded vessels (concrete pavement, controlled rain water drain). Alternative: Double wall, select the less expensive solution. |
| • Drainage | | | | | | | | |
| - Site drainage system can accept spilled LPG | | | | | | | | (4) Sewer system has an area classification but is not designed to accept spilled LPG. |
| - Area/basin normally isolated from site drainage system | ☑ | | | ☑ | | ☑ | | |
| - Arrangement incorporates water sealed interceptor | ☑ | | ☑ | ☑ | ☑ | ☑ | | (4) Underground pipes for normal rain water drain are permanently flooded with water. |
| • Other leak management features | | | ☑ | | | ☑ | | (3) Water drainage from vessel bottom or along liquid bottom line in a closed system and with double valves arrangement.<br>(6) Gas detectors to be installed. |

Basis of selection (*numeral indicates participant concerned*)

(3) Company standard practice.

(4) No written guidelines.

(5) LPGA codes.

## 12. Area Classification

The leak management provisions considered in section 11 do not address concerns relating to the ignition of a leak at its origin. The approach in this instance has to be the exclusion of all sources of ignition.

The various standard electrical classification codes have sections dealing specifically with LPG storage installations. All these codes are, explicitly or implicitly, risk based so it is prudent to adopt an intrinsically safe approach if particularly onerous conditions apply (e.g. exceptionally high leak frequency, adverse weather conditions, etc.).

Management procedures generally prohibit mobile sources of ignition in the vicinity of any LPG installation and plot layout should be consistent with this objective.

**Area classification – 2,000 tes unit**

The extent of the flammable cloud associated with a leak is dependent on the source conditions, the size of the leak and the weather conditions. The potential size of a leak is generally a function of the size of the source system and hence the scale of the installation. Blind adherence to code guidance may be inappropriate where large installations are concerned. For situations other than those where an intrinsically safe approach is selected it is advisable to assess potential leak sizes, to undertake dispersion calculations for the weather conditions experienced at the site concerned and to undertake a risk assessment accordingly.

**Area classification – 20 tes unit**

Direct adoption of code advice is probably appropriate for an installation of this size but it should be confirmed that that it incorporates no unconventional features.

**Area Classification 2,000 tes unit**
*(note – it is assumed that the immediate vicinity of PSV vents, pumps, etc. will be zoned as required by local national codes)*

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • No electrical equipment in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | ☑ | ☑ | | | | (4) Exception: submerged pumps in deep cold storage vessels, detectors see below. |
| - Bund / sill (above ground vessels) | | | | | | ☑ | | |
| - Other | | | | | ☑ | | | (6) Electrical equipment shall be at 15m unless a separation wall. |
| •Zone 0 in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | | ☑ | | | | (4) Interior of vessels needs normally no classification. Detectors for level, pressure, and temperature are Zone 0. |
| - Bund / sill (above ground vessels) | ☑ | | | | | | | |
| - Other | | | | | | | | |
| • Zone 1 in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | | ☑ | | | | (4) Zoning is defined around flanges following guidelines. |
| - Bund / sill (above ground vessels) | | | | | | | | |
| - Other | | | | | | | | |
| • Zone 2 (near grade horizontal distance) within: | | | | | | | | |
| - 5m (or similar) of LPG PSV vent | ☑ | ☑ | ☑ | | | | | (2) Very dependent on situation. |
| - 30m (or similar) of vessel wall (above ground vessels) | ☑ | | | | ☑ | ☑ | | |
| - 15m (or similar) of vessel wall (above ground vessels) | | ☑ | | | | | | (2) Very dependent on situation. |
| - 15m (or similar) of mound / shaft (underground vessels) | | | | | | | | |
| - 7.5m (or similar) of mound / shaft (underground vessels) | | | ☑ | | | | | |
| - 30m (or similar) of bund / sill (above ground vessels) | | | | | | | | |
| - 15m (or similar) of bund / sill (above ground vessels) | | | | | | | | (2) Very dependent on situation. |
| - 5m (or similar) of bund / sill (above ground vessels) | | | | | | | | (2) Very dependent on situation. |
| - Other | | ☑ | | | | | | (2) 1,5 – 3 meters classified areas also exists. |

Basis of selection (numeral indicates participant concerned)

(1) TRbF 110.

(2) Other according **Local regulations or company standards, whichever is more stringent**

(3) ILA.AF.HAC.0021, “Classificazione Luoghi con Pericolo di Esplosione per la presenza di gas o vapori infiammabili in accordo alla CEI EN 60079-10”, Rev. 0, Nov. 1999.

(4) “Explosionsschutz- Richtlinien” .

## Area Classification 20 tes unit

*(note – it is assumed that the immediate vicinity of PSV vents, pumps, etc. will be zoned as required by local national codes)*

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • No electrical equipment in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | | ☑ | | | | 4) Exception: submerged pumps in deep cold storage vessels, detectors see below. |
| - Bund / sill (above ground vessels) | | | ☑ | | | | ☑ | |
| - Other | | | | | ☑ | | | (6) Electrical equipment shall be at 15m unless a separation wall. |
| •Zone 0 in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | | ☑ | | | | (4) Interior of vessels needs normally no classification. Detectors for level, pressure, temperature are Zone 0. |
| - Bund / sill (above ground vessels) | ☑ | | | | | | | |
| - Other | | | | | | | | |
| • Zone 1 in: | | | | | | | | |
| - Mound / shaft (underground (buried) vessels) | | | | ☑ | | | | (4) Zoning is defined around flanges following guidelines. |
| - Bund / sill (above ground vessels) | | | ☑ | | | | | (3) Vertical extension depending on bund height (if any). |
| - Other | | | | | | | | |
| • Zone 2 (near grade horizontal distance) within: | | | | | | | | |
| - 5m (or similar) of LPG PSV vent | ☑ | | ☑ | | | | | |
| - 30m (or similar) of vessel wall (above ground vessels) | ☑ | | | | | | | |
| - 15m (or similar) of vessel wall (above ground vessels) | | | | | | ☑ | | |
| - 15m (or similar) of mound / shaft (underground vessels) | | | ☑ | | | | | |
| - 7.5m (or similar) of mound / shaft (underground vessels) | | | | | | | | |
| - 30m (or similar) of bund / sill (above ground vessels) | | | | | | | | |
| - 15m (or similar) of bund / sill (above ground vessels) | | | | | | | | |
| - 5m (or similar) of bund / sill (above ground vessels) | | | ☑ | | | | | (3) Around the bund. |
| - Other | | | | | | | | |

Basis of selection (numeral indicates participant concerned)

(1) TRbF 110.

(3) ILA.AF.HAC.0021, “Classificazione Luoghi con Pericolo di Esplosione per la presenza di gas o vapori infiammabili in accordo alla CEI EN 60079-10”, Rev. 0, Nov. 1999.

(4) “Explosionsschutz- Richtlinien”.

# 13. Monitoring Arrangements

The overfilling of an LPG storage installation must be prevented. Flare liquid knockout drums are unlikely to have sufficient capacity to contain a sustained overfill. A relief valve venting liquid LPG to atmosphere is a major hazard. Therefore the provision of a high integrity high level detection and prevention system is always essential. The fitting of sight glasses to an LPG installation is generally prohibited.

Low pressure, as well as high pressure, can result in the failure of containment of an LPG storage vessel not designed for full vacuum. Large changes in ambient temperature, level changes or vent pressure control system problems can cause major pressure reductions so the provision of high integrity pressure monitoring arrangements is advisable.

The possibility of a fire affecting an LPG installation can never be entirely discounted. Major loss prevention requires the early and reliable detection of a fire. Heat detector and/or fire detector* and/or fusible plug arrangements are typically provided but the coverage and effectiveness of such systems is difficult to test.

The loss of LPG can cause a reduction in pressure which will reduce the temperature of the LPG and pipework and containment vessels in contact with the LPG. Unless steels with suitable low temperature resistance have been chosen this can increase the risk of brittle failure.

An effective release detection and monitoring strategy will substantially reduce the fire risk. It must in any case provide for the early detection of a leak sufficient to cause brittle fracture of the containment. The response of many multipoint flammable gas detection systems is too slow for reliable fire prevention and the location of the sensor heads for the full range of weather conditions is generally problematical. Nevertheless such systems are typically provided as a principle component of the detection and monitoring strategy.

The upstream end of the particularly vulnerable bottom outlet line is sometimes double piped with flammable gas monitoring of the interspace. This arrangement is generally applied to any covered section of an LPG line associated with a mounded or buried storage installation.

Many large installations are now also provided with CCTV coverage with monitors in the control centre. A large leak is generally evident if it is within the field of view of the camera. However, although CCTV coverage can greatly assist situation assessment, it cannot be regarded as a protective device because it possesses no facility to attract attention to the onset of the problem.

**Monitoring arrangements – 2,000 tes unit**

Most large LPG storage installations are equipped with dual high level and high pressure detection systems which automatically isolate the feed stream. They are typically also equipped with low level and low pressure alarms and dual vent pressure control systems.

Most have comprehensive fire and flammable vapour detection systems with the latter automatically isolating the feedstream if it senses the presence of a flammable atmosphere in the vicinity of the installation.

**Monitoring arrangements – 20 tes unit**

A similar configuration of monitoring arrangements is generally applied regardless of the scale of the installation, but integrity levels generally reflect the perceived magnitude of the hazard.

* *Heat detector and/or fire detector arrangements typically involve the wrapping of LPG lines with heat sensitive tape. High temperature causes an isolation valve to close. An alternative is to use plastic tubing pressurised with instrument air and a low pressure alarm which actuates if the plastic tube fails.*

**Monitoring Arrangements 2,000 tes unit**
('cr' – in control centre, 'lo' – at storage facility)

| | Selection | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Overfill prevention (number per vessel) | | | | | | | | |
| - LI (lo) | | | 3 | 2 | 1 | 1 | 1 | (4) No glass allowed, for bigger vessels additional local indication of a transmitter.<br>(4) Double indication is standard. |
| - LAH (lo) | | | 3 | 2 | | 1 | | (4) Double indication is standard. |
| - LIH(cr) | | | 3 | 2 | | 1 | 1 | (4) Double indication is standard. |
| - LAH (cr) | 1 | 1 | 3 | 2 | 1 | 2 | 1 | (4) Double indication is standard. |
| - LHH (cr) closes fill line valve(s) | 1 | 1 | 3 | 2 | 1 | 2 | 1 | (4) Double indication is standard.<br>(4) LHH trip redundant, SIL3, especially when safety valve vents to atmosphere. |
| - Other | | | | | | | | |
| • Vessel pressure (number per vessel) | | | | | | | | |
| - PI (lo) | | | 2 | 1 | 1 | 1 | 1 | |
| - PAH (lo) | 1 | | 2 | 1 | | 1 | | |
| - PIH(cr) | 1 | 1 | 2 | 1 | | 1 | 1 | |
| - PAH (cr) | | 1 | 2 | 1 | 1 | 2 | 1 | |
| - PHH (cr) closes fill line valve(s) | 1 | 2 | 2 | 1 | | 2 | 1 | (4) PHH redundant, SIL3 when flaring is not possible. |
| - PHH (cr) actuates water sprays/monitors | 1 | | | | | | | (4) Mounded vessels may have lower design pressure, no solar radiation. No automatic actuation of water spray systems.<br>(5) Depends on local climate. |
| -Other | | | | ☑ | | | | (4) Reverse flow protection for pipes. to process |
| • Gas detectors | | | | | | | | |
| - None | | | | | | | | |
| - Alarm (cr) | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | ☑ | (5) Typically adjacent to pumps. |
| - Alarm (lo) | ☑ | | ☑ | ☑ | | ☑ | ☑ | |
| - Alarm site fire brigade | ☑ | | ☑ | ☑ | | ☑ | | (4) A single detector failure should not send the fire brigade to the site. Normally fire brigade will be alarmed from control room. Automatic alarm will be sent directly to the fire brigade when multiple detectors show HH-.<br>(6) When 2 or more alarm. |
| - Automatically initiates active fire protection system | ☑ | ☑ | | | | | | (2) Possibly<br>(4) No automatic start by detectors. |
| - Automatically close LPG inlet | ☑ | ☑ | ☑ | ☑ | | | ☑ | (2) Possibly. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| /outlet valves | | | | | | | | (3) According to a Voting Logic<br>(4) Emergency program started from control room or local push button. |
| - Other | | | | | | | | |
| • Fire detectors | | | | | | | | |
| - None | | | | | | | | |
| - Alarm (cr) | ☑ | ☑ | ☑ | ☑ | ☑ | | ☑ | |
| - Alarm (lo) | ☑ | | ☑ | ☑ | | | ☑ | |
| - Alarm site fire brigade | ☑ | ☑ | ☑ | | | | | (4) A single detector failure should not send the fire brigade to the site. Normally fire brigade will be alarmed from control room. Automatic alarm will be sent directly to the fire brigade when multiple detectors show HH-. |
| • Fire detectors - continued | | | | | | | | |
| - Automatically initiate active fire protection system | ☑ | ☑ | | | | | ☑ | |
| - Automatically close LPG inlet /outlet valves | | | ☑ | | | | ☑ | |
| - Other | | | | | | | | |
| • Video surveillance (cr) of | | | | | | | | |
| - LPG storage area | | ☑ | ☑ | ☑ | | | | |
| - Active regions of liquid LPG transfer systems | | | ☑ | ☑ | | ☑ | | |
| - LPG pumps only | | | | | | | | |
| - Other | | | | ☑ | | | | (4) Flare |

Basis of selection (*numeral indicates participant concerned*)

(2) & (3) Company standard practice or guideline.

(5) Risk assessment.

**Monitoring Arrangements 20 tes unit**

('cr' – in control centre, 'lo' – at storage facility)

| | Selection | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Overfill prevention (number per vessel) | | | | | | | | |
| - LI (lo) | | | 3 | 2 | 1 | 1 | 1 | (4) No glass allowed, for bigger vessels additional local indication of a transmitter. |
| | | | | | | | | (4) Double indication is standard. |
| - LAH (lo) | | | 3 | 2 | | 1 | 1 | (4) Double indication is standard. |
| - LIH(cr) | | | 3 | 2 | | 1 | 1 | (4) Double indication is standard. |
| - LAH (cr) | 1 | | 3 | 2 | 1 | 2 | 1 | (4) Double indication is standard. |
| - LHH (cr) closes fill line valve(s) | 1 | | 3 | 2 | 1 | 2 | 1 | (4) Double indication is standard. |
| | | | | | | | | (4) LHH trip redundant, SIL3, especially when safety valve vents to atmosphere. |
| - Other | | | | | | | | |
| • Vessel pressure (number per vessel) | | | | | | | | |
| - PI (lo) | | | 2 | 1 | 1 | 1 | 1 | |
| - PAH (lo) | 1 | | 2 | 1 | | 1 | | |
| - PIH(cr) | 1 | | 2 | 1 | | 1 | 1 | |
| - PAH (cr) | | | 2 | 1 | 1 | 2 | 1 | |
| - PHH (cr) closes fill line valve(s) | 1 | | 2 | 1 | | 2 | 1 | (4) PHH redundant, SIL3 when flaring is not possible. |
| - PHH (cr) actuates water sprays/monitors | 1 | | | | | | | (4) Mounded vessels may have lower design pressure, no solar radiation. No automatic actuation of water spray systems. |
| | | | | | | | | (5) Depends on local climate. |
| -Other | | | | ☑ | | | | (4) Reverse flow protection for pipes to process |
| • Gas detectors | | | | | | | | |
| - None | | | | | | | | |
| - Alarm (cr) | ☑ | | ☑ | ☑ | ☑ | ☑ | ☑ | (5) Typically adjacent to pumps. |
| - Alarm (lo) | ☑ | | ☑ | ☑ | | ☑ | ☑ | |
| - Alarm site fire brigade | ☑ | | ☑ | ☑ | | ☑ | | (4) A single detector failure should not send the fire brigade to the site. Normally fire brigade will be alarmed from control room. Automatic alarm will be sent directly to the fire brigade when multiple detectors show HH-. |
| | | | | | | | | (6) When 2 or more alarm. |
| - Automatically initiates active fire protection system | ☑ | | | | | | | (4) No automatic start by detectors. |
| - Automatically close LPG inlet | ☑ | | ☑ | ☑ | | | ☑ | (3) According to a Voting Logic |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| /outlet valves | | | | | | | | (4) Emergency program started from control room or local push button. |
| - Other | | | | | | | | |
| • Fire detectors | | | | | | | | |
| - None | | | | | | | | |
| - Alarm (cr) | ☑ | | ☑ | ☑ | ☑ | | ☑ | |
| - Alarm (lo) | ☑ | | ☑ | ☑ | | | ☑ | |
| - Alarm site fire brigade | ☑ | | ☑ | | | | | (4) A single detector failure should not send the fire brigade to the site. Normally fire brigade will be alarmed from control room. Automatic alarm will be sent directly to the fire brigade when multiple detectors show HH-. |
| - Automatically initiate active fire protection system | ☑ | | | | | | | |
| • Fire detectors | | | | | | | | |
| - Automatically close LPG inlet /outlet valves | | | ☑ | | | | | |
| - Other | | | | | | | | |
| • Video surveillance (cr) of | | | | | | | | |
| - LPG storage area | | | ☑ | | | | | |
| - Active regions of liquid LPG transfer systems | | | ☑ | | | ☑ | | |
| - LPG pumps only | | | | | | | | |
| - Other | | | | | | | | |

Basis of selection (*numeral indicates participant concerned*)

(3) Company standard practice.

(5) Risk assessment.

# 14. Additional Protection for 'Toxic Highly Flammable' LPGs

The protective measures referenced in this report are applicable to any highly flammable LPG but the potential to form a toxic as well as a flammable cloud in the event of release significantly magnifies any hazards. The assessment of these hazards is beyond the scope of this report.

The location of a toxic LPG storage installation relative to persons in its vicinity and to any operations that might threaten its integrity clearly requires special consideration. The general configuration of the preventative and protective measures applied to the installation itself is typically similar to that adopted for a non-toxic situation. However, the integrity of these measures needs to be reinforced to ensure that the risks to those in its vicinity are tolerable.

Any proposal involving the bulk storage and handling of a highly flammable and toxic LPG should be subjected to a rigorous situation specific consequence and risk assessment.

**Additional protective measures which would be applied if the feedstock LPG were ‘highly
flammable’ and ‘toxic’ (v.p. 2.0 to 2.7 barg at 20°C) 2,000 tes unit**

| | **Selection** | | | | | | | **Comments** (numeral indicates participants concerned) |
|---|---|---|---|---|---|---|---|---|
| **Participant** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| • Vessel type | | | | | | | | |
| -Horizontal drum(s) | 10 | 1 | (3) | (4) | | | | (3) 3 minimum<br>(4) Multiple double walled vessels.<br>(4) First considerations: Use all possible tools, modify the process to avoid big storage of toxic gases! Produce toxic products at the site with low intermediate storage. 2000tes storage capacity is normally too much. Control intermediate volume between the two shells, permanent purging with Nitrogen or other inert gases, gas detectors in purge gas outlet. |
| -Spheres | | | | | 2 | | | (5) As for non-toxics. |
| • Vessel setting | | | | | | | | |
| - Above ground, open aspect | ☑ | | | | ☑ | | | (1) Or semi-mounded. |
| - In single mound | | | ☑ | | | | | (3) Or Above-ground Fireproofed. |
| - Vessels individually mounded | | | | ☑ | | | | (4) Steel saddles on concrete pavement. |
| • Separation distance between the storage vessel(s) and: | ‘ok’ if the case study plan depicted separation distances are satisfactory | | | | | | | |
| -Flammables storage | | | (3) | (4) | (5) | | | (3) 40 – 60 m.<br>(4) See guidelines.<br>(5) As for non-toxics. |
| -Other LPG storage | | | (3) | (4) | (5) | | | (3) 25 m.<br>(4) See guidelines.<br>(5) As for non-toxics. |
| -Flare | | | ok | (4) | (5) | | | (4) See guidelines.<br>(5) As for non-toxics. |
| -Process plant | | | ok | ok | (5) | | | (5) As for non-toxics |
| -Control centre | (1) | | ok | (4) | (5) | | | (1) 50m.<br>(4) Discuss the single case in a safety review. Consequences of a toxic emission from a leak of the same size are quite different from LPG-spill which is only flammable.<br>(5) Determine according to a risk assessment. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| -Offices | | | (3) | (4) | (5) | | | (3) To be assessed on the basis of frequency of release and dispersion calculations.<br>(4) Discuss the single case in a safety review. Consequences of a toxic emission from a leak of the same size are quite different from LPG-spill which is only flammable.<br>(5) Determine according to a risk assessment. |
| • Separation distance between the storage vessel(s) and: | ‘ok’ if the case study plan depicted separation distances are satisfactory | | | | | | | |
| - Product office & driver’s amenities | | | (3) | (4) | (5) | | | (3) To be assessed on the basis of frequency of release and dispersion calculations.<br>(4) Discuss the single case in a safety review. Consequences of a toxic emission from a leak of the same size are quite different from LPG-spill which is only flammable.<br>(5) Determine according to a risk assessment. |
| - Site fence | (1) | | (3) | (4) | (5) | | | (1) 120 m due to the max. separation distance in TRB 801 N0. 25, appendix.<br>(3) To be assessed on the basis of frequency of release and dispersion calculations.<br>(4) Discuss the single case in a safety review. Consequences of a toxic emission from a leak of the same size are quite different from LPG-spill which is only inflammable.<br>(5) Determine according to a risk assessment. |
| • Secondary fire/BLEVE protection | (1) | | (3) | (4) | (5) | | | (1) Top deluge and sprinkler.<br>(3) As for non-toxics.<br>(4) Should be the same as for other LPG, but removal of contaminated fire water may become a problem, retention basin?<br>(5) As for non-toxics. |
| • Overpressure protection | (1) | | (3) | (4) | (5) | | | (1) Safety valve and 2 high pressure switches.<br>(3) As for non-toxics.<br>(4) No relief valve vents to atmosphere allowed.<br>(5) As for non-toxics because relief to flare. |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| • Connections to storage vessel(s) | (1) | | (3) | (4) | (5) | | | (1) Due to TRB 801 No. 25 appendix and TRB 601.<br>(3) As for non-toxics.<br>(4) Water spray, controlled removal of contaminated water.<br>(5) As for non-toxics. |
| • Leak management | (1) | | (3) | (4) | (5) | | | (1) Due to TRB 801 No. 25 appendix and TRB 601.<br>(3) Spill containment in bund or drainage to a nearby basin if Above-ground vessel.<br>(4) Discuss the single case in a safety review. Consequences of a toxic emission from a leak of the same size are quite different from LPG-spill which is only inflammable. Tolerable concentration may be 1/1000 of LEL.<br>(5) For toxic would want to limit evaporation area. |
| • Area Classification | (1) | | | (4) | (5) | | | (1) Due to TRB 801 No. 25 appendix and TRB 601.<br>(4) Follow guidelines, but with respect to Note 10 area classification is not the predominant problem.<br>(5) As for non-toxics. |
| • Monitoring arrangements | (1) | | | (4) | | | | (1) Due to TRB 801 No. 25 appendix and TRB 601.<br>(4) Discuss the single case in a safety review.<br>(5) Determine according to a risk assessment. |

Basis of selection (*numeral indicates participant concerned*)

(2) Company standard practice or guideline.

(5) Risk Assessment

# 15. References

(1) Fire protection of Pressurised LPG Storage and the Prevention of BLEVEs -EPSC

Communication 24th February 1998.

(2) Comparison of Selected LPG Related Codes and Standards – Community Documentation Centre on Industrial Risk, Institute for Systems Engineering and Informatics, Commission of the

European Communities, EUR 14636 EN, 1992. (ISBN 92-826-4737-4)

# 16. EPSC Questionnaire – Summary of Responses

21 companies responded 5 of which stated that they had no LPG (>3 tes) storage units. The summary below relates to the responses of those 16 companies which do possess LPG (>3 tes) storage units.

Some interpretation of individual responses was necessary in order to formulate this summary.

(x) denotes the number of companies who provided the associated response.

| Question | Response |
|---|---|
| Q1 (a). What types of pressurised LPG storage (>3tes) does your company use? | • Above ground<br>▪ Spheres (2)<br>▪ Horizontal drums (3)<br>▪ Vessel type not specified (10)<br>• Buried (3)<br>• Mounded –<br>▪ Horizontal drums (2)<br>▪ Vessel type not specified (5) |
| Q1 (b). What design is preferred for new installations? | • No comment (7)<br>• Depends on capacity and location (2)<br>• Favoured arrangement – Fully refrigerated (1)<br>• Above ground (7)<br>• Buried (0)<br>• Mounded (2)<br>• Buried to be avoided if regulations allow (2) |
| Q2. What fire protection arrangements are used? | • Depends on capacity and location (1)<br>• PSVs rated for fire (3)<br>• Active<br>• Active protection systems preferred (1)<br>• Type not specified (3)<br>o Back-up to passive protection arrangements (2)<br>o No fixed provisions on small installations (2)<br>• Water sprinklers / sprays / flooding / top deluge systems (10)<br>o Fusible plug / heat / flame sensor initiated (4)<br>o On all installations > 5m$^3$ capacity (1)<br>• Fixed water monitors (6)<br>o Back-up to top deluge (2)<br>o Back-up to sprinklers (1)<br>• Water flooding (1)<br>• Water application rate<br>o Spheres require 100 l/m$^2$ h (TRB 610, App 8) (1) |

| | |
|---|---|
| | o 10 l/m2/min spray / sprinkler / deluge systems (3)<br>o Determined by risk analysis (1)<br>o Monitor system 1000 usgpm for 2 hours (1)<br><br>• Passive<br>• Passive protection systems preferred (1)<br>• Mounding (2)<br>• Fireproofed vessel supports (2)<br>• Sheeted fire resistant insulation (class 0-25, ASTM E-84) (1)<br>• Fire resistant coatings on vessels (2)<br>o Vessels < 100 tes (1)<br>o Preferred to mounding (1)<br>o On exposed surfaces (1)<br>o Underside of tanks (1) |
| Q3. What other measures are employed to prevent escalation / BLEVE? | • Selection of measures applied depends on<br>• Location<br>• Outcome of risk assessment (2)<br>• Proprietary arrangements (Sulzer-Ringe) (1)<br>• Vessel size minimisation (1)<br>• Separation distance extension<br>• Between LPG storage vessels (8)<br>• To other systems / equipment (7)<br>• To LPG unloading station (1)<br>• To processing facilities (1)<br>• To storage for other combustible / flammable materials (3)<br>• Surface below storage vessels<br>• Bunded (5)<br>o Shallow sill but no bund (1)<br>• Sloped to prevent liquid accumulation under vessel (6)<br>o And drains to collection / evaporation pit (2)<br>o And drains to sea (1)<br>• Drains to<br>o Collection area (3)<br>o Retaining basin (4)<br>• Surface sloped to prevent accumulation under pump(s) (1)<br>• Enhanced valve and piping standards (1)<br>• Leak points located to prevent flame impingement on storage vessel (1)<br>• Bottom outlet connection<br>• Single bottom outlet connection (1)<br>• No flanges upstream of first valve (1)<br>• First valve is ‘firesafe or ‘trunnion’ type ball valve (1) |

| | |
|---|---|
| | • Second valve is ‘firesafe’ remote actuated (1)<br>• Incorporates<br>o Remote actuated emergency isolation valve (3)<br>o Automatic self closing valve (1)<br>• Line to pump(s) sprinkler protected (2)<br>• Passive fire protection (1)<br>• Inlet line incorporates<br>o Remote actuated emergency isolation valve (2)<br>o Automatic self closing valve (1)<br>• Provisions to limit duration of an LPG release (1)<br>• Piping is vehicle impact protected (1)<br>• Well trained and equipped works fire brigade (1)<br>• Works fire brigade equipped<br>• To cool LPG vessels in the event of fire - Mobile water sprays, monitors, etc. (8)<br>o Back-up to top deluge (2)<br>• To fight LPG fires (3)<br>• Situation specific emergency response plan (5)<br>• Operator training (1) |
| Q4. What monitoring, gas detection, fire detection and activation systems are used for prevention/alerting? | • Video monitoring (2)<br>• Gas detection / alarm system (14)<br>• Isolates inlet and outlet streams (1)<br>• Spilled liquid detection / alarm system (1)<br>• Pressure monitoring / high alarm (6)<br>• Independent PAH (1)<br>• Temperature monitoring / high alarm (5)<br>• Level indication / monitoring (5)<br>• 2*LI + 1*LAH (all independent) (2)<br>• 2*LI (1)<br>• Level recorder<br>• Overfill prevention system (4)<br>• Fire detection / alarm system (7)<br>• Horizontal drums only (1)<br>• Isolates inlet and outlet streams (1)<br>• Sensor wire (1)<br>• Optical (1)<br>• Regular condition monitoring (1)<br>• Design HAZOP (1) |
| Q5. What are the reasons for your company’s use of this predominant design? | • International codes & standards (1)<br>• National codes, standards & regulations (5)<br>• UK LPGITA codes of practice / guidance notes (1)<br>• UK HSE codes of practice / guidance notes (1)<br>• Local regulations / regulatory authority requirement (3)<br>• Outcome of research / incident studies by<br>• Our company (4)<br>• Works fire brigade (1)<br>• Unspecified (3) |

| | |
|---|---|
| | • Operating experience (7)<br>• Host sites determine safety concept (1)<br>• Storage area risk assessments (2)<br>• Safety assessment of the buried LPG storage option in progress (1) |
| Q6. Are you aware of changes to national legislation in any European country since 1990 which relate to LPG storage? | • No (5)<br>• Yes but details not provided (3)<br>• Germany –<br>    • TRB 801 No. 25 (1997) – advises buried storage (1)<br>    • Storfallverordnung directive on major accidents (1)<br>    • New LPG storage directive being prepared (1)<br>• France<br>    • Separation distances to be increased (1)<br>    • Above ground storage to be replaced with mounded storage (1)<br>    • Incorporate internal isolating valves (1)<br>    • Legal requirement for spray rings (1)<br>• Netherlands - Authorities now require refrigerated storage for LPGs (1)<br>• Norway (details not provided) |
| Q7. Has your company carried out or sponsored any research or testing on the practical effectiveness of these designs for fire protection of pressurised LPG storage within the last ten years? | • No (10)<br>• Yes –<br>    • Turbo engine project (1)<br>    • Sphere firewater application rates (by BAM) (1)<br>    • Fire resistant coatings (GASAFE program) (1)<br>    • Intumescent coatings (GESIP) (1)<br>    • Active & passive fire protection systems unspecified (1) |
| Q8. Would your company be willing to send a copy of any LPG Storage guideline / standard you use to the EPSC secretariat for use solely in EPSC Contact Group meetings? | • No<br>    • No company standards/guides specifically relating to LPG storage (5)<br>    • No reasons given (6)<br>• Yes (5) |
| Q9(a). Do you handle LPGs other than Butane/Propane? | • No (4)<br>• Yes<br>    • Listing not provided (3)<br>    • Propylene oxide (1)<br>    • Vinyl chloride monomer (4)<br>    • Ammonia (1)<br>    • Dimethyl ether (2)<br>    • Triethylamine (1)<br>    • Ethylene oxide (2)<br>    • Diethylenetriamine (1)<br>    • Methyl chloride (1)<br>    • Butadiene (2) |

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| | • Ethylene (1)<br>• Propylene (1)<br>• Trimethylamine (1)<br>• Dimethylamine (1)<br><br>• Yes (8) |
| Q9(b). Are the same fire protection measures applied for these substances?<br><br>Q9(c). Are any additional measures taken due to their possible toxic or reactive hazards? | • Depends on nature of material concerned (1)<br>• QRA with additional protective measures added as necessary to meet company risk acceptance criteria (1)<br>• Water spray scrubbing for leaks on systems located in buildings (1)<br>• Works fire brigade has toxic cloud dispersion capability (1)<br>• Propylene oxide<br>  • Thermal insulation added (1)<br>  • Nitrogen blanketing added (1)<br>• Diethylenetriamine<br>  • As for butane/propane (1)<br>• Ethylene oxide<br>  • Double walled vessels (1)<br>• Amines<br>  • Reinforcement of gas detection arrangements (1)<br>• Butadiene<br>  • Reinforcement of gas detection arrangements (1) |