

Appendix 2.

LPG ROAD TANK WAGON PARKING

RISK ASSESSMENT

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Section 0 INTRODUCTION

The HSNO legislation requires a road tank wagon to be parked either in a transit depot (for up to 3 days) or at a hazardous substance location. An amendment to the tank wagon regulations requires that where an LPG tank wagon of greater than 12,000 litres water capacity is parked for a more than an hour then a fixed water spray cage must be provided. This amendment was included in the Gazette Notice amendment without consultation with the LPG industry.

LPG & Safety Consultants Ltd was contracted by the LPG Association to undertake a risk assessment of LPG road tank wagon parking. This report reviews the hazards associated with the parking of LPG road tank wagons and discusses relevant fire protection requirements. Various sections of the report will cover the current NZ scene for road tanker parking, risks with LPG storage, comparison of New Zealand and international legislation, LPG tank wagon safety systems, hazard assessment and conclusions.

References consulted for the preparation of this report were:

- 1 Hazard Study of Liquefied Petroleum Gas in Automotive Retail Outlets, Dept of Environment and Planning, New South Wales
- 2 Risk Management Program Guidance for Propane Storage Facilities (40 CFR Part 68), United States Environment Protection Agency
- 3 Safety Precautions in LPG Transportation, Fire Prevention No 141
- 4 Risk Assessment of Future LPG Facilities in New Zealand, Liquid Fuels Trust Board Report No LF 5006
- 5 Fire Safety Analysis Manual for LP Gas Storage Facilities developed by the National Fire Protection Association and the National Propane Gas Association, United States
- 6 AS/NZS 1596: 2004 the Storage and Handling of LP Gas
- 7 LP-Gas Code Handbook, National Fire Protection Association
- 8 Liquefied Petroleum Gases, Guide to Properties, Applications and Uses Williams and Lom.
- 9 Code of Practice for Vehicles Transporting LP Gas by Road, Dept of Labour, NZ
- 10 BLEVE Probability of an LPG Road Tanker during Unloading, Health and Safety Executive, UK
- 11 Hazardous Goods Storage Facilities, Dept of Labour, NZ

Section 1 EXECUTIVE SUMMARY

A parked road tank wagon presents a lower risk than a stationary tank in that it is not connected to other stationary pipe work, being filled, engaged in pumping, vaporisation or other product transfer operations. All valves and internal valves are closed.

A fire safety analysis as detailed in Section 11 and Appendix O of AS/NZS 1596 should be undertaken for each existing road tanker parking site and any fire protection systems installed where the analysis proves them to be necessary.

Section 2 NEW ZEALAND SCENE

There are 21 transport/transit depots in New Zealand currently used for the parking of LPG road tank wagons. The tank wagons are parked either full or nominally empty on these sites. Of these sites only 8 have some water spray facilities but they do not have sufficient to cover all tank wagons parked.

In addition to this is the need to have tank wagons and equipment maintained periodically at garages and contractors sites around the country. None of these sites will have spray cage facilities. A number of these facilities have operated for the past 25 years without spray cages and without any incidents.

Section 3 RISKS WITH LPG STORAGE

LPG because of its particular physical properties has a greater degree of inherent risk than other common fuels such as petrol or diesel. The particular hazardous properties are:

- (i) It is stored in pressurised form, thus any loss of containment (pipe fracture, flange leakage, etc) will result in the loss of LPG liquid or vapour at a higher rate than a non-pressurised fuel;
- (ii) It is maintained as a liquid due to pressure, thus when released to the atmosphere a significant fraction will vapourise substantially expanding the flammable region;
- (iii) Its vapour is heavier than air thus any leakage will drift at ground level, dispersing at a rate depending on the weather conditions;
- (iv) It can be involved in open-air unconfined explosions if present in sufficient amount.

To counter the greater inherent risk there are several safety features incorporated in LPG tank wagon designs, these features are discussed in Section 5.

In this section, the types of incident that can occur with LPG are reviewed. Subsequently, in the hazard analysis, calculations will be presented to quantify the likely consequences of these incidents.

3.1 Leakage of LPG

Leakage of LPG is the most common type of incident reported. There are many possible leakage points on an LPG tank wagon. The most likely leakage points are:

- Pump seal failure;
- Flange leakage;
- Connecting pipework crack or fracture;
- Hose leakage;
- Relief valve leakage

Leakage from the tank is unlikely as these are strong pressure vessels. Although a number of tank wagons have been involved in road accidents, any subsequent leaks have been from pipework and fittings rather than from a punctured tank. It should be noted that even when road tankers have been involved in road accidents gas leaks have been very rare.

Although the consequences of a leakage can be severe, in the majority of cases the vapour disperses away safely. The criterion for safe dispersal is that the vapour must fall below the lower flammable limit (LFL = 2.0% in the case of LPG). This requires a 50:1 dilution with air. In the case of small leakages this distance is small - 10 litres/minute of LPG will disperse below the LFL within 3 metres in most circumstances. Larger leakages can take greater distances to disperse safely.

The main hazard from leakage is a flash fire and if a very large leakage occurs an explosion is possible. As LPG vapour disperses, because it is heavier than air, it will flow along the ground in cloud-form, between 10cm - 1m in depth, depending on the size of the release. Dense vapour clouds disperse less rapidly than buoyant gas releases (such as natural gas) and their movement is related to the slope of the ground as well as the wind direction. If the cloud drifts into an ignition source (e.g. open flame, lighted cigarette, heater, running car engine, etc.) while it is above the lower flammable limit, then the cloud may catch fire and the flame will flash back to the source of the leakage. Any person within or adjacent to the flash fire would probably suffer serious or fatal injury.

There are no significant toxic effects with LPG. Also, asphyxiation is unlikely given the amount of LPG on site and the open air environment.

3.2 Leakage and explosion

With very large releases of LPG, if ignited, the flame front can accelerate sufficiently to cause an explosion. Such open-air explosions are called unconfined vapour cloud explosions (UVCE). These are different to confined vapour explosions which require very much less flammable vapour to explode.

There have been 114 UVCE's between 1930 and 1974 worldwide. There is very little international data for the period since 1974. These UVCE's have mostly been associated with relatively large chemical processing works. In the UK, the Government Committee on Major Hazards originally proposed that 15 tonnes of fuel within the flammable limits was the minimum necessary to permit a UVCE. Less than this amount was thought to produce a flash fire. However, a major UVCE at Beek in Holland involving 5.5 tonnes of propylene (an LPG material) clearly challenged this view. Subsequently the Dutch Committee for the Prevention of Disasters suggested that as little as 100kg (0.1 tonne) of fuel could cause a UVCE. They now use several hundred kg of fuel as the lower limit, however.

With regard to the smallest amount of LPG necessary to cause a UVCE, 5 tonnes would seem to be the lower limit. As mentioned there have only been 114 UVCE's worldwide (up to 1974) and most of these have been associated with large releases (20-100 tonnes). There would have been many more small releases than large ones.

Thus the accident record does suggest smaller leaks (say under 5 tonnes) are more likely to catch fire than explode.

Tank wagons vary in size with a typical wagon holding 13 tonnes and the largest 18 tonnes. In any case of LPG release, a significant fraction (about 35%) will immediately vapourise and form a cloud. Some of the liquid will stay in the cloud as aerosol and some will rain out onto the ground, where it will boil off to vapour slowly. Thus the likely maximum size of cloud within the flammable limits from a 13 tonne truck around 7 tonnes and from an 18 tonne truck around 9.5 tonnes. This assumes complete tank failure. It is difficult to propose a credible mechanism for this to occur in practice other than one associated with fire, in which case a BLEVE rather than a UVCE will occur.

3.3 Leakage and Fire

Following leakage, fire must be considered likely. LPG is highly flammable and on site control of sources of ignition is important.

The primary hazard to on site and neighbouring land uses from a leakage and fire is thermal radiation. If the leaking LPG is being consumed by fire, it cannot accumulate to a size sufficient to explode. In practice LPG fires are rarely extinguished until the source of LPG is shut off, as the unignited vapour poses a greater danger than burning LPG being cooled with water sprays and under the supervision of the fire service.

If the leak is under the tank, from the tank wagon pipework, then the flame will heat the tank and its contents, thereby increasing the internal tank pressure. The relief valve on an LPG tank will pop open at about 1.7 MPa. This corresponds to a propane liquid temperature of 52°C. The amount of LPG released will be large and as fire is present, it will almost certainly catch fire. Because of the greater flow rate and higher point of release (top of vessel), the amount of thermal radiation received at neighbouring land-uses will be much greater.

3.4 Leakage, Fire and BLEVE

A particular hazard with pressurised liquefied gas storage in a fire situation is a BLEVE - Boiling Liquid Expanding Vapour Explosion. This is a major fireball-type incident.

The cause of BLEVE is sudden rupture of a pressure vessel in a fire, thereby releasing the flammable contents rapidly and violently. Once the pressure is lost the released contents will instantly boil, creating 250 volumes of vapour for each volume of liquid vapourised. Thus the tank contents expand rapidly simultaneously the expanding cloud will be ignited by the existing fire. Fire causes the expanding cloud to be buoyant and it will rise in a characteristic fireball shape. The whole release and combustion takes place in 4-15 seconds, depending on the quantity of fuel. Thermal radiation levels are intense and there is no warning time to take cover, Although BLEVE is referred to as an explosion, the main hazard to humans is thermal radiation. Overpressure effects are minor.

The usual cause of pressure vessel failure is weakening of the steel shell by incident thermal radiation. In a fire flame can impinge on the tank from below and above. The tank shell will not be significantly heated below the liquid level as the boiling liquid there will cool the steel. However, above the liquid level there is only LPG vapour and this will not cool the steel shell exposed to flame. Thus the steel above the liquid level will be heated to a temperature at which its yield strength is greatly reduced.

LPG tank wagons have relief valves to relieve excess pressure caused by boiling contents in a fire situation. However, these will not reduce the internal pressure, but will only keep it from rising excessively. The pressure vessel is designed on the basis of a certain material strength. If this is weakened by fire it will rupture. Tests have shown that 13mm steel plate exposed to fire will reach 690°C in 8 minutes and that rupture of the pressure vessel would occur 2.5 minutes later. However a road tank wagon would only reach these temperatures if empty and exposed to a major fire.

There are some effective means to protect an LPG road tank wagon from BLEVE:

- Leak free tank, fittings and pipework
- Control of on site sources of ignition
- Fixed water spray system
- Fire proof insulation around the tank

Grading the ground under the tank to drain away liquid aids in BLEVE protection, but is not as effective as any of the above systems.

Fire-proof insulation has some operational problems in that corrosion can occur beneath the insulation on the tank and inspection is made very difficult by the insulation cover.

Section 4 COMPARISON OF LEGISLATION

In this Section of the report, the road tank wagon parking requirements in New Zealand are compared with those required by other overseas codes and legislation. These include USA, UK, and Australian examples.

4.1 New Zealand

The storage and handling of LPG and required separation distances were originally controlled by the New Zealand Dangerous Goods (Class 2 Gases) Regulations, 1980. The parking of road tank wagons was not included in the legislation so the Chief Inspector of Dangerous Goods issued the following guidelines for the approval of tank wagon parking areas.

OVERNIGHT PARKING OF FILLED OR PARTLY FILLED LPG TANKWAGON (Set of Conditions used as a basis for Approval)

- 1 Approval will be limited to 100,000 litres (w.c.) in tank wagons unless the subject of special consideration. Note - the above figure includes Class 3 and Class 2(d) tank wagons if both units are parked in the one depot.*

2. *Regardless of the size of depot, if Class 2(d) tank wagons are parked within the depot they are to be treated on the basis of storage in static tanks and the appropriate isolation distances and provisions applied as follows:*

(a) *Tank wagons to be isolated from protected works and public places as per table - Reg 71(2)*

LPG SEPARATION DISTANCES

<i>Tank capacity</i>	<i>public place</i>	<i>protected work</i>
<i>Under 500 litres</i>	<i>2m</i>	<i>2m</i>
<i>500 - 1,000</i>	<i>3m</i>	<i>3m</i>
<i>1,000 - 5,000</i>	<i>5m</i>	<i>8m</i>
<i>5,000 - 10,000</i>	<i>7m</i>	<i>11m</i>
<i>10,000 - 20,000</i>	<i>9m</i>	<i>15m</i>
<i>20,000 - 50,000</i>	<i>10m</i>	<i>17m</i>

(b) *Tank wagons to be separated by two thirds diameter of tank or 1m if tanks under 100,000 lts or 2m if tanks exceed 10,000 lts - Reg. 71 (7).*

(c) *Tank wagons not to be parked end to end - Reg. 71(7)*

(d) *No parking within a Class 3 compound or within 3m of the wall of a Class 3 compound - Reg. 71(9) (a)*

(e) *No parking closer to Class 3 tanks than 6m for tanks up to 100,000 lts water capacity or 15m for tanks in excess of 100,000 lts. - Reg 71(9) (b) Note: These distances also apply to underground tank fill, dip and vent pipes.*

(f) (i) *Parking area not to be located beneath power lines.*
(ii) *Parking area is not located in depression in the ground or compounded unless approved*
(iii) *If tank wagons are of more than 7,500 lts capacity, they shall be isolated from entry points to drains by the appropriate public place isolation distance Reg. 69 - Note oil sumps and separator traps not permitted in parking area.*

(g) *Parking area to be fenced, unless forming part of larger fenced area from which the public are excluded. Reg. 57.*

(h) *All sources of ignition to be isolated from the parking area by the appropriate public place isolation distance Reg. 73.*

(i) *Parking area to be cleared of all rubbish and combustible vegetation by 3m. This distance to be increased to 8m if capacity of tank wagon is over 20,000 lts - Reg. 81.*

(j) *Notices to be displayed in approved locations at parking area Reg. 82(1)*

(k) *Appropriate fire extinguishing apparatus to be provided for parking area as per Reg 78*

3. General

- (a) *Parking of tank wagon units to be so arranged, that they will not impede fire fighting access to any part of the premises.*
- (b) *Tractor units must remain attached to semi-trailers when parked overnight unless:*
- (i) *The unit is adequately designed to withstand all forces on their legs in the as loaded condition without the tractor unit attached; and*
 - (ii) *A suitable tractor unit is available to shift the semi-trailers should the need arise.*
- (c) *Arrangements are to be made for the removal of the tank wagons by authorised personnel, in the event of an emergency near the parking area.*
- (d) *The fire service to be advised of the presence of overnight tank wagon parking facilities.*
- (e) *Adequate illumination must be available to ensure that vehicles can be removed from the site should the need arise.*

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Note: Conditions 3 (b) (i) and (ii) are only applicable to units awaiting transfer between the North and South Islands with Chief Inspectors Approval.

There were no requirements for water spray cages to be installed at road tank wagon parking facilities. These conditions were never issued to the LPG industry and were never written into subsequent revisions of the Dangerous Goods Regulations.

Road Tanker Parking under HSNO legislation

As mentioned above under the old Dangerous Goods Regulations the parking of road tank wagons was covered by a directive from the Chief Inspector of Dangerous Goods, Dept of Labour. These directives do not remain in force under the HSNO legislation and the parking of road tankers is covered by a number of interpretations from ERMA, parts of the Controls Regulations and Gazette Notice 35 as amended. This document sets out the interpretations and the requirements of the HSNO legislation.

Test Certifier Update 15 (15 July 2005) posed the following question:

"If a container is located on a trailer or rail wagon whether connected or not to a tractor unit and is parked at a location, is the location considered a transit depot?"

The answer lies in whether or not the driver is in control.

In our view (ERMA) the definition of transit depot in the Hazardous Substance (Classes 1 to 5 Controls) Regulations is structured in this manner to distinguish between a vehicle that is under the control of the driver (i. e. at the truck or near to it and who should hold the appropriate licence such that he/she is deemed to be the approved handler) and a truck that is parked up without the driver being present. Hence when a truck with a container of hazardous substances is parked up for more than the stipulated time period without the driver being present, the place where it is parked is required to meet the requirements of a transit depot. "

Test Certifier Update 24 (18 November 2005) states:

"A road tanker may only be left unattended for 5 minutes and then only under specified conditions that are set out in regulation 41 of the Hazardous Substances (Tank Wagons and Transportable Containers) Regulations. Otherwise, the road tank wagon must be parked at a transit depot (for up to three days) or at a hazardous substance location.

Tank wagon operators are encouraged to park with the tanker nominally empty, however, for logistical reasons this may not always be practicable. When tank wagons are parked the aboveground tank isolation distances should be used as well as satisfying the separation distances from high and/or low intensity land use.

The requirement at a transit depot for flammable substances is set out in regulation 83 of the Hazardous Substances (Class 1 to 5 Controls) Regulations. Separation distances are specified where a road tanker is loaded with "containers". A container is not specifically defined but the interpretation is that these include packages and transportable containers. A tank wagon is a vehicle but when parked it is more appropriate to consider it a tank. Gazette Notice 35 provides separation distances for tank wagons from both HILU and LILU".

Regulation 55 of the Hazardous Substances (Classes 1 to 5 Controls) Regulations 2001 (as amended) requires that where over 100kg of LPG is present for more than 18 hours it must be stored in a hazardous substance location or transit depot.

TRANSIT DEPOT REQUIREMENTS

A transit depot is defined as a permanent place used as a transport depot that is designed to hold hazardous substances in closed containers for periods that are more than 18 hours and not more than 3 days. It excludes a means of transport, and any place where the substances are held for sale or supply.

Regulation 83 of the Controls Regulations requires the person in charge of the transit depot to carry out the following:

- 1 Notify an enforcement officer 30 days prior to commencing storage.
- 2 The approved handler requirements of regulation 56 are met.
- 3 Intertank separation of:
 - (a) 3 metres from other vehicles with compatible substances;
 - (b) 5 metres from other vehicles with incompatible substances;
 - (c) 3 metres from compatible containers not on a vehicle;

- (d) 5 metres from incompatible containers not on a vehicle.
- 4 Substances not on a vehicle are kept 5 metres from incompatible substances.
- 5 Ensure all substances located at the depot remain within their container and the containers remain closed.
- 6 Ensure any electrical equipment at the depot will not become an ignition source.
- 7 Ensure there is compliance with the signage requirements of the Identification Regulations.

Part 2 of Schedule 10 of Gazette Notice 35 (as amended) details the requirements for "Separation of substances not located at a hazardous substance location." In particular clause 8 contains the isolation distances from high and low intensity land use areas for aboveground stationary tanks, transportable containers or tank wagons. In reality this requires the following isolation distances for road tankers parked in a transit depot:

Size of tank		HILU	LILU
Water capacity	(tonnes)	(metres)	(metres)
20,000	10	15	9
24,000	12	15.36	9.18
30,000	15	15.9	9.45
36,000	18	16.44	9.72
40,000	20	16.8	9.9
50,000	25	17	10

HAZARDOUS SUBSTANCE LOCATION REQUIREMENTS

Regulation 77 details the requirements for the person in charge of a place to establish a hazardous substance location. The brief details of these requirements are:

- 1 Notify an enforcement officer of the street address and maximum quantity and hazard classification of all substances present.
- 2 Appoint approved handlers where required.
- 3 Acquire any relevant test certificates as required.
- 4 Have a site plan available for inspection.
- 5 Have a hazardous area and controlled zone drawing available.
- 6 Establish and maintain hazardous atmosphere zones.

Regulation 81 sets out the test certification requirements for hazardous substance locations. The person in charge of the location where the substances are present must ensure that the location or place has a current test certificate certifying that:

- 1 An enforcement officer has been notified.
- 2 Substances are under the control of an approved handler where necessary.
- 3 The substances are secured.
- 4 A hazardous atmosphere zone is established and documented.
- 5 Incompatible substances are separated.
- 6 Signage requirements of the Identification Regulations are met.
- 7 Emergency Management Regulation requirements are met.

- 8 Site plans etc as required by regulation 77 have been met.
- 9 The requirements of schedule 10 of Gazette Notice 35 are met.

Part 3 of Schedule 10 of Gazette Notice 35 (as amended) details the requirements for: "Separation of substances present at hazardous substance location." In particular clause 21 contains the requirement to isolate aboveground stationary tanks, transportable containers or tank wagons from the boundary of a controlled zone. In reality this requires the following isolation distances for road tankers parked in a location:

Size of tank		HILU	LILU
Water capacity	(tonnes)	(metres)	(metres)
20,000	10	15	9
24,000	12	15.36	9.18
30,000	15	15.9	9.45
36,000	18	16.44	9.72
40,000	20	16.8	9.9
50,000	25	17	10

Clause 32 allows isolation distances to extend beyond a boundary if agreement with the neighbouring property owner is obtained. Clause 33 allows up to 50% isolation reduction provided certain criteria for screen walls are put in place.

There are no requirements in schedule 10 for water spray cage; these requirements are set out in Part 9 of Schedule 8 "Controls for stationary container systems". Clause 4 I (2) set out the facilities for fighting a fire that must be available in respect of every above ground stationary tank. An above ground stationary tank is a stationary tank that is fixed to or resting on the ground; or fixed or attached to a structure that is fixed to or resting on the ground. A stationary tank is a tank that is used for the storage or supply of hazardous substances and is normally located at a specific place. It can be debated whether this definition includes a parked up road tank wagon. In my opinion it does not as the tank is not fixed or resting on the ground. A parked tank wagon also presents a lower risk than a stationary tank in that it is not connected to other stationary pipework, being refilled, engaged in pumping, vaporisation or other product transfer operations and all valves and internal valves are closed.

However Gazette Notice No 70 dated 27 June 2006 included an amendment to Regulation 42 of the Hazardous Substances (Tank Wagon and Transportable Containers) Regulations 2004. This amendment introduced a requirement that all LPG tank wagons over 12,000 litres water capacity are required to park under a water spray cage if they are parked for a period of time greater than one hour. If the tank wagon is in gaseous form only then a hydrant and monitor or equivalent need only be provided.

This amendment was added after the consultation on the matters to be included in the Gazette Notice was concluded so there was no possibility of industry discussion on these requirements.

4.2 United States

Separation distances in the United States are those recommended in the National Fire Protection Association Code for the Storage and Handling of Liquefied Petroleum Gases (NFPA 58). The NFPA 58 Code is one of the longest standing codes for liquefied petroleum gas. It was originally issued in 1940 and it has been updated and amended many times since then.

Separation distances are specified in Paragraph 3-2.2.2 of NFPA 58 (1998 edition). These are listed below.

NFPA 58 LPG RECOMMENDED SEPARATION DISTANCES

Tank capacity	Minimum required separation distances
Under 500 litres	nil
500 – 1,000	3m
1,000 – 1,900	3m
1,900 – 7,600	7.6m
7,600 – 114,000	15m

The separations specified in this Table are measured from the tank to the nearest building or line of adjoining property which may be built upon. The Code requires a fire safety analysis for storage tanks containing over 15,000 litres water capacity. In heavily populated or congested areas, the Code suggests the recommended separation distances be modified, based on the findings of the fire safety analysis. There are no specific requirements for water spray cages over parked road tank wagons.

Section 6 of the Code covers the Vehicular Transportation of LP-Gas and includes the parking and garaging of vehicles. All vehicles have to conform to DOT Hazardous Material Regulations (Title 49 Code of Federal Regulations) for interstate and interprovince transportation, NFPA 58 included these requirements together with additional requirements for intrastate and intraprovince transportation. The specific parking requirements are as follows:

Section 6-6 Parking and Garaging Vehicles Used to Carry LP-Gas Cargo

6-6.1 Application

This section applies to the parking (except parking associated with a liquid transfer operation) and garaging of vehicles used for the transportation of LP-Gas. Such vehicles include those used to carry portable containers (cylinders) and those used to carry LP-Gas cargo tanks (road tank wagons).

6-6.2 Parking

6-6.2.1 Vehicles carrying or containing LP-Gas parked outdoors shall comply with the following:

- (a) Vehicles shall not be left unattended on any street, highway, avenue, or alley, provided that drivers are not prevented from those necessary absences from the vehicle connected with their normal duties, nor shall this requirement prevent stops for meals or rest stops during the day or night.*

- (b) *Vehicles shall not be parked in congested areas. Such vehicles shall be permitted to be parked off the street in uncongested areas if at least 15 m from any building used for assembly, institutional, or multiple residential occupancy. This requirement shall not prohibit the parking of vehicles carrying portable containers or cargo vehicles of up to 13,000 litres water capacity or less on streets adjacent to the driver's residence in uncongested residential areas, provided such parking locations are at least 15 m from a building used for assembly, institutional, or multiple residential occupancy.*

The remainder of the section deals with the parking of vehicles inside a building. There are no fire protection requirements for the parking of the vehicles nor are these included in the fire safety analysis requirements.

4.3 United Kingdom

The Health and Safety at Work Act 1974, is the central legislation covering safety in the UK. The Health and Safety Executive (HSE) is its executive body. The HSE at its creation adopted existing Codes of Practice. In the case of LPG this was originally a Home Office Code.

The HSE has reissued the Code with some amendments as document HS/ G34: The Storage of LPG at Fixed Installations. The purpose of the code is to guide local authorities responsible for enforcing safety requirements at such sites. The Code sets out spacing requirements for bulk sites and industrial/commercial/domestic sites.

HS/G34 LPG SEPARATION DISTANCES

Tank capacity	Minimum separation distance
150 - 500 litres	2.5m
500 – 2,500 litres	3m
2,500 – 9,000 litres	7.5m
9,000 - 135,000 litres	15m

The separation distances in this Table are measured from the tank to the nearest building, boundary or property line or fixed source of ignition. There do not appear to be any specific requirements for the parking of road tank wagons or requirements for water spray cages for tank wagons.

4.4 Australia

Clause 10.8.5 of Standard AS/NZS 1596 sets out requirements for the parking and garaging of a road tank wagon. It states:

Vehicles which carry or contain LP Gas, other than in the vehicle's engine fuel tank, shall not be parked within any building other than a shelter which has at least three sides open, or is otherwise designed so as to permit complete dispersal of any LP Gas that may escape.

There is no other specific parking or fire protection requirements for tank wagons.

However it would be prudent to isolate the tank wagon as if it was an aboveground tank. The standard differentiates between two types of adjacent land uses: protected works and public places. A protected work would be a building normally containing people, a storage area for hazardous materials, or a berthed ship. Typical buildings include dwellings, churches, schools, hospitals, offices and factories. Specifically excluded is the office of the LPG facility itself. A public place is any place, other than private property, open to the public and including a street or road.

LP GAS RECOMMENDED SEPARATION DISTANCES

Tank capacity	Minimum recommended separation distances	
	Public Places	Protected Places
Under 500 litres	nil	nil
1,000	2	3
8,000	6	10
10,000	7	11
20,000	9	15
50,000	10	17

To determine any fire protection requirements a fire safety site evaluation is required using section 11 Fire Safety and Appendix O Fire Exposure Protection. The principle used is to protect the tank wagon from a neighbouring building fire.

5.5 Separation distances by hazard assessment

Most legislation for the storage of hazardous materials set out minimum separation distances without stating the basis for the distances. In fact, two concepts underlie these; previous experience and protection of the tank from external activities. For the first, accident records are analysed and if they are sufficiently serious and/or frequent, then separation distances may be increased. The reasons for this may be more related to access for emergency services than to potential consequences. A problem with this approach is that as new facilities are developed, they are often different in design to earlier facilities and often larger in scale. Also a feature of accident statistics is that often a report is made only if some injury or death has occurred. Serious incidents that do not because casualties may be unreported (e.g. a large flammable vapour release that disperses safely rather than being ignited). The second concept, protection of the tank, is based on the rationale that the tank will safely contain the LPG provided that its integrity is not jeopardised by external activities (such as ignition sources, electrical wiring, vehicle movements, etc.). By requiring some minimum separation these external activities are kept away from the tank.

An alternative approach to setting separation distances is one based on a hazard assessment of the facility to predict likely consequences from a range of possible incidents. This can be further broken down depending on whether a single major incident is selected as the basis (maximum credible incident or worst possible incident methods) or whether all possible incidents are identified and probabilities included to determine some overall level of risk (full hazard assessment method). The philosophy is quite different to that involved in setting code distances. Here the potential for the hazardous material to escape from containment and thence to catch fire or explode or harmlessly disperse is assessed. If fire or explosion result, models are available to

predict thermal radiation levels or blast intensities at various distances. As thermal and blast effects on people and buildings are well known, separation distances can be set to minimise the consequences of death or injury.

Thermal separation distances due to fire incidents are based on the maximum permissible incident heat flux at neighbouring locations:

Outdoor recreation areas, beaches	5 kw/m ²
Residential dwellings, vulnerable storage	12.5 kw/m ²
Public roads, railways	21 kw/m ²
Property line of LNG facility	31.5 kw/m ²

The value of 5kw/m² is in general agreement with API Code RP 521 for the design of safe exclusion zones for people around flares or other process vents. The 12.5 kw/m² level is sufficient to cause combustible materials to ignite spontaneously after 20 minutes exposure.

Flammable gas dispersion is based on the maximum pipeline rupture case with spill duration of not less than 10 minutes. The separation distance is the distance calculated for the gas cloud to reach one half of the lower flammable limit. The 1/2 LFL criterion allows for inaccuracies in model predictions and any in homogeneity in vapour cloud concentrations. The probability of cloud ignition or of wind direction is not included in calculating the separation distances.

There is no equivalent code for LPG installations. However the types of hazard posed by the two materials (LPG and LNG) are similar and thus the underlying philosophy is still relevant.

It is worth noting that the Standards Association of Australia already recognises the principle of setting safety requirements according to the nature of the groups at risk. For example the Refrigeration Code AS 1677 (which covers toxic refrigerants) classifies buildings by the vulnerability /mobility /organisation of the people inside them. In order of decreasing vulnerability class and thus decreasing safety requirements are:

- Public institutions – hospitals, prison
- Public buildings – halls, theatres
- Residential dwellings
- Commercial premises – public may be present
- Industrial premises – employees only

5. LPG TANK WAGON SAFETY SYSTEMS

There are several safety systems for protecting an LPG tank wagon. These are usually required by legislation, standards and codes. The safety systems, taken as a whole, are substantially more stringent than apply to petrol or most other hydrocarbon storage facilities. This is recognition of the inherently greater risks with LPG and the accumulated experience of preventable accidents.

Some of the more important safety features for LPG tank wagons are discussed in this section. The purpose is to highlight the specific details of each device, how it protects the tank wagon, and under what circumstances it might fail. The items to be discussed include:

- Tank design
- Pressure relief valves
- Remotely actuated isolation valve
- Excess flow valve
- Crash barriers

5.1 Tank design

All LPG tank wagons must be built to comply with internationally recognised pressure vessel standards. These are subject to annual independent third party inspection to ensure continued compliance with the design codes.

Most codes require tank wagons be designed for a pressure of 1.75 MPa. This is roughly equivalent to the pressure that would exist with propane contents at 50°C. With white painted tanks, this temperature is unlikely to be exceeded under any summer temperature conditions. However, an external fire could raise the temperature (and hence pressure) of the contents above this design value. A pressure relief valve is required to prevent the internal pressure rising significantly above design by venting vapour to the atmosphere.

5.2 Pressure relief valves

Relief valves are devices used to relieve excess pressure and thus to protect a pressure container from bursting. Tank wagon codes require pressure vessel to be fitted with one or more pressure relief valve to vent vapour to the atmosphere in the event of excess pressure within the tank. The relief valve consists of a spring-loaded plug which sits on an orifice open to the tank. When an excess pressure exists in the tank, the pressure force acting on the bottom of the plug overcomes the spring force holding it in place and the valve pops open. LPG vapour from the tank then vents to the atmosphere until the pressure falls below the set point of the relief valve. The relief valve is sized to cope with a pool fire engulfing the tank. The release of LPG vapour to the atmosphere is hazardous, but less so than over pressuring the tank as that could otherwise burst and results in the rapid loss of total vessel contents, leading to a BLEVE or fireball.

Causes for tank overpressure and thus relief valve release include tank overfilling and external heat input (such as fire). The largest release, as previously noted, is caused by a pool fire engulfing the vessel. In such a case, the LPG vented would also catch fire, significantly increasing the thermal radiation at neighbouring land-uses. Note however, that if the vent catches fire all the LPG is consumed in the flame and thus a large, flammable, heavy gas cloud could not form and drift downwind. A release caused by overfilling or by a fire at one end of the vessel away from the relief valve would give rise to a release that might or might not ignite. Static electricity caused by the velocity of the discharge might ignite the LPG even where no fire is involved, however.

A relief valve must always be freely open to the tank and to the atmosphere. No intervening block valve or excess flow valve may be fitted. The relief valve is always located on the top of the tank so that vapour and not liquid is relieved.

5.3 Remotely actuated isolation valve

The liquid outlet on the bottom of an LPG road tank wagon delivers LPG to the pump for delivery. A leakage from this line (50mm diameter) could be very large. Consequently, codes require the installation of a remotely actuated isolation valve (also known as a quick closing internal valve).

The valve must be located adjacent to the tank shell on the liquid outlet line. It can be pneumatically operated, shutting on loss of air pressure or held open using a fusible link during discharge but closed on completion of the tanker operations. This type of valve is common in industry and has proven to be very reliable as it is fail-safe. Any fault in the pneumatic actuation system or fusible link will result in the valve closing to its safe position.

5.4 Excess flow valves

Excess flow valves are required to be fitted to all significant openings on an LPG tank wagon, other than the relief valve opening. They are designed to shut automatically when the flow passing through the valve exceeds some set point, typically 1.5 times the normal maximum flow rate. A key feature of excess flow valves is that like relief valves they are passive safety devices. No human intervention is required for their operation. In the event of some failure in the pipework, pump or delivery hose, the loss of downstream pressure causes a sudden increase in flow rate shutting the excess flow valve. All the excess flow valves had shut, allowing only their small designed bleed flow to occur.

The provision of excess flow valves is a significant safety feature. They greatly improve the system safety, countering the greater inherent risks of LPG compared with petrol. In the event of some major leakage downstream, there would be a loss of backpressure and the flow rate would increase significantly, posing a major hazard if venting to atmosphere. However, the pressure difference would overcome the spring and automatically return the valve to the closed position. The excess flow valve would stay in this position, bleeding LPG slowly across the valve seat. The bleed rate is insufficient to pose any significant hazard. Even in the event of an external fire, flames cannot propagate back through the valve as there is no air inside the tank to support combustion.

5.5 Crash barriers

The purpose of crash barriers is fairly obvious. They are required by standards and codes to prevent damage to the parked tank wagon, its associated pipework from manoeuvring vehicles. Stanchions or ARMCO guard rails are usually specified for this purpose.

Stanchions are 1.2m high 75mm diameter pipes filled with concrete 1.5m away from the tank wagon and spaced 1.2m apart. The ARMCO railing must be 700mm high and at least 1.5m away from the tank.

In assessing the likely causes of incidents that might affect neighbouring land uses, the possibility of vehicle impact on the tank wagon must be considered as one of the more credible incidents. Specific incidents could include:

- (a) Low speed car manoeuvring impact into crash barriers;
- (b) Low speed truck manoeuvring impact into crash barriers.

It is highly unlikely that a low speed manoeuvring car would possess sufficient kinetic energy to knock over either the stanchions or the ARMCO railing. A fully laden 18 tonne capacity LPG tanker wagon and tractor can weigh approximately 40 tonnes and manoeuvring speeds are of the order of 8-12 kilometres/hour. Whilst the brakes on LPG vehicles are invariably well maintained, the surrounding ground can be slippery due to grease or oil spills or the weather. Thus it is quite easy to envisage a truck manoeuvring accident striking the crash barriers at between 8-12 kph.

There are no published data on low speed manoeuvring accidents onto crash barriers. Published data relate to high speed impacts. Nevertheless, there must be real doubt as to whether the 1.2m high 75mm diameter stanchions could halt a fully laden truck, as possibly only 2 stanchions would be hit. The ARMCO guard rails are likely to be more effective. The strength of these rails is not in the horizontal rail rather it is in the vertical supports. The purpose of the railing is to spread a localised impact over several vertical supports, not just those actually hit. The installation of more stanchions, closer together will achieve the same result.

6. Hazard Assessment

The desire of the community to be protected from undue risks from neighbouring hazardous facilities has led to the development of various hazard assessment methodologies. The methodologies differ primarily in whether a single incident is chosen as being the critical one in determining safe operations or whether a whole range of incidents, each with some probability of occurrence, is considered. The former methods are known as worst possible or maximum credible event methods, depending on the incident selected. The latter methods constitute what is known as a full hazard assessment.

The techniques of hazard assessment differ in detail from case to case, but nevertheless they always follow the same basic principles. These are:

1. The identification of a complete set of failure cases which could cause injuries or deaths;
2. The determination of the extent of area in which more than a specified level of damage would occur for each failure case;
3. Estimation of the probability of each failure case;
4. Summation of the damage of the failure cases to determine some overall level of risk.

Each of these steps involves considerable analysis. The identification of failure cases, for example, could be based on an examination of the historical record of incidents, a technical audit by experienced engineers, the results of a hazard and operability study, or judgment and commonsense.

To determine the extent of damage from a single incident, a variety of techniques is needed to cope with the wide variation of possible incidents. Discharge rate models are required for pressurised liquefied gases (such as LPG) and must account for the important two phase (vapour/liquid) flashing flow which occurs after a leakage.

The physical effects of fires and explosions and the determination of the consequences of these on people and structures at various separations are now sufficiently well understood for model estimates to be reasonably accurate. As mentioned previously, however, the lower limit for the quantity of hydrocarbon material that will explode in the open (unconfined vapour cloud explosion) is subject to debate. The dispersion of heavier than air vapours, such as that from LPG, is less well modelled. Many studies use the half LFL (lower flammability limit) rather than the LFL distance for setting separation distances to allow for model inaccuracy and cloud inhomogeneity. Small scale dispersion trials have been carried out and these may be used for guidance.

The prediction of failure probabilities is a difficult task, particularly when the events concerned are extremely rare. Failure rate statistics are available for many components in an LPG storage facility, but care must be exercised in generalising an industry-wide statistic into a particular failure rate for a given component in LPG service. Fault tree analysis is one individual failures contributing to some hazardous incident. Given the relative simplicity of a road tank wagon parking facility, such an approach is not warranted.

6.1 Leakage

Based on the accident record, leakage is the most likely incident. The risk to neighbouring land uses is that the leakage will be of sufficient magnitude to cause a flammable, heavy vapour cloud to form, which will drift across the site boundary and into neighbouring properties. This could be ignited, causing a flash-fire, which would be fatal to anyone within and adjacent to the cloud.

It is industry experience that connecting pipelines and hoses are far more likely to leak than the main pressure vessel itself. The source of the leak may be:

1. Flange leak, flanges are end pieces on pipe lengths, valves and pumps which are bolted together with some intervening sealing material to form pipe systems. Leaks can arise due to loosening the bolts, seal failure, or mechanical stress bending the flange.
2. Pump seal leak, pump seals are necessary where the driving motor shaft enters the pump body; these are subject to wear or even complete failure if excessive vibration or mechanical stress occurs.

- 3 Pipe fracture, this would be most likely due to mechanical impact; LPG is not corrosive or erosive so these are not likely causes.
- 4 Hose leakage, flexible hoses are intrinsically less robust than solid pipework and they may be subject to mishandling and the rubber subject to ageing; leaks are also possible where the hose connects to the end coupling.
- 5 Relief valve, this may leak due to poor reseating after lifting previously or other cause, and as there are no stop valves around the relief, this is difficult to stop.

In fact, designers of LPG tank wagons and regulatory authorities are well aware of all these possible leakage incidents and have included specific safety features to protect against them. Equipment includes excess flow valves, remotely actuated shut-off valves, etc.

Several of the possible leakages are likely to be small and of no consequence to neighbouring land uses. For example, a slightly passing relief valve or pump seal would only give rise to a minor problem. A 2mm diameter hole leaking under full tank pressure will release around 3 kg/min of LPG. Under most atmospheric conditions this will disperse to under the lower flammable limit within 3m from the leak point. This would pose no hazard from a drifting vapour cloud to neighbouring land uses.

However, larger incidents are possible, notably pipe fracture or a leaking delivery hose. The leakage rate is a function of the pressure difference, which itself is determined by the LPG composition and temperature; the table below gives leakage rates for various leak sizes for two compositions at 20°C.

LPG RELEASE RATE FROM VARIOUS SIZED HOLES

Source of Leakage	Leakage diameter	LPG release rate 60:40	
		pure propane	Propane: Butane
Flange seal	2mm	0.052 kg/sec	0.043 kg/sec
Small pipe fracture	25mm	8.1	6.7
Medium pipe frac	50mm	32	27

In practice all pipes and hoses are protected with excess flow valves which would quickly shut. Allowing for the dynamic response of an excess flow valve and the inventory in the line, a loss of up to 100 kg from fracture of the 50mm line must be considered likely. After this loss the leak would be restricted to the small excess flow valve bleed rate which may be ignored in determining safety separation distances to neighbouring land uses. A 50mm line is the most common line size used for pumping LPG on a tank wagon.

Another possible source of leakage is a pump seal or flange leak of only moderate size. If the leakage rate is of the same order or slightly greater than the normal delivery rate then the excess flow valve will not sense an increase in flow and it will not shut. Excess flow valves on the tank wagon are typically up to 100 kg/minute. The rapid loss of 100 kg of LPG liquid will be accompanied by immediate flashing or boiling as the LPG adjusts to ambient pressure conditions. The amount of flashing will be of the order of 30 - 35 %. The vapour will entrain many small droplets and some of the remaining liquid will rain out onto the ground. In the process of flashing to vapour, the liquid is chilled to well below zero and it will quickly boil-off on the ground. Thus spills of the order of 100 kg are likely to form uniform vapour clouds of that mass very quickly.

The most relevant experimental work is that carried out by the U. K. Health and Safety Directorate at Port on Down in 1977. It may be concluded from these experiments that a 100 kg release of LPG should disperse to below the lower flammable limit (2% by volume) within 5 - 15 m under most weather conditions, but under calm conditions, the flammable cloud may extend to beyond 40 m.

Pump seal failure:

Small seal leaks would not give rise to a 100 kg cloud of LPG within the flammable limits. This would require a major shaft/seal failure. As the system is protected by excess flow valves then a 100 kg cloud requires: pump failure, excess flow valve failure or flow below set point, and the failure of the manual actuation of shutoff system. The probability of this is taken as 10 % of the pump failure rate, hence 10×10^{-6} per year (10 chances in a million per year).

LPG hose failure:

LPG hoses are covered by specific standards and codes which lay down mechanical and inspection standards and such hoses are always protected with excess flow valves. The tank wagon hose is used on average 80 hours/year/site (3 times/week for half an hour each time) giving a failure rate of 80×10^{-6} per year. However the hose is not in use when the tank wagon is parked.

Pipe fracture:

A pipe crack or fracture of a liquid line could give rise to a release of the order of 10 kg. The most common pipe size in the LPG system is 50 mm. There would be 3 pipe segments of this approximate dimension carrying liquid. This would give a failure rate of 7.8×10^{-6} per year.

Flange failure:

Most flange leaks are small and would not give rise to a 100 kg flammable vapour cloud. An exception would be a mechanical impact, but such failures are already included in the pipe fracture incident.

6.2 Catastrophic leakage

As well as the medium size leakage, it is important to assess the likelihood of catastrophic vessel failure leading to an almost instantaneous release of the total vessel inventory. This would most likely lead to a BLEVE, flash fire, or if sufficiently large, to an unconfined vapour cloud explosion.

LPG vessels are built to internationally accepted pressure vessel codes which require full X-ray inspection of welds for faults. These could cause shell failure after some period in service; however, most such faults would be expected to be found by visual inspection and in the initial pressure test.

Another factor to consider in assessing the probability of catastrophic failure is the safety features incorporated into an LPG tank. The most important of these are the excess flow valves, the pneumatically operated remote shut-off valve and the crash barriers. The first two protect against nozzle/connection rupture as the flow is shut-off in the event of rupture, while the crash barriers prevent vehicles from crashing into the tank and its main connection.

6.3 Fire

Fire is always an important concern with LPG storage facilities. Once a leak occurs the escaping vapour can find an ignition source and thence flash back to the source of the leakage. The fire will continue to burn until the LPG is exhausted or an upstream valve is closed.

6.3.1 Flash fire

A flash fire of such a leakage would be fatal for any person caught within it. In section 6.1 it is shown that a 100 kg release of LPG will disperse safely within 15m in windy conditions and about 40 m in calm conditions. As windy conditions in general correspond to daytime and calm conditions to nighttimes, it is convenient to separate these two periods.

In daytime there is greater activity on the site, truck deliveries are being made, and there will be several ignition sources about. At night there will be less activity and fewer ignition sources. Thus it is reasonable to apportion 80 % of medium size releases to daytime (90 in a million per year) and 20 % to nighttimes (20 in a million per year).

A reasonable ignition probability for short distance dispersion might be 50 % in the day and 20 % at night. Finally, in terms of fatalities, the risk is direction dependent. That is, if the wind is blowing northwards and the vulnerable land use is to the west, then a flash fire is likely to have no effect. As the area affected is 30 degrees of arc, the probability of being caught within the flammable cloud is $30/360 = 0.083$.

In total, the individual risk from a 100 kg LPG flash fire is a product of the frequency of release, the ignition probability and the affected area.

Daytime release (windy conditions, fatalities within 15 m radius)

Probability of death (within 15 m)

$$= (\text{frequency of release}) \times (\text{ignition probability}) \times (\text{affected area})$$

$$= (90) \times (0.5) \times (0.083)$$

$$= 4 \text{ in a million per year}$$

Night time release (calm conditions, fatalities within 40m radius)

Probability of death (within 40 m)

$$= (20) \times (0.2) \times (0.083)$$

$$= 0.3 \text{ in a million per year}$$

It should be remembered that during the day most tank wagons would be on the road making deliveries.

Other types of fires are possible. These include: pool fires where the flammable material exists in a liquid pool and the vapour above it burns strongly; jet fires where the flammable material is ejected under pressure from the leak point and the flame assumes a highly elongated shape; and BLEVE where all the pressurised flammable material is suddenly released and burns in a rapidly expanding and rising fireball.

In industrial risk assessment, the thermal radiation criterion is 5kw/m² as this corresponds to 16 seconds for pain threshold and 30 seconds for severe burning. It is assumed that a healthy adult can escape to some safe shelter in this time. As it is the standard figure it will be applied to the tank wagon parking.

6.3.2 Pool fires

Pool fires with LPG are less likely than with other fuels because a significant fraction of LPG would vapourise after leaking. The consequences of a pool fire are direct thermal radiation to neighbouring land-uses, and more significantly, warming of the LPG tank wagon. The fire will raise the temperature, and hence pressure of the contents. Once this reaches approximately 1.7 M Pa the relief valve will open to prevent a further rise in pressure. The vapour so released will almost certainly ignite as the vessel itself is being heated by a pool fire. The amount of heat radiated from a relief valve fire will greatly exceed that from the pool fire due to the large amount of vapour that must be relieved to maintain the pressure. Additionally, as the relief occurs from the top of the vessel there is likely to be a clear line of sight to neighbouring land uses. This may not be so for pool fires which are at ground level.

The calculations for pool fire assumed an average intensity of radiation from the surface of the flame of 92kw/m². This is little affected by the composition of the LPG. Using geometric view factors the thermal radiation intensity from the pool fire to

various separations may be readily calculated. Allowance was made for atmospheric absorption of some of the radiant heat.

6.3.3 Jet fires

Jet fires can result when a pipe fracture or other leak occurs. Because LPG is being ejected under pressure it will form a jet and the flame will propagate along the jet. For leaks near the tank, this can result in jet flames impinging directly onto the tank shell. This will heat the tank in a similar manner to the pool fire, with the consequence of higher thermal radiation from the relief valve.

Some comment as to the effectiveness of the design safety factors is warranted. The main liquid line from an LPG tank wagon is fitted with a remotely actuated shut-off valve. This valve is also usually fire actuated by a fusible link. If the source of a fire impinging on the tank is LPG from the main liquid line and the fire impinges on the fusible link, then the valve will almost certainly shut. No device is totally reliable and fusible links do have some history of failures. However, if the source of the fire is other than this then closing of the remotely actuated valve will have no effect on the fire and the relief valve will eventually lift.

6.4 Fire and BLEVE.

The mechanism for a Boiling Liquid Expanding Vapour Explosion (BLEVE) has been previously described as a fire enveloping a pressure vessel. The steel in contact with the LPG vapour, which has poor thermal conductivity, will be heated, weakened, and rupture releasing the full vessel contents virtually instantaneously. The released contents will be ignited by the external fire creating a rapidly expanding fireball.

CONSEQUENCES OF BLEVE FROM TANK WAGON

Tank capacity (Kilograms)	Fireball Dia. (Metres)	Distance to burns (metres)	
		12.5 kw/m ²	1.6 kw/m ²
4,000	92	215	603
10,000	124	290	812
13,000	135	316	884
15,750	145	340	950
18,000	151	354	989

Given the situation where full separation for a worst possible incident is not possible, it is necessary for the design engineer to alter the design of the facility, as appropriate, to ensure that the BLEVE incident cannot occur with any credible probability.

There are several design features that are possible to reduce significantly the probability of a BLEVE from an LPG tank wagon. The safest method is to ensure that there cannot be flame impingement on the tank itself.

Other methods include insulation and water sprays. Insulation can delay heating of the steel shell (and hence weakening) from 10 minutes for the unprotected shell to about 45 minutes or more. By this time the Fire Brigade will almost certainly be present and be applying sufficient cooling water to keep the container cool and hence prevent the

BLEVE occurring. Unfortunately at present there is no insulating material acceptable to the industry that will do the job, not corrode the LPG tank, allow inspections, and withstand firewater sprays. An alternative procedure for many tanks is to require that a permanent water spray pipe system be constructed around the tank. This is designed to apply 10litres/m²/min to the tank surface. This is sufficient to keep the shell cool in a fire situation and to prevent a BLEVE incident. Such systems are not totally reliable and are expensive to install. They must be actuated in the event of a fire, nozzles can block-up and regular testing is necessary.

Design measures can be taken, however, to ensure that the probability of a pool or jet fire beneath or around the tank wagon is not credible. These include:

Grading the ground beneath the tank wagon. This is to ensure that any spilled LPG from the tank or other fuel on the site cannot run under the tank and thus expose the shell to flame impingement. The grading should extend at least 2m beyond the tank itself. A grade of 1:40 is desirable.

Kerbs may be necessary to ensure that major spillages of other fuels cannot drain under the tank.

Crash barriers must be of sufficient strength to withstand any on site manoeuvring vehicles.

The range of incidents considered in the hazard analysis is summarised below:

RANGE OF LPG INCIDENTS POSSIBLE

Incident	Possible consequences
Small leakage of LPG	Disperse safely or minor fire with no risk to neighbouring land-uses.
Medium leakage of LPG	Disperse safely or ignition and flash fire, death in within or adjacent to cloud at time of ignition.
Pool or jet fire of LPG	Thermal radiation effects at neighbouring land uses.
Fire at tank leading to relief valve fire	Increased thermal radiation effects at neighbouring land uses.
Prolonged fire at tank leading to a BLEVE	Intense thermal radiation affects causing deaths at substantial distances.
Catastrophic leakage of LPG (3-4 tonnes)	Safe dispersion less likely, ignition and flash fire probable over a substantial distance.

Catastrophic leakage of LPG (10 tonnes) As above, but potential for unconfined explosion with overpressure effects for a substantial distance.

7 CONCLUSIONS

This report has examined the safety systems associated with a typical LPG tank wagon parking area and the separation distances to neighbouring land-uses required. There have been no large incidents causing multiple fatalities nor any leaks or fire incidents which have the potential for serious consequences and have required evacuations.

The separation distances for LPG storage facilities to neighbouring land uses and any road tank wagon parking requirements were reviewed for U.S.A., U.K., and Australia. For the most common LPG tank wagon (18 tonne) the separation to the nearest house, shop, school or other protected work is 16.5m. This is broadly in line with requirements in the U.S.A., U.K. and Australia. The tank wagons should be isolated from areas of high and low intensity land use in compliance with the HSNO legislation. Location test certificates should be issued for the sites. Emphasis should be placed on maintaining the controlled and hazardous area zones around the parking area.

A typical tank wagon was described including the tank design, fire protection, safety valves, remote isolation valves, excess flow valves and crash barriers.

A parked road tank wagon is a safe form of storage as many of the normal risks do not exist. In this way a parked tanker is a lower risk than a stationary tank or a tank wagon on the road.

Certain design features that could reduce the likelihood of a major incident or its magnitude should the incident occur are recommended. The ground beneath an aboveground tank should be graded to direct away leaks and kerbs around the tank should be installed to prevent spills of other flammable materials running under the tank.

Crash barriers are an important safety feature to protect against manoeuvring vehicles.

Rather than a blanket ruling for water spray systems each tank wagon parking site should be assessed using the fire safety criteria from AS/NZS 1596 to determine any fire protection requirements.