MANUAL

PRESSURISED BULK STORAGE INSTALLATIONS FOR LPG

DEP 30.06.10.12-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for the layout, location and safety and operability aspects of above-ground and mounded storage of LPG in pressure vessels. LPG includes commercial propane, commercial butane and mixtures thereof.

Excluded from the scope of this DEP is the storage of pressurised pentane; for this the Principal should be consulted.

This DEP is a revision of the DEP with the same number dated November 1986.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIOP/SIEP/SIC, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company and to Contractors nominated by them (i.e. the distribution code is "C" as described in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, gas handling installations, chemical plants, oil and gas production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

For the purpose of this manual, the following definitions shall hold:

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 ABBREVIATIONS

ESD	Emergency shut down
PRV	Pressure relief valve

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (4).

2. ABOVE-GROUND BULK STORAGE OF LPG IN PRESSURE VESSELS

2.1 LAYOUT AND LOCATION

2.1.1 General

LPG pressure vessels should be grouped in rows and not in blocks.

Horizontal vessels shall be placed in parallel and not in line with or at right angles to one another as the possibility exists that, if involved in a fire, vessels may be propelled along their longitudinal axis. Horizontal vessels shall not be directed towards nearby plants or storage.

For a typical layout see Figure 1.

All LPG storage and associated facilities, e.g. piping, pumps, compressors, vaporisers, control systems and facilities for loading/unloading bulk road vehicles and rail tankers, shall, whenever practicable, be located on the same site.

The following points shall be taken into consideration when selecting and preparing the layout of the site:

- The maximum number of vessels in any above-ground group shall be six. Groups shall be separated by at least 15 m. For the determination of safety distances, refer to (2.1.2).
- The site topography, with particular reference to its effect on the flow of escaped liquid and vapour to possible ignition sources, important work areas and possible constraints on the dispersion of vapour.
- The availability of space to accommodate all foreseen operations and likely future extensions.
- The direction of the prevailing wind, i.e. LPG storage should be downwind of other facilities.
- The current and future use of the adjoining land, e.g. whether residential, industrial, etc.
- The routes to road/rail/water LPG handling facilities should be segregated from other product movements.
- Ease of access for fire fighting and other emergency services.
- The availability of at least two non-adjacent means of escape from the site.
- The vessels should be located away from storage facilities for which no bunding is required, e.g. cryogenic storage.

2.1.2 Safety Distances

(a) Vessel capacity

(i) Individual vessel capacity greater than 135 m^3

The layout and design of bulk storage installations with individual vessel sizes greater than 135 m^3 shall be based on a hazard analysis and on an assessment of the consequences of the identified hazard at the boundary and at critical areas in the plant. The details of the fire safety assessment procedures are given in Report OH 96-30202, supported by the Shell Hazard Consequence Model FRED (Report MF 95-1519).

Vessels shall be located and spaced such that, in the event of a fire as described in (2.1.2(b)), allowable heat radiation flux levels will be in accordance with Table 1.

Further, they shall be located such that the distances to fixed ignition sources are in accordance with (2.1.2(e)).

Figure 2 shows the safety distances which may be used to make preliminary layouts for the spacing of equipment. The final spacing shall be determined after an assessment based on Report OH 96-30202 and FRED has been performed.

(ii) Individual vessel capacity not exceeding 135 m^3

Tables 2 and 3 include safety distances which should be applied to installations with individual storage vessels equal to or less than 135 m^3 capacity.
The Principal may, in view of local circumstances, elect to apply radiation assessments to installations equal to or less than 135 m^3, in which case the conditions of (2.1.2(b)), (2.1.2(c)) should apply.

(b) Radiation flux levels

The radiation flux levels shall be based on the ignition of product escaping from the vessel nozzles/fittings or from other identified leak sources in associated piping and equipment and possibly forming a pool of a size dictated by the spillage rate, evaporation rate and duration (refer to (2.1.2(c)) and the local topography).

Radiation from a fire located outside the LPG storage area shall also be taken into account.

(c) Leakage

The rate of leakage and its duration shall be based on identified possible leak sources in the system. Refer to Report OH 96-30202.

The identification and quantitative assessment of such leak sources shall include a systematic evaluation of the design and operating procedures for the installation, taking into account failure modes, likelihood and consequences.

Leakages from the vessel shell, or all welded connections to the vessel shell, are not considered likely where Group practice is followed with respect to design, engineering, construction, operation and maintenance of the vessel.

(d) Relief valve fire

When considering radiation from a relief valve fire, the valve(s) shall be assumed to be discharging at rated capacity under atmospheric conditions prevailing at the site.

(e) Distances from LPG storage facilities to fixed sources of ignition

Fixed sources of ignition are defined as plant furnaces and boilers, fixed engines and similar facilities.

Vessels above 135 m^3 capacity, pump bays and loading/discharge facilities shall be located to ensure the following minimum distances to fixed sources of ignition, irrespective of the requirements of (2.1.2(a)):

- 22.5 metres for storage vessels not exceeding 265 m^3;
- 30 metres for storage vessels exceeding 265 m^3;
- 25 metres for pump bays and loading/unloading facilities.

Deflection walls may be used to extend the vapour travel path to meet these safety distances. Such walls should be so located as to minimise the risk of flame engulfment of storage vessels, in the event of ignition of escaped product, and also to ensure free ventilation of the storage area from at least three directions, taking account of prevailing

winds.

2.1.3 Piping

Only piping directly associated with the storage vessels shall be located within the storage area (refer to 2.2.4, Figure 4 and Figure 5).

Piping shall be fire protected by water sprays/monitors, and pipe supports shall be protected by passive means (refer to (2.9)).

For the purpose of deflecting solar radiation, shields may be considered to prevent vapour locks.

2.1.4 Grading and ground finish

Spills shall be drained away from equipment as quickly as possible, to ensure that escaped product cannot collect under vessels or remain in their immediate vicinity. To facilitate the flow of escaped product and prevent its penetration into the soil, the ground shall be finished with concrete paving sloping towards the perimeter drain channels.

For further information, refer to DEP 34.14.20.31-Gen.

2.1.5 Separation

There shall be a positive separation/deflection, e.g. a wall of 0.6 metre maximum height, between the storage vessels and the pipe manifold/track to prevent the flow of any leakage from one to the other. Deflection walls may be considered between vessels to prevent product escape from one vessel from flowing under another (see Figure 1).

2.1.6 Confinement

Bund walls interfere with the ventilation of the site and impede the vaporisation/dispersion of escaped products and shall not be used.

2.1.7 Surface drainage

DEP 34.14.20.31-Gen. shall apply.

2.2 VESSELS

2.2.1 Types of vessels

(a) Horizontal cylindrical vessels

Horizontal vessels up to 200 m^3 capacity are normally shop fabricated and transported to site. Larger size vessels are generally supplied as shop fabricated sub-assemblies which are subsequently welded together and stress relieved, as required, on site.

(b) Vertical cylindrical vessels

Vertical vessels are generally used where space is limited and vessels of large capacity are not required. Although there are no practical limitations on size, the economic break even point for constructing spheres is likely to limit the size of vertical vessels. Normally vertical vessels are limited to 10 metres diameter and to 25 metres height (approximately 1,750 m^3). For units of the same capacity, vertical vessels require less space than horizontal vessels but are more demanding on foundation work.

(c) Spherical vessels

Spherical vessels normally have a larger capacity than horizontal or vertical vessels because of the more favourable economies of scale. Approximately 3,500 m^3 may be considered as the practical upper limit. They are site erected from pre-formed plates and shop fabricated sub-assemblies.

2.2.2 Applicable codes

LPG storage vessels shall comply with DEP 31.22.10.32-Gen. or, if approved by the Principal, DEP 31.22.20.31-Gen.

NOTE: For marketing depots/consumer installations, LPG storage vessels with a capacity not exceeding 265 m^3 shall comply with BS 5500 or an equivalent local code if acceptable to the Principal and local regulations.

Unless otherwise specified by the Principal, the Manufacturer shall be responsible for obtaining the required certificates of acceptance for the storage vessels from the appropriate authorities.

2.2.3 Design temperature and pressure

(a) Maximum operating temperature (MOT)

The MOT is the highest temperature attained by the product in the storage vessel under normal operating conditions. The MOT is therefore the the maximum temperature on receipt into storage or the assessed temperature for the relevant climate, whichever is the higher.

The assessed temperatures are 35 °C, 40 °C and 45 °C for temperate, tropical and desert climates respectively. If assessed temperatures have been established by local regulations or by the design code specified by the Principal, then these shall be used for design purposes.

(b) Maximum operating pressure (MOP)

The MOP is the vapour pressure of the product concerned (refer to Table 4) corresponding to the MOT.

(c) Design pressure (DP)

The DP shall be taken equal to 110% of MOP, with a minimum of (MOP+1) bar (refer to DEP 01.00.01.30-Gen.) to ensure full closure of the pressure relief valves (PRVs) when normal conditions have been restored after an overpressure situation.

The DP is defined for the top of the vessel, hence the liquid static head shall be added for lower parts.

The use of a vapour return line and/or top spray filling is recommended as a means of limiting excessive back-pressure build-up in vessels during the filling operation. Vapour return systems also prevent vacuum from developing during discharge. If such systems are not used, then the DP should be checked to ensure that the back-pressures generated when filling are adequately covered, in order to avoid product loss through spurious relief.

The relationship between temperature and vapour pressure of commercial propane, commercial butane and propane/butane mixtures is shown in Figure 3.

(d) Upper design temperature (UDT)

The UDT is the temperature corresponding to the DP.

(e) Lower design temperature (LDT)

DEP 30.10.02.31-Gen. shall apply.

(f) Vacuum conditions (external pressure)

Provisions to cope with vacuum conditions are required where ambient temperatures can be expected to fall below the Atmospheric Boiling Point (ABP) of the product stored, or where very high liquid withdrawal rates are applied without an adequate vapour return system. In these cases, which normally only apply to butane storage, vessels shall be designed for full vacuum.

Table 5 provides details of the pressure in a vessel containing n-butane at low temperatures, which shall be compensated for.

2.2.4 Connections

(a) General

The number of nozzles on vessels, particularly below the liquid level, shall be minimised.

Nozzle flanges shall be in accordance with ASME B16.5.

Nozzles to which product transfer piping, product drains and pressure relief systems are connected shall be at least DN 50.

Flanges in horizontal piping under vessels and within the bunded area shall be avoided for safety reasons (flame impingement in event of fire).

(b) Bottom connections

For details, see Figure 4.

There shall be only one bottom connection, which may be used for filling, withdrawal and draining. The connecting pipe shall be welded and not flanged to this nozzle. The pipe shall be regarded as part of the vessel. All joints in this bottom pipe up to and including the first valve shall be welded, fully radiographed and post-weld heat-treated. The minimum size of the bottom pipe is DN 100. The pipe thickness shall be as determined by the pressure vessel code but shall be not less than Schedule 80 or, for pipes larger than DN 100, Schedule 40.

The product line shall be:

- as short as possible and sloping downwards from the vessel to the pump suction;
- insulated and traced at locations where freezing can occur. Inspection windows shall be provided to allow monitoring of corrosion under insulation. The tracing shall not be welded to the product line;

- provided with a water drain system upstream of the operational valve(s) at the manifold (refer to (2.2.4(c));
- provided with an ESD valve (refer to (2.4.2));

  This ESD valve shall be welded to the product line and located downstream of the separation/deflection wall.

  Under no circumstances shall this valve be provided with a handwheel/lever override.

  Where the pumps net positive suction head (NPSH) requirements are critical, consideration shall be given to using a full bore ball valve.

  The valve and actuator assembly shall be protected from heat radiation by a spray water system. In addition, the actuator shall be insulated, in order to withstand a minimum of 15 minutes' exposure to fire.

  The valve and actuator assembly shall comply with the hazardous area classification.

Only in locations subjected to moderate/severe earthquake conditions (refer to DEP 34.00.01.30-Gen.) or where local regulations dictate, shall the ESD valve be internally mounted. Redundant fire and gas detectors shall be installed in the direct vicinity of the ESD valve. In this case (refer to Figure 5), the product line shall be:

- Provided with a shut-off valve directly downstream of the ESD valve. This shut-off valve may be fitted with an actuator and be remotely controlled, but should also be capable of being manually operated.
- Provided with a flanged tee, to accommodate an elbow between it and a DN 50 valve to provide a bypass in case of malfunction of the internal ESD valve.
- Fire-insulated at all flanges immediately beneath the vessel.

(c) Drain system

A drain connection shall be provided for each storage vessel and shall consist of a nozzle not larger than DN 50 (schedule 80) welded to the bottom line (see Figures 4 and 5), to which a fire-safe ball valve, again not larger than DN 50 (upstream drain valve), shall be connected.

The essential feature of the drain system is that it is based on two manual shut-off ball valves separated by at least 600 mm of adequately supported piping with a fall towards the outlet to ensure that both valves are never simultaneously blocked open by ice. Furthermore, the two drain valves shall be so positioned as to enable simultaneous operation of both valves by a single operator.

The downstream drain valve shall be a DN 20, quick-acting, spring-loaded type (spring-to-close) valve which will operate as a dead man's handle. The discharge point shall be lined up to flare via a local knock-out vessel. The line shall be protected against mechanical damage. The rate of draining and the volume of the piping contents between the bottom of the storage vessel and the drain connection shall determine the size of the knock-out vessel. For details on sizing and equipment, refer to DEP 80.45.10.10-Gen.

A vent to atmosphere may be considered only if there are no flare facilities or if a connection to flare would be impractical due to long distances. In this case, the downstream drain valve shall be followed by a DN 20 pipe into a small separator vessel with discharge to atmosphere at a safe location. The discharge point shall always be in a freely ventilated area outside the periphery of the vessel.

Subsequently, the water from the vessel shall be routed to the continuously oil contaminated (COC) system.

At locations where freezing can occur, the drain valves, separator/knock-out vessel and

lines shall be adequately insulated and heat traced. The tracing shall not be welded to the product drain line.

(d) Top connections

The nozzles of all top connections shall be above the maximum liquid level.

(i) Pipe connections

Liquid and vapour lines terminating in the vapour space should be flange connected to a nozzle at the top of the vessel. Liquid fill connections shall be provided with a non-return valve directly connected to the vessel nozzle and a close coupled fire-safe shut-off valve preferably of the remotely operated type. If flow may be bi-directional, the vapour connection shall be fitted with a remotely operated fire-safe shut-off valve.

To prevent the release of liquid in the event of a pipe leak, the internal pipe shall not extend below the maximum liquid level.

(ii) Manhole

There should be only one manhole except in very long horizontal vessels where two or more manholes may be required to facilitate access/escape for maintenance/ inspection personnel and improve gas freeing. The manhole cover should be used to its maximum extent for the location of connections/fittings, e.g. instruments.

(iii) PRV connection

PRVs shall be connected to the vapour space of the vessel. For further details refer to (2.4.8).

(e) Instrument connections

Connections for instruments shall, where practicable, be above the maximum liquid level of the vessel to prevent the release of liquid in the event of a tubing leak. Instrument connections should be located where impact damage and shearing off of the fittings are unlikely to occur. All instruments in open connection with the vessel shall be protected by a shut-off valve.

2.2.5 Supports and foundations

(a) Supports

Supports shall be capable of carrying the vessel full of water.

The vessels shall be properly anchored to the foundation.

Horizontal vessels shall have two steel saddle supports for mounting on concrete pedestals. One saddle shall be a fixed support and the other a sliding support to permit expansion and contraction of the vessel. The saddles shall be welded to the shell. The sliding support shall not permit the vessel to move in the transverse and vertical directions. The fixed support shall be at the same end of the vessel as the bottom nozzle.

The supports shall incline the vessel at a minimum slope of 0.25% for complete draining.

The concrete pedestals shall be high enough to protect the vessel from flotation in the event of flooding and to give adequate NPSH for pump suction.

Vertical vessels and spheres shall have tubular steel leg supports connected to the shell.

(b) Design of foundations

The Manufacturer shall submit within two weeks of the order acceptance a loading diagram for the foundation design. This shall include loads on the foundations, dimensions and location of base plates and holding-down bolts. Loading data and load

combinations shall be in accordance with DEP 34.00.01.30-Gen.

(c) Structural steel

Structural steel for platforms, stairs and railings shall be in accordance with DEP 34.28.00.31-Gen. Galvanised grating shall be used for stair treads and platforms (refer to DEP 34.28.00.31-Gen. and Standard Drawing S 28.022).

(d) Fire proofing

DEP 34.19.20.11-Gen. shall apply.

2.2.6 Identification

Storage vessels should be identified with a serial number (e.g. 1, 2, 3, etc.) painted prominently on the shell. Vessel markings shall also comply with any local regulations.

In addition, product identification marking shall be prominently located next to receipt and discharge connections.

2.3 INSTRUMENTATION

2.3.1 General

All instrument components in contact with LPG (liquid or vapour) shall be suitable for LPG service and for operation over the range of liquids level and design temperatures/ pressures of the vessel and preferably also at its test pressure. All instruments and associated data transmission systems shall be suitable for the hazardous area class in which they are located. For details on instrumentation, refer to DEP 32.31.00.32-Gen.

2.3.2 Level measurement

One failure-revealing level gauge for continuous indication shall be employed. Only if its expected mean-time-between-failure would result in operationally unacceptable availability figures should a second gauge, working on a different measurement principle, be considered.

If a local indication of level is required independently of the main gauge, a second, less accurate, level instrument may be provided. This instrument shall not be used for safeguarding functions.

All instruments shall be robust. Glass level gauges shall not be used.

2.3.3 Level protective functions and alarms

(a) General

In order to protect against overfilling due to product receipt and/or liquid expansion, all LPG storage vessels shall be equipped with a liquid level safeguarding and alarm system, which shall consist of either maximum liquid level gauges (minimum ullage gauges), high level alarm, high-high level (emergency) alarm or a combination of these. Level alarms shall have both visual and audible output.

Figures 6 and 7 allow alarm settings (liquid expansion/ullage tube length) to be determined for various vessel sizes.

Also, low level alarm, low-low level (emergency) alarm or a combination of these should be considered, e.g. for pump protection. Because all connections have to be made from the top of the vessel, dependable and serviceable low level switches are difficult to install. Hence for pump protection the derived switching functions from the analogue instrument may be used. A liquid sensor mounted in the suction line is an alternative solution for pump protection.

(b) Maximum safe filling level

The maximum safe filling level (see Figure 8) shall be set so that the vessel will never become more than 99% liquid full when the bulk mean temperature of the liquid reaches the maximum operating temperature (see (2.2.3(a)).

The maximum safe filling level shall be based on the maximum rise in product temperature that may occur in practice. This rise will be the difference between the lowest in-vessel product temperature and the maximum operating temperature. The maximum safe filling level is determined as follows:

$$V_f - 0.99\, V \frac{g_l}{g_m}$$

Where: V_f = Maximum safe filling volume in litres

V = Vessel capacity in litres

g_i = Density of liquid at maximum operating temperature

g_m = Density of liquid at lowest storage temperature

Where reliable minimum temperatures are not available, a rise of at least 30 °C should be allowed for. Refer to Figure 6 when calculating the extent of product expansion, using the temperature section of the curve most appropriate to the product temperatures experienced at the location.

(c) Types of filling operation

(i) Vessels smaller than 50 m^3 which are filled at relatively low transfer rates from rail/road vehicles and are closely supervised during filling should be equipped at least with fixed ullage gauges as a means of overfill protection.

(ii) Vessels which are filled at continuous but relatively low rundown rates from process units and other vessels which are operated with little supervision shall be equipped at least with a high level indicator/alarm (LIA/H) and high-high level alarm (LA/HH) (refer to Note 1 and Figure 10). Typically, the LIA/H and LA/HH are set at 90% and 95% respectively of the gross vessel capacity, (refer to Note 2). However, these settings may need to be lowered to give the operator sufficient time to redirect the flow manually.

(iii) Vessels which are filled at relatively high flow rates, e.g. from marine tankers or cross country pipelines, shall be equipped with a LIA/H and a high-high level emergency trip (LZA/HH) (refer to Note 1 and Figure 11). The LZA/HH shall stop the filling operation by closing the filling valve(s) and/or stopping pumps/ compressors. Measures shall be taken in the design to protect equipment against the effects of possible pressure surges.

In order to ensure a safe operating margin (10 minutes minimum to vessel overfill), the LZA/HH shall be set not higher than 95%.

The LIA/H shall be set at a level to allow sufficient time (at least 10 minutes) for action to be taken before the liquid level reaches the LZA/HH setting (see Note 2).

NOTES:
1. LA/H, LA/HH and LZA/HH shall be independent measurements. The relevant instruments may, however, be combined and mounted on the main gauge, provided that they are of a balanced servo-operated or Radar type and have power transmission and readouts completely separated, to ensure that failure of both level indicators and thus the associated transmitters/alarms at the same time is unlikely. Alarm functions may be derived from the analogue instruments.

2. The level at LIA/H is the normal working level before allowing for thermal expansion. The variation in temperature experienced in practice may allow a higher level or necessitate a lower level.

2.3.4 Pressure measurement

A pressure transmitter shall be connected to the vapour space of the vessel. If a local indication is required, a local indicator should be mounted at ground level. Manometers should not be used.

2.3.5 Pressure protective functions and alarms

High or low pressure (and possibly vacuum) can develop when vessels without spray filling or vapour return systems are involved in high rate transfer operations. In these cases, consideration shall be given to installing a high and low pressure alarm and a high and low pressure emergency alarm, with appropriate automatic trip actions to stop or reduce product flow.

The high pressure emergency alarm shall be set 5% below the opening pressure of the lowest PRV setting.

2.3.6 Temperature measurement

Resistance thermometers and data transmission systems should be intrinsically safe and suitable for operation in the hazardous area class in which they are located.

All storage vessels which form part of a product stock control or custody transfer procedure shall have at least one spot temperature measuring instrument in each of the liquid and vapour spaces.

Vessels 4 metres or more in height should be fitted with multi-spot thermometers with at least four spot measuring elements, one of which should always be in the vapour phase and the remaining three distributed over the liquid phase when the vessel is full.

For vessels less than 4 metres in height one spot thermometer should be located in the vapour space as close as practicable to the top of the vessel and one within 1 metre of the bottom.

The temperature sensitive element should be at least 500 mm from the vessel shell in order to avoid external thermal effects.

2.3.7 Temperature protective functions and alarms

Under normal circumstances no alarms or protective functions systems are required for temperature.

2.3.8 Gas detectors

DEP 32.30.20.11-Gen. and DEP 80.47.10.30-Gen. shall apply.

2.4 VALVES

2.4.1 General

Various functions of valves are discussed in the following paragraphs in relation to the systems in which they are used.

2.4.2 Remotely operated valves (ROVs) and emergency shut down (ESD) valves

ROVs may be actuated electrically, by a directly coupled motor, hydraulically or pneumatically.

ROVs are normally operated from control rooms/centres and should incorporate provision for local operation/override or other fail-safe means to ensure protection for personnel engaged in maintenance, etc.

Actuated valves shall be carefully selected as a complete unit to meet specific service conditions and performance requirements. Close co-operation with suppliers of actuators/valves is essential to ensure that units of the required quality are supplied and correctly installed.

For the design of hydraulic systems, refer to DEP 31.36.10.30-Gen. See also Figure 9 for a typical remotely operated hydraulic safety valve.

ESD valves are ROVs, either hydraulically or pneumatically actuated, used to isolate vessels and sections of piping/equipment in emergency situations, e.g. to limit leakage in the event of equipment failure.

ESD valves may be actuated automatically (e.g. by a fusible link in the power supply to the actuator, by the plant alarm system and/or by gas detection), or manually (by a push button).

Pneumatic ESD valves close automatically when the power supply to the actuator is cut off.

All ESD valves shall have tight shut-off characteristics and be fail-safe and fire-safe to BS 6755-2, API 6FA or ISO 10497.

Fusible sections (typical failure temperature 150 °C) should be fitted in the service piping to actuators of ESD valves to provide automatic closure of the ESD system in case of fire in critical areas.

ESD valves shall not be provided with handwheels or operating levers, unless there are specific local requirements that manual override be provided.

Attention should be paid to the location of the remote controls for ESD valves, and to the number of ESD valves included in a single shutdown system: for example, in a small depot it may be considered safer to include all ESD valves in a single system so that all ESD valves in the system are closed simultaneously, whereas in other plants it may be necessary to use several ESD systems.

The manual shutdown controls shall be located at various positions over the site and shall be clearly indicated with an appropriate notice. The location of the controls for ESD valves will depend on the manner in which the plant is supervised and operated, but the number of positions from which the ESD system can be activated shall be limited to the minimum required for safe operation.
Consideration shall be given to automatically linking the closure of ESD valves to the emergency alarm and water spray system.
Where appropriate, the shutdown system design should include automatic pumps trips activated by ESD valve closure.

2.4.3 Non-return valves (NRVs)

NRVs are designed to prevent the reverse flow of liquid or gaseous products. Due to their possible unreliability, in particular if inadequately maintained and tested, these valves shall not be relied upon for positive shut-off.

There are no codes covering the fire-safe performance requirements of NRVs, but if NRVs are used they should be constructed of fire resistant materials.

2.4.4 Excess flow valves

Excess flow valves are designed to shut when flow conditions are in excess of design flow rates, e.g. in the case of a hose or pipe failure. These valves should not be used due to their unproven reliability.

2.4.5 Drain valves

All vessels shall be provided with a double valve drain system for operational drainage (refer to (2.2.4(c))).

At low points in pipelines and equipment, drain points shall be fitted with a shut-off valve which shall be blank flanged when not in use.

2.4.6 Vent valves

Equipment and piping sections shall be provided with vent valves as required, which enable a final check on proper depressurisation. They can also be used for air removal during purging operations. Vent valves shall be blind flanged when not in use.

2.4.7 Depressuring valves/provisions for depressuring

Equipment and piping sections shall also be provided with a valve connection (preferably to flare in order to limit hydrocarbon emissions to atmosphere or, if impractical, to a safe location) for depressuring purposes.

2.4.8 Pressure relief valves (PRVs)

(a) Installation requirements

Overpressure can result from either abnormal operating conditions (e.g. overfilling or too high product rundown temperatures) or fire exposure. Separate PRVs shall be provided for each duty:

- PRVs to cope with abnormal operating conditions shall be lined up to flare or to a safe location via a vent system.

  Subject to approval by the Principal, a spare PRV position may be omitted, provided that product rundown is not allowed into the vessel while the PRV is being replaced. This omission shall be duly covered by operating instructions.

  PRVs discharging to a flare/vent system shall do so via a local knock-out vessel. The line connecting a PRV to a flare/vent system shall be provided with a full bore isolation valve, locked open under normal operation. The line shall be self-draining towards the knock-out vessel and shall be protected against mechanical damage. Its supports shall be fire-proofed to prevent it from collapsing in a fire and being 'pinched shut'. Adequate means shall be provided to deal with hydrate and ice formation.

  The maximum rundown rate into storage shall determine the size of the knock-out vessel. For details on sizing and equipment, refer to DEP 80.45.10.10-Gen.

- PRVs to cope with fire exposure shall discharge to atmosphere through a vertical tail pipe. A spare PRV position shall be provided.

For typical arrangements of PRVs, see Figure 12.

For specification and installation of PRVs, refer to DEP 80.45.10.10-Gen.

(c) Setting and sizing

(i) PRVs for abnormal operating conditions

- Setting

  PRVs for abnormal operating conditions shall have a set pressure (SP) not exceeding the design pressure (DP) of the vessel.

- Sizing

  DEP 80.45.10.10-Gen. shall apply.

(ii) PRVs for fire exposure

- Setting

  For ASME VIII vessels, PRVs intended to deal with fire exposure only shall have an SP not exceeding 110% of the vessel DP and the accumulation shall not exceed 21% of the DP.

  For BS 5500 vessels, PRVs intended to deal with fire exposure only shall have an SP not exceeding the vessel DP and the accumulation shall not exceed 10% of the DP. In this case, the SP of the PRVs dealing with abnormal operating conditions shall be lowered accordingly.

  If the vessel is built to another code, that code shall then apply.

  For further details, refer to DEP 80.45.10.10-Gen.

- Sizing

Sizing shall be in accordance with:

- NFPA 58 for vessels not exceeding 135 m^3 capacity;
- DEP 80.45.10.10-Gen. for vessels above 135 m^3 capacity.

2.4.9 Thermal Expansion Relief Valves (TERVs)

DEP 80.45.10.10-Gen. shall apply. Refer to Figure 13 for a typical TERV cascade set-up.

2.5 PIPING

2.5.1 General

Pipe and piping components shall be in accordance with DEP 31.38.01.11-Gen. DEP 30.10.02.31-Gen. shall apply for material selection.

The bottom pipe of a pressure storage vessel, including the first valve at the manifold, shall be regarded as an integral part of the storage vessel (refer to (2.2.4(b))).

Product pipes in the storage area shall be as short as possible, preferably above ground and, where appropriate, protected against collision/impact.

Butt-welded connections shall be used for all sizes of product transfer piping, except where flanged joints are unavoidable or necessary. Process piping shall be not less than DN 50. Threaded connections shall not be used.

Pipes shall be adequately supported and provisions shall be made for expansion, contraction, jarring and vibration. Expansion bellows shall not be used.

Instrument tubing and sampling points shall be minimum DN 15 (schedule 80) with an isolation valve fitted at the nozzle (refer to (2.2.4(e))) and shall be protected against impact, e.g. by bracing. Instrument piping shall be as short as possible and extended branching should be avoided.

All pump suction lines shall slope continuously downwards from the storage vessel to the pump suction.

All piping shall be sloped to facilitate commissioning, gas-freeing and draining and shall be fitted with blanked vent and drain valves as required.

2.5.2 Segregation of propane/butane systems

Piping systems for propane and butane should be segregated to prevent propane from entering butane systems and vice versa. If this is impracticable, it shall be ensured that in the event of faulty operation the system will not be endangered and the faulty operation will be evident, e.g. by use of pressure alarms or trips.

Piping systems handling more than one grade of LPG should meet either (i) or (ii) below:

(i) The total system should be designed for propane unless all connections between the propane and butane systems are designed to allow only one system to be connected at any time by either of the following:

- Removable spool pieces, or interconnected spectacle blinds if connection changes, e.g. to line up a spare pump, are infrequent.
- Swivel joints if connection changes are made regularly, e.g. one liquid and vapour line being used for more than one grade.

The system shall ensure that if more than one connection has to be switched, they shall all be switched simultaneously, e.g. by interlocks.

(ii) Control valves should be installed adjacent to interface detectors or sphere detecting signals, in order to switch product flow, e.g. if products are batched through pipelines.

2.5.3 Identification of piping

Piping contents shall be clearly identified, particularly at cross-over points, terminal fittings, etc. Colour coding and the location of such coding shall comply with local regulations.

2.6 SAMPLING SYSTEM

DEP 30.06.10.11-Gen. shall apply.

2.7 PURGING CONNECTIONS

Separate purging connections shall not be provided if use can be made of existing drains, vents and sampling points.

2.8 AREA CLASSIFICATION, EARTHING AND LIGHTNING PROTECTION

Area classification shall be in accordance with DEP 80.00.10.10-Gen.

The construction and installation of electrical equipment in hazardous areas shall comply with IEC 79-14.

Vessels and other equipment shall be earthed in accordance with DEP 33.64.10.10-Gen.

Lightning protection of LPG storage vessels is not required.

2.9 FIRE PROTECTION FACILITIES

DEP 80.47.10.30-Gen. and DEP 80.47.10.31-Gen. shall apply.

3. MOUNDED BULK STORAGE OF LPG IN PRESSURE VESSELS

3.1 LAYOUT AND LOCATION

3.1.1 General

Reference is made to (2) for those aspects of pressurised LPG storage that are common to both above-ground and mounded installations.

Vessels shall be located so that:

- they do not affect, and are not affected by, other nearby underground structures (e.g. foundations, pipelines, sewers);
- they are not subjected to loads from vehicles;
- they are not affected by other hazards such as power cables and cathodically protected pipelines.

Unlike above-ground vessels, mounded installations may be positioned in line.

3.1.2 Safety distances

This section shall apply only to fully mounded vessels. Partially mounded vessels shall be treated as above-ground vessels.

(a) Vessel capacity

(i) Individual vessel capacity greater than 135 m^3

Vessels shall be located and spaced so that in the event of a fire (refer to (2.1.2(b))), allowable heat radiation flux levels will be in accordance with Table 1.

Figure 14 shows safety distances which may be used to make preliminary layouts for the spacing of equipment. The final spacing shall be determined after an assessment based on Report OH 96-30202 and a FRED has been performed.

(ii) Individual vessel capacity not exceeding 135 m^3

Tables 6 and 7 include safety distances which should be applied to installations with individual storage vessels equal to or less than 135 m^3 capacity.

(b) Radiation flux levels

Refer to (2.1.2(b)).

(c) Leakage

Refer to (2.1.2(c)).

(d) Relief valve fire

Refer to (2.1.2(d)).

(e) Distances from LPG storage facilities to fixed sources of ignition

Refer to (2.1.2(e)).

3.1.3 Earth cover

DEP 34.51.11.30-Gen. shall apply.

3.2 VESSELS

3.2.1 Types of vessels

Horizontal, cylindrical vessels are normally used for mounded storage.

3.2.2 Design temperature and pressure

(a) Maximum operating temperature (MOT)

For mounded storage the effect of solar radiation may be ignored, hence there is no need to take the assessed temperature into account. The MOT is therefore the maximum temperature of the product on receipt into storage.

(b) Maximum operating pressure (MOP)

Refer to (2.2.3(b)).

(c) Design pressure (DP)

Refer to (2.2.3(c)).

(d) Upper design temperature (UDT)

Refer to (2.2.3(d)).

(e) Lower design temperature (LDT)

Refer to (2.2.3(e)).

(f) Vacuum conditions (external pressure)

Refer to (2.2.3(f)).

3.2.3 Vessel fabrication

DEP 34.51.11.30-Gen. shall apply.

3.2.4 Corrosion protection/coating

DEP 34.51.11.30-Gen. shall apply.

3.2.5 Vessel connections

(a) General

(2.2.4(a)) shall apply with the following supplementary requirements:

Connections for mounded vessels should be at the top, and top connections shall be extended to a level above the soil cover. Soil settlement permitting, a bottom discharge in an inspection tunnel may be considered for operational requirements. Fittings at or above ground level shall be protected against accidental damage, e.g. impact.

All connections to mounded vessels shall be welded to the vessel; the first flange of such connections shall not be covered by earth.

(b) Drain facilities

(2.2.4(c)) shall apply with the following supplementary requirements:

For vessels with top connections only, draining will require the installation of a dip pipe with an ESD valve fitted to a nozzle at the top of the vessel. These connections shall be protected against impact.

3.3 INSTRUMENTATION

Instrumentation facilities for mounded storage vessels are, in general, similar to those covered in (2.3) for above-ground vessels.

3.4 VALVES

3.4.1 General

(2.4) shall apply, subject to the modifications of (3.4.2) below.

3.4.2 Capacity of PRVs

Due to the limited exposed surface area, consideration shall be given to combining the duties for abnormal conditions and fire exposure. The relief capacity shall cover the greater of either the capacity required for abnormal operating conditions or for fire exposure. In this case, the PRVs shall discharge to flare or vent to safe location. A spare PRV position shall be provided.

3.5 PERIODIC INSPECTION REQUIREMENTS

3.5.1 Vessel inspection

DEP 34.51.11.30-Gen. shall apply.

3.5.2 Settlement recording

DEP 34.51.11.30-Gen. shall apply.

3.6 PIPING

(2.5) shall apply.

3.7 SAMPLING SYSTEM

(2.6) shall apply

3.8 PURGING CONNECTIONS

(2.7) shall apply.

3.9 AREA CLASSIFICATION, EARTHING AND LIGHTNING PROTECTION

(2.8) shall apply.

3.10 FIRE PROTECTION FACILITIES

(2.9) shall apply.

4. REFERENCES

In this DEP reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Index to standard drawings	DEP 00.00.06.06-Gen.
Definition and determination of temperature and pressure levels	DEP 01.00.01.30-Gen.
Equipment in LPG installations	DEP 30.06.10.11-Gen.
Metallic materials - prevention of brittle fracture	DEP 30.10.02.31-Gen.
Pressure vessels (amendments/supplements to BS 5500)	DEP 31.22.10.32-Gen.
Pressure vessels (amendments/supplements to ASME Section VIII Division 1 and Division 2)	DEP 31.22.20.31-Gen.
Hydraulic systems for operation of valves	DEP 31.36.10.30-Gen.
Piping classes - Basis of design	DEP 31.38.01.10-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
MF Piping Classes	DEP 31.38.01.12-Gen.
Fire, gas and smoke detection systems	DEP 32.30.20.11-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Classification and implementation of instrumented protective functions	DEP 32.80.10.10-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Drainage and primary treatment facilities	DEP 34.14.20.31-Gen.
Fire hazards and fireproofing/cold splash protection of fire structures	DEP 34.19.20.11-Gen.
Steel structures	DEP 34.28.00.31-Gen.
Mounded horizontal cylindrical bulk storage vessels for pressurised gases at ambient temperatures	DEP 34.51.11.30-Gen.
Area classification (Amendments/supplements to IP 15)	DEP 80.00.10.10-Gen.
Pressure relief, emergency depressuring, flare and vent systems	DEP 80.45.10.10-Gen.
Assessment of the fire safety of onshore installations	DEP 80.47.10.30-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.
FRED - User guide version 2.2	Report MF 95-1519
Pre-incident planning guide	Report OH 96-30202

STANDARD DRAWING

Grating	S 28.022

NOTE: The latest revisions of Standard Drawings are identified in DEP 00.00.06.06-Gen.

AMERICAN STANDARDS

Specification for fire test for valves	API 6FA

Issued by:
American Petroleum Institute
Publications and Distribution Section
1220 L Street Northwest
Washington DC 20005, USA.

Rules for construction of pressure vessels	ASME VIII
Pipe flanges and flanged fittings	ASME B16.5

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY10017, USA.

Standard for the storage and handling of liquefied petroleum gases	NFPA 58

Issued by:
National Fire Protection Association
One Batterymarch Park
PO Box 9101
Quincy, MA 02269-9101
USA.

BRITISH STANDARDS

Unfired fusion welded pressure vessels	BS 5500
Testing of Valves - Part 2: Specification for fire type-testing requirements	BS 6755-2

Issued by:
British Standards Institution
389 Chiswick High Road
London W4 4AL, United Kingdom.

INTERNATIONAL STANDARDS

Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)	IEC 79-14

Issued by:
International Electrotechnical Commission
3 Rue de Varembé
1211-Geneva 20, Switzerland.
Copies can also be obtained from national standards organizations.

Testing of valves -Fire type-testing requirements	ISO 10497

Issued by:
International Organization for Standardization
Case Postal 56
CH-1211 Geneva 20, Switzerland.
Copies can also be obtained from national standards organizations.

APPENDIX 1 TABLES

Table 1 Radiation flux limits for above-ground LPG pressure storage vessels

Target		Maximum radiation flux levels kW/m^2
Equipment inside boundary		
The outer surface of adjacent pressure storage vessels:	(1)	
Protected	(2)	44
Unprotected	(3)	8
The outer surface of adjacent storage tanks containing flammable products (including refrigerated storage) and process facilities:	(1) (4)	
Protected	(2)	32
Unprotected	(3)	8
The above-ground connections, including PRVs, of mounded LPG storage vessels		8
Filling/discharge points		8
Control room, maintenance workshops, laboratories, warehouses, etc.		8
Administrative buildings		5
Outside boundary		
Remote area	(5)	13
Urban area	(6)	5
Critical area	(7)	1.5

NOTES:

(1) When siting pressure storage vessels relative to refrigerated product tanks, the radiation flux level on the pressure vessel shell shall be limited to 8 kW/m^2.

(2) Such facilities/areas are protected by means of water sprays, insulation, radiation screens or similar systems.

(3) Protection is provided by spacing alone.

(4) Special consideration shall be given to the location of floating roof tanks containing volatile products, since effective water cooling of their roof structure is impracticable.

(5) An area only infrequently occupied by small numbers of persons, e.g. moorland, farmland, desert, but where immediate escape should be possible. Plant designs based on radiation flux levels of 13 kW/m^2 shall allow for possible future changes in land use outside the plant.

(6) An area which is neither a remote area nor a critical area.

(7) This is either an unshielded area of critical importance where personnel not equipped with protective clothing may be required at all times, including during emergencies, or a place difficult or dangerous to evacuate at short notice (e.g. plant entrance, hospital, sports stadium).

Table 2 Minimum safety distances for above-ground LPG pressure storage vessels (capacity £ 135 m^3)

Code (1) (from Figure 2)	Description	Minimum safety distance (metres)
A	*Between LPG storage vessels* (4)	$(D_1 + D_2) / 4$
	Between LPG storage vessels and:	
B	- the edges of restricted plant/depot roads and pipe tracks (5)	10
	- the centre of the top of the bund wall surrounding crude oil, Class I and Class II product tanks - the tank shell for Class III product tanks and Class II product tanks not requiring a bund (6)	15
C	- bulk loading/discharge points, cylinder filling/ storage areas and buildings storing flammable material	25
D	- the external retention wall of atmospheric pressure, refrigerated product storage tanks (7)	1.5 D_r
E	- laboratories, control rooms, main offices, other buildings where people are concentrated, and site boundary	Related to the vessel capacity. See Table 3
F	- the edges of unrestricted plant/depot roads (5)	15
G	- the battery limits of processing units	25
H	- air intakes and other fixed sources of ignition	15
I	- the edge of the mound of a mounded vessel, or the periphery of a buried vessel (5)	5
J	- the manifold separation wall (centre)	5

NOTES:

(1) Safety distances B, C and D are dictated by the potential hazards of other plant items as specified in the above table on LPG storage vessels. Other distances are dictated by the potential hazards of LPG storage vessels on other plant items.

(2) Safety distances for vessels exceeding 135 m^3 capacity shall be verified by a radiation assessment. See Table 1 and Figure 2.

(3) Safety distances shall be measured from the periphery of the vessel nearest to the hazard.

(4) Distance required for access of earth moving equipment. Minimum shall be 2.5 metres.

D_1 and D_2 are the diameters of two adjacent vessels.

(5) Consideration shall be given to restricting the movement of traffic during draining operations. Refer to (2.1.2(e)) for minimum vapour path travel to source of ignition.

(6) Definition of product class is in accordance with IP Model Code of Safe Practice, Part 15.

(7) D_r is the diameter of the outer tank of the refrigerated storage tank.

Table 3 Minimum safety distance "E" for above-ground LPG pressure storage vessels (capacity £ 135 m^3)

Vessel capacity (m^3)	Safety distance "E" (metres)
Capacity ≤ 2.5	3.0
2.5 < Capacity ≤ 5	5.0
5 < Capacity ≤ 10	7.5
10 < Capacity ≤ 50	15.0
50 < Capacity ≤ 95	22.5
95 < Capacity ≤ 135	30.0

NOTES: (1) Safety distances for vessels exceeding 135 m^3 capacity shall be verified by a radiation assessment. See Table 1.

(2) Distance "E" is defined in Table 2 and is shown on Figure 2.

(3) Vessels exceeding 2.5 m^3 capacity shall not be located less than two vessel diameters from the solid wall of a building.

Table 4 Vapour pressure of commercial butane and propane at assessed temperatures

Storage vessels in:	Assessed temperature (°C)	Vapour pressure (bar absolute)	Vapour pressure (bar absolute)
		Commercial butane	Commercial propane
Temperate climates	35	5.5	14.8
Tropical climates	40	6.2	16.7
Desert climates	45	7.0	18.8

Table 5 Vapour pressure of normal butane at sub-zero temperatures

Temperature (°C)	Pressure (bar absolute)
-5	0.80
-10	0.66
-15	0.56
-20	0.46

Table 6 Minimum safety distances for mounded LPG pressure storage vessels (capacity £ 135 m^3)

Code (1) (from Figure 14)	Description	Minimum safety distance (metres)
A	*Between mounded LPG storage vessels (measured between the peripheries)* (3)	1
	Between above-ground connections, PRV, etc., and: (3) (4)	
B	- the edges of restricted plant/depot roads and pipe tracks (5)	7.5
	- the centre of the top of the bund wall surrounding crude oil, Class I and Class II product tanks - the tank shell for Class III product tanks and Class II product tanks not requiring a bund (6)	10
C	- bulk loading/discharge points, cylinder filling/ storage areas, buildings storing flammable material, and above-ground LPG storage vessels	15
D	- the external retention wall of atmospheric pressure refrigerated product storage tanks (7)	D_r
E	- laboratories, control rooms, main offices, other buildings where people are concentrated, and site boundary	Related to the vessel capacity, see Table 7
F	- the edges of unrestricted plant/depot roads (5)	10
G	- the battery limits of processing units	15
H	- air intakes and other sources of ignition	15
I	*Between the edge of the mound of a mounded vessel or the periphery of a buried vessel and an above-ground storage vessel* (3)	5
J	*Between the edge of the mound and all neighbouring facilities*	1
K	*Between the vessel shell and all neighbouring facilities*	3

NOTES:
(1) Safety distances B, C and D are dictated by the potential hazards of other plant items as specified in the above table on LPG storage vessels. Other distances are dictated by the potential hazards of LPG storage vessels on other plant items.
(2) Safety distances for vessels exceeding 135 m^3 capacity shall be verified by a radiation assessment. See Table 1 and Figure 14.
(3) Distance required for safe operation of earth moving and other maintenance equipment.
(4) Safety distances shall be measured from exposed nozzles, tank fittings, etc. of the vessel nearest to the hazard.
(5) Consideration shall given to restricting the movement of traffic during draining operations.
(6) Definition of product class is in accordance with IP Model Code of Safe Practice, Part 15.
(7) D_r is the diameter of the outer tank of the refrigerated storage tank.

Table 7 Minimum safety distance "E" for mounded LPG pressure storage vessels (capacity £ 135 m^3)

Vessel capacity (m^3)	Safety distance "E" (metres)
Capacity ≤ 2.5	2.0
2.5 < Capacity ≤ 5	3.0
5 < Capacity ≤ 10	4.0
10 < Capacity ≤ 50	7.5
50 < Capacity ≤ 95	12.0
95 < Capacity ≤ 135	15.0

NOTES: (1) Safety distances for vessels exceeding 135 m^3 capacity shall be verified by a radiation assessment. See Table 1.

(2) Distance "E" is defined in Table 6 and is shown on Figure 14.

APPENDIX 2 FIGURES

Figure 1 Typical layout of LPG pressure storage vessels

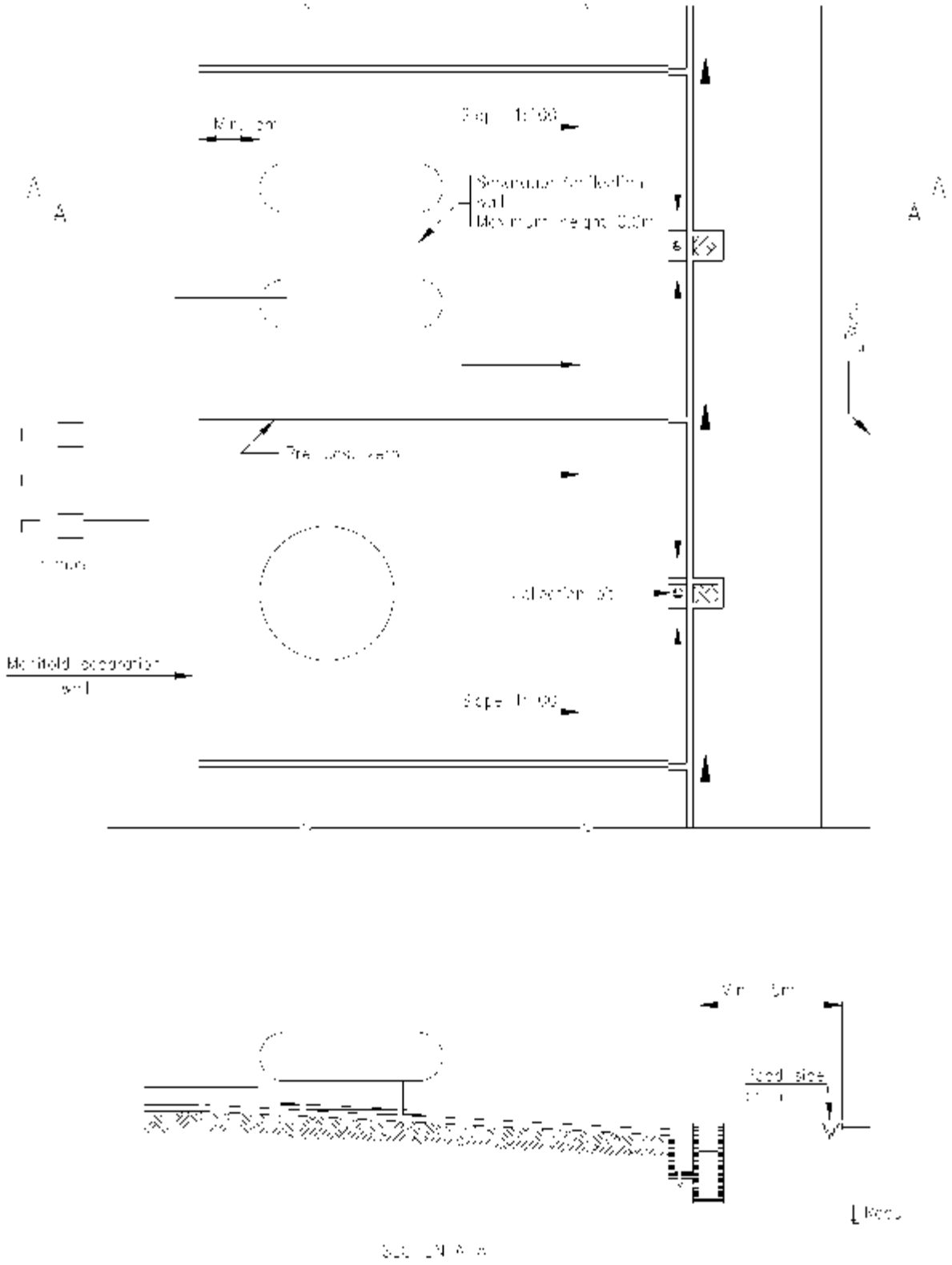
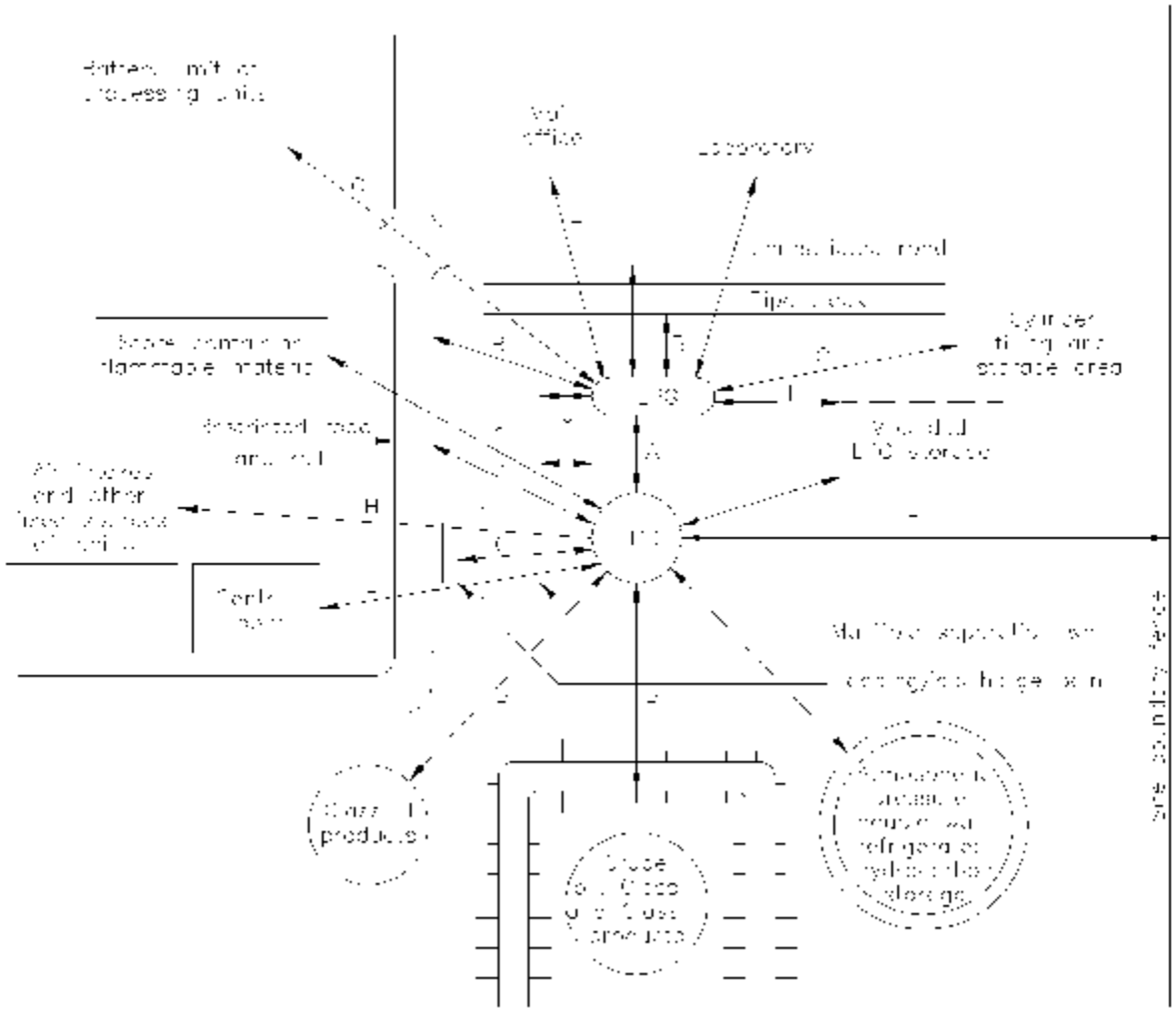


Figure 2 Safety distances for above-ground LPG pressure storage vessels (capacity > 135 m^3)



Vessel capacity (m^3)	Safety distance (metres) (2)									
(1)	A (3)	B	C	D (4)	E	F	G	H	I	J
135 < Capacity ≤ 265	$(D_1+D_2)/4$	15	25	1.5 D_r	37.5	22.5	25	22.5	15	5
265 < Capacity ≤ 500	$(D_1+D_2)/4$	15	25	1.5 D_r	60	22.5	25	22.5	15	5
Capacity > 500	$(D_1+D_2)/4$	15	25	1.5 D_r	60	30.0	25	30.0	15	5

NOTES: (1) For vessels with capacity not exceeding 135 m^3, see Table 2.

(2) All distances shall be verified by radiation assessment. See (2.1.2).

(3) D_1 and D_2 are the diameters of two adjacent vessels.

(4) D_r is the diameter of the outer tank of the refrigerated storage tank.

Figure 3 Vapour pressure/temperature relationships for pressurised commercial butane/propane mixtures by volume

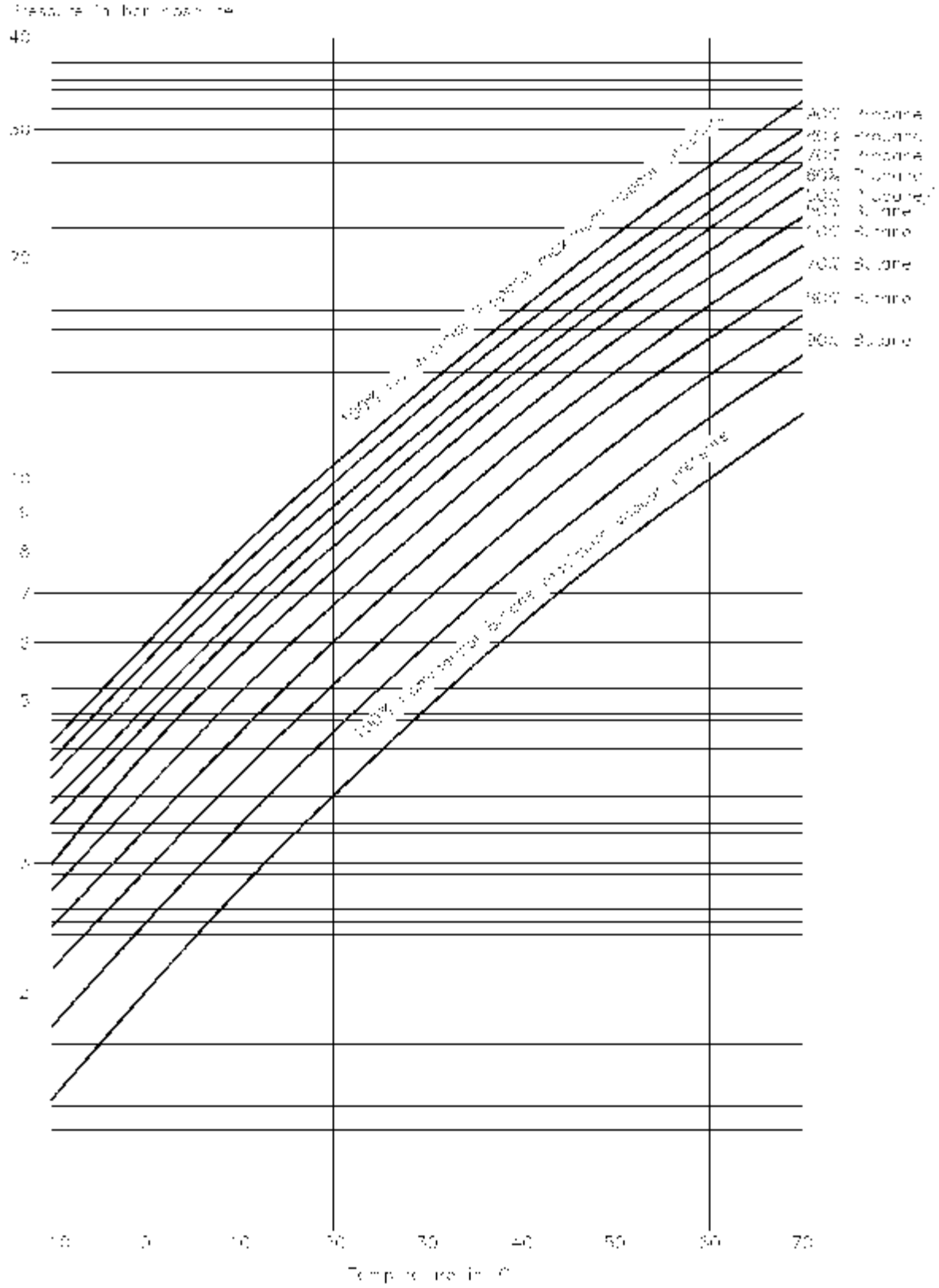


Figure 4 Bottom connection at LPG pressure storage vessels with ESD valve at the manifold side of the separation wall

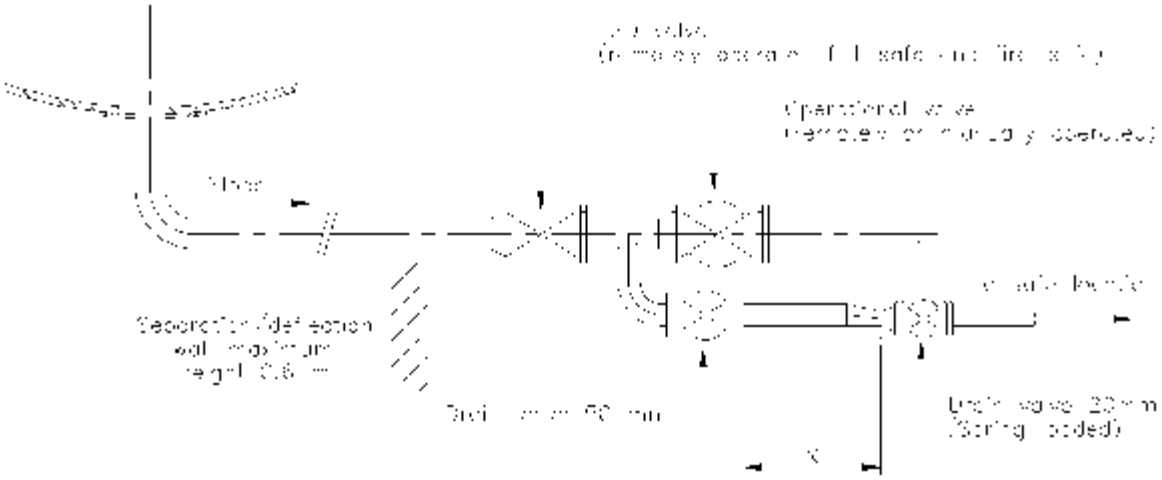
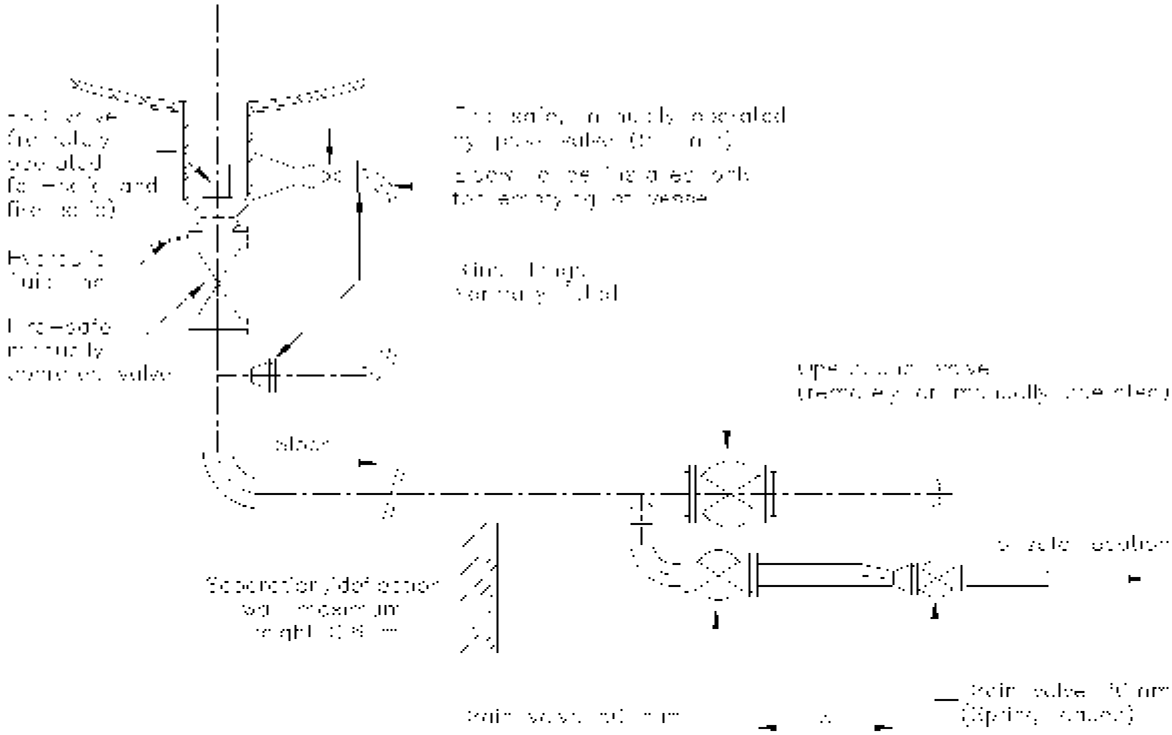
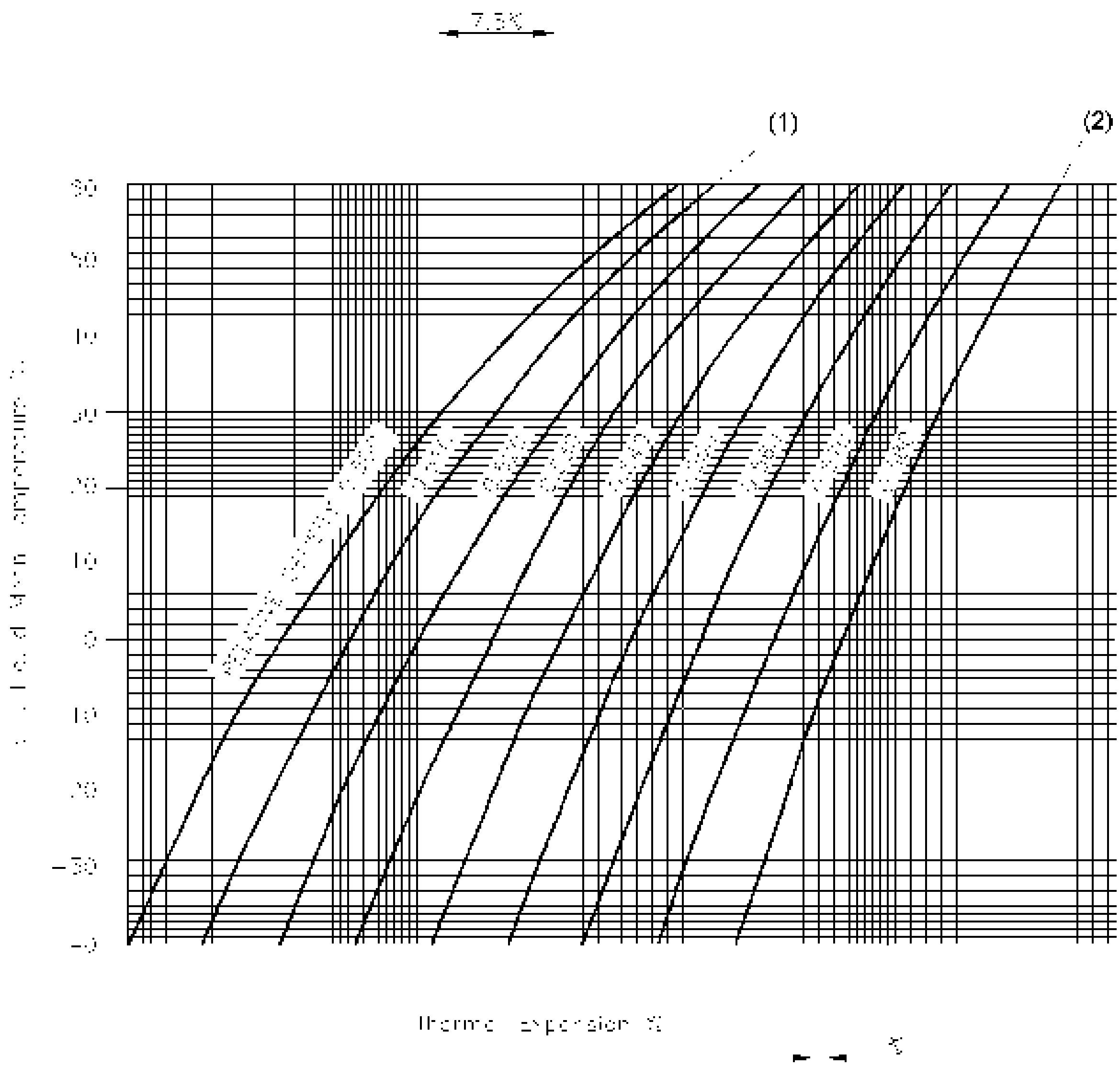


Figure 5 Bottom connection at LPG pressure storage vessels with internal ESD valve and drain system outside the separation wall



* Minimum [illegible] m
Maximum [illegible] simultaneous operation [illegible] valves by a single operator

Figure 6 Typical LPG liquid volume correction graph



(1) [illegible]
(2) [illegible]

[illegible]
[illegible] 7.5% [illegible]

[illegible] NFPA 58 [illegible]

Figure 7 Graph to determine the setting of level alarm/ullage gauges for overfill protection of horizontal and spherical LPG pressure vessels

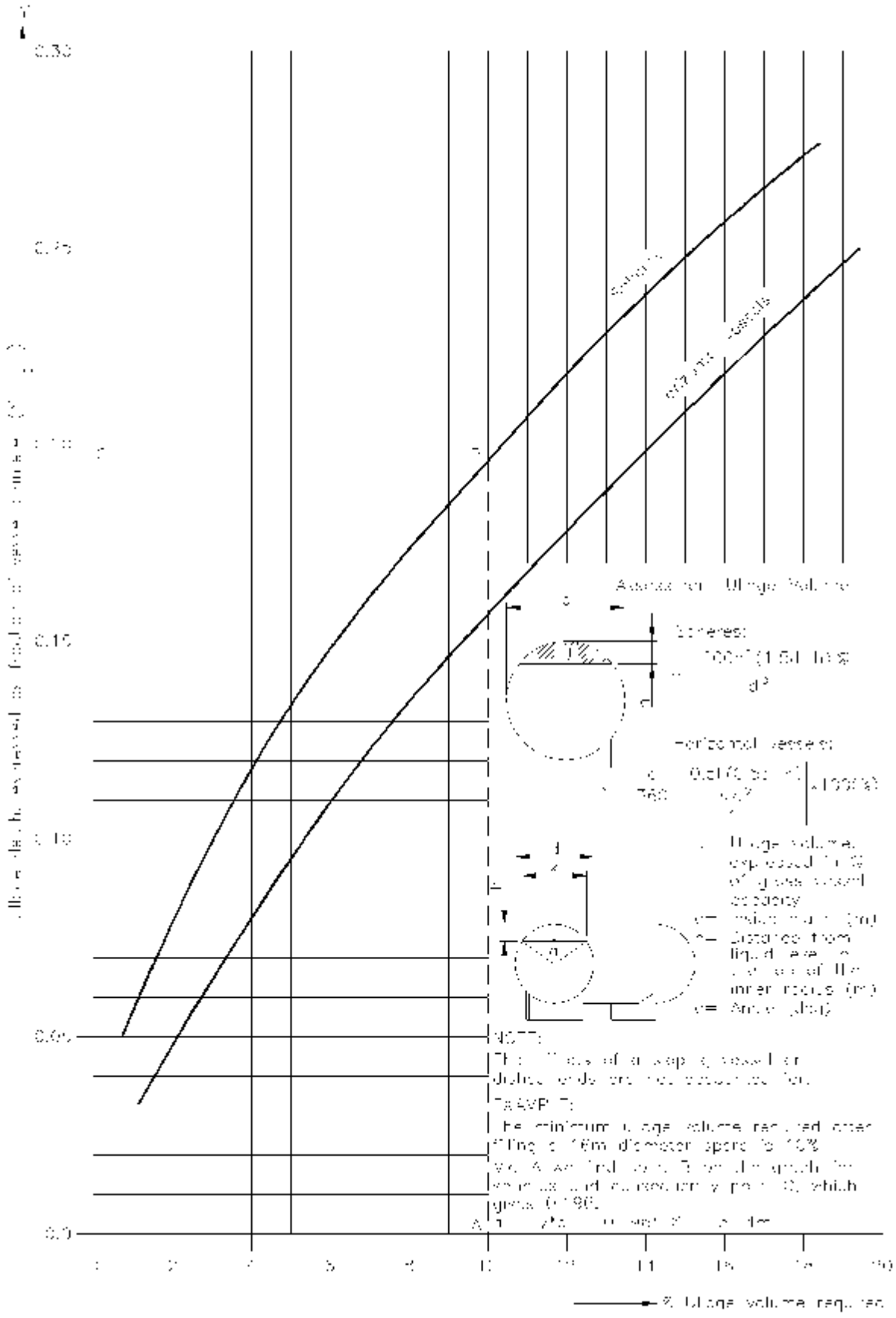

0.30
0.15
0.0
% Ullage volume required

Figure 8 Typical arrangement for High Level set points

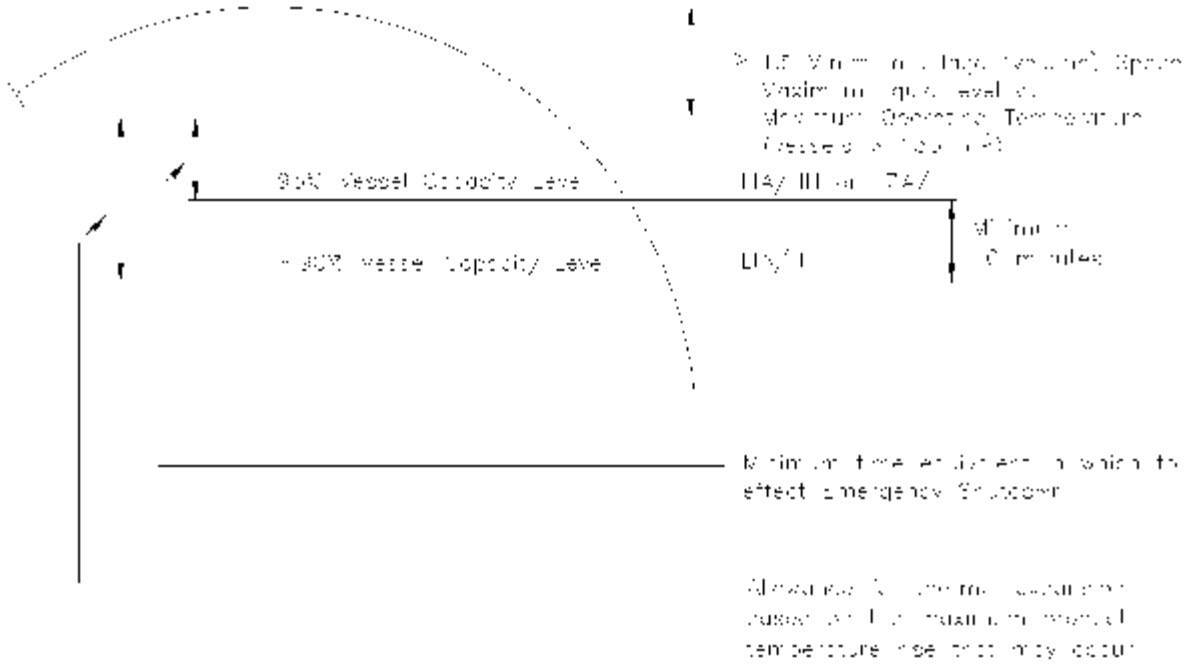


Figure 9 Typical control system for a remotely operated (hydraulic) valve

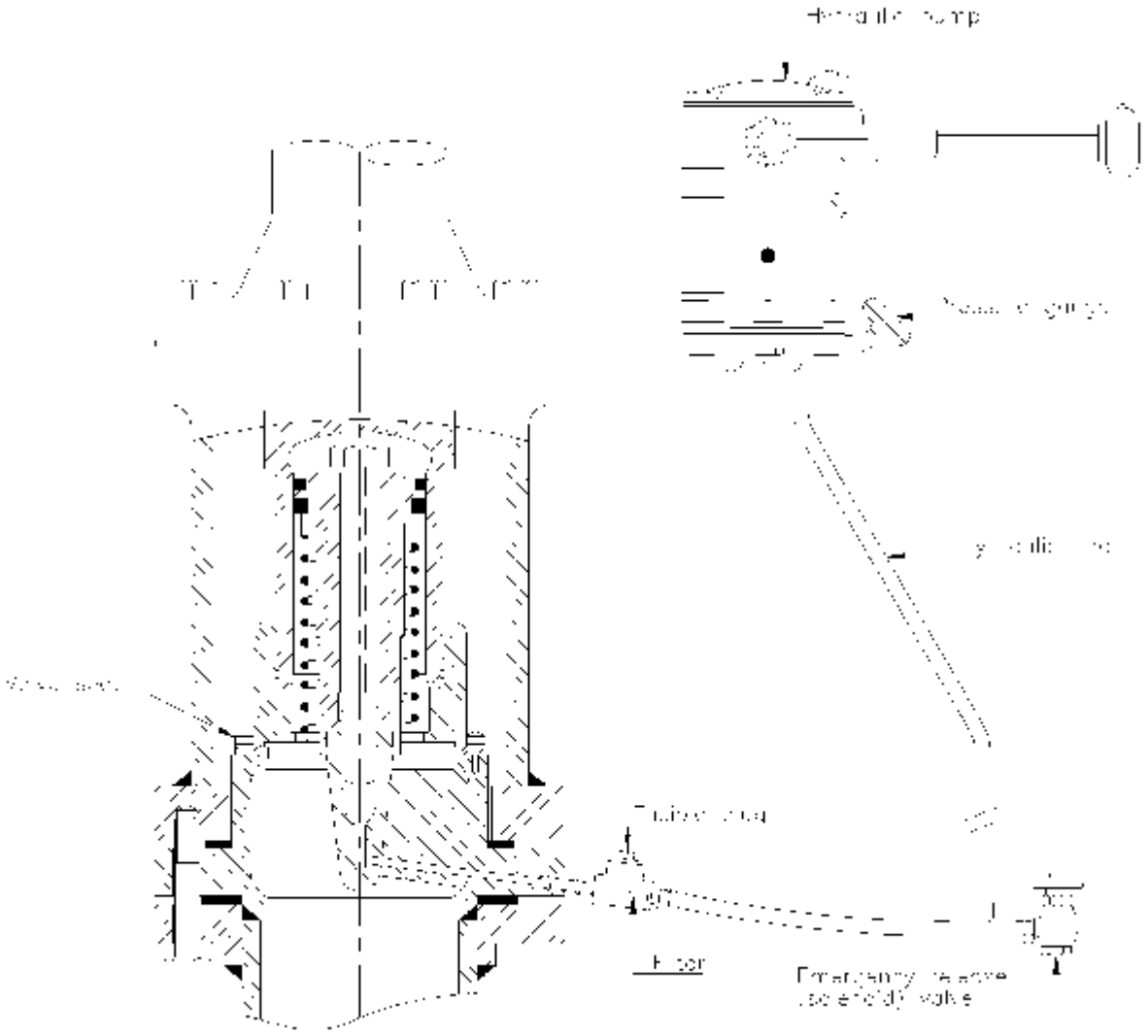
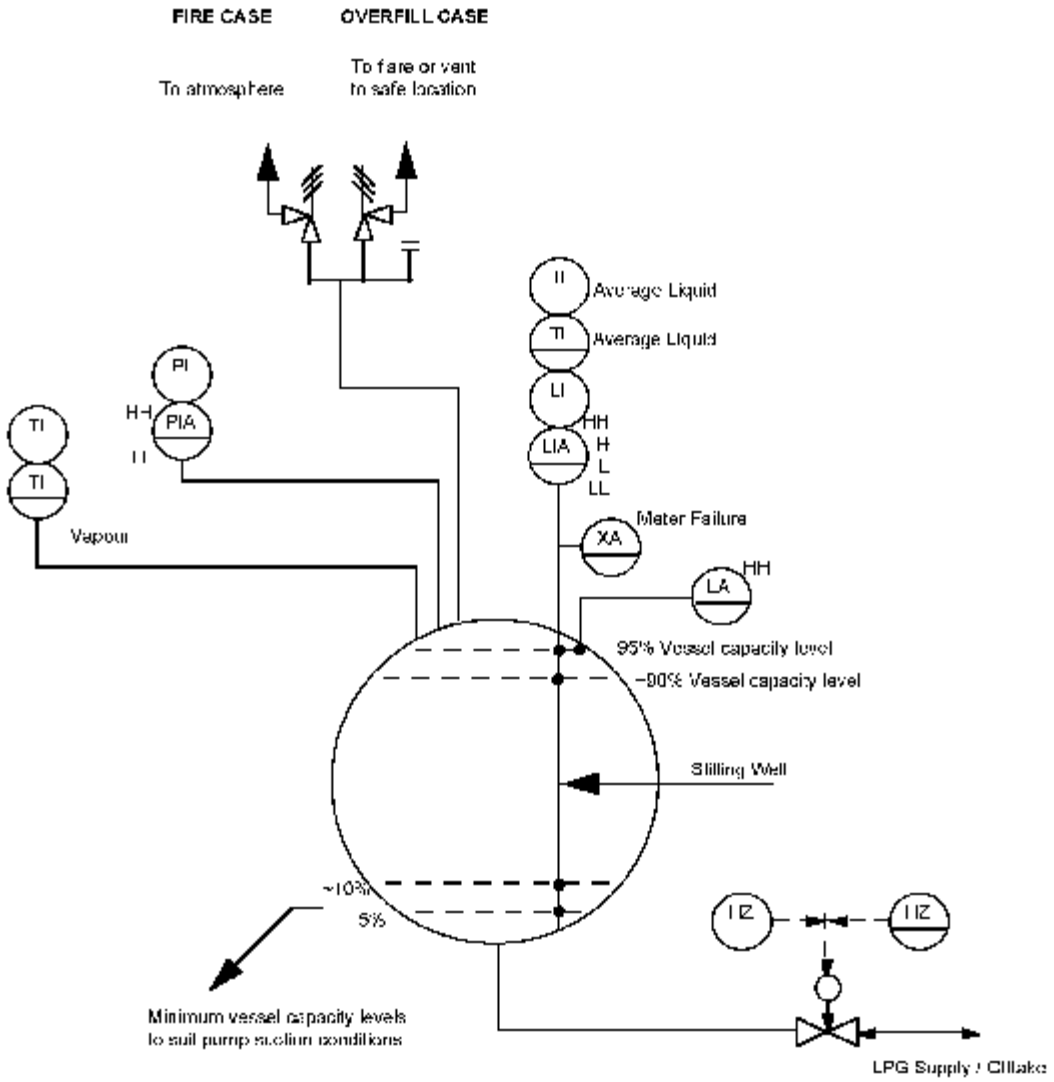


Figure 10 Protection system for situations in which filling/delivery rates are based on alarms and corrective actions are manually implemented

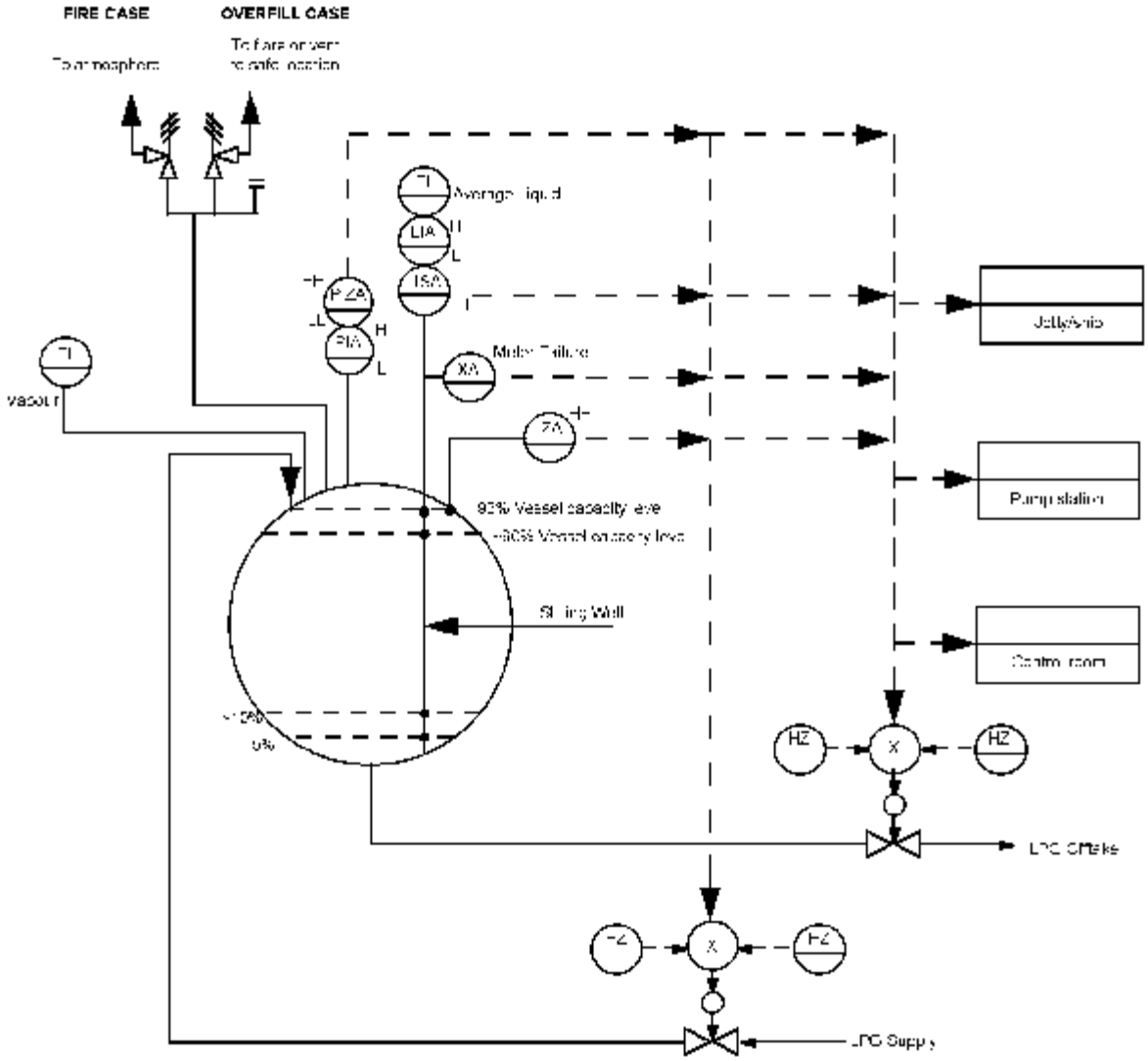


SUGGESTED ALARM PRIORITIES					
Alarm	Priority				Suggested Action
	Record	Low	High	Emergency	
PIA/HH	X			X	Stop Supply
PIA/LL	X			X	Stop Offtake
LA/HH	X			X	Stop Supply
LIA/HH	X		X		Stop Supply
LIA/H	X	X			Re-route Supply
LIA/L	X	X			Re-route Offtake
LIA/LL	X		X		Stop Offtake
HZ	X			X	Stop Supply and Offtake
XA	X			X	Call-out Instrument Maintenance

NOTES: (1) For location of the emergency shutdown valves, see Figures 4 and 5.
(2) Maximum relieving pressure for fire exposure: see (2.4.8).
(3) Situation for example in process plants and installations where filling rates are low.

(4) Typically, the LIA/H and LA/HH are set at 90% and 95% respectively of the gross vessel capacity. However, these settings may need to be lowered to give the operator sufficient time, at least 20 minutes, to redirect the flow manually.

Figure 11 Protection system for situations in which filling/delivery rates are high and corrective actions are automatically implemented



SUGGESTED ALARM PRIORITIES					
Alarm	Priority				Suggested Action
	Record	Low	High	Emergency	
PIZA/HH PIZA/LL	X X			X X	Trip Supply Valve Trip Offtake Valve
PIA/H PIA/L	X X		X X		Re-route Supply Re-route Offtake
LZA/HH	X			X	Trip Supply Valve
LIA/H LIA/L LISA/LL	X X X	X X	X		Re-route Supply Re-route Offtake Trip Pump
HZ	X			X	Stop Supply and Offtake
XA	X			X	Call-out Instrument Maintenance

NOTES: (1) For location of the emergency shutdown valves, see Figures 4 and 5.

(2) Maximum relieving pressure for fire exposure: see (2.4.8).

(3) On failure of level gauge, repair time shall be less than 4 to 8 hours, to be specified locally.

Continuation of pump-out operations requires increased surveillance of PIZA/LL by operating personnel.

(4) PIZA/LL can be used to indicate zero liquid level. Priority of alarm from PIA/L to be set high.

(5) For IPF classification, refer to DEP 32.80.10.10-Gen.

Figure 12 Typical arrangements for pressure relief valves

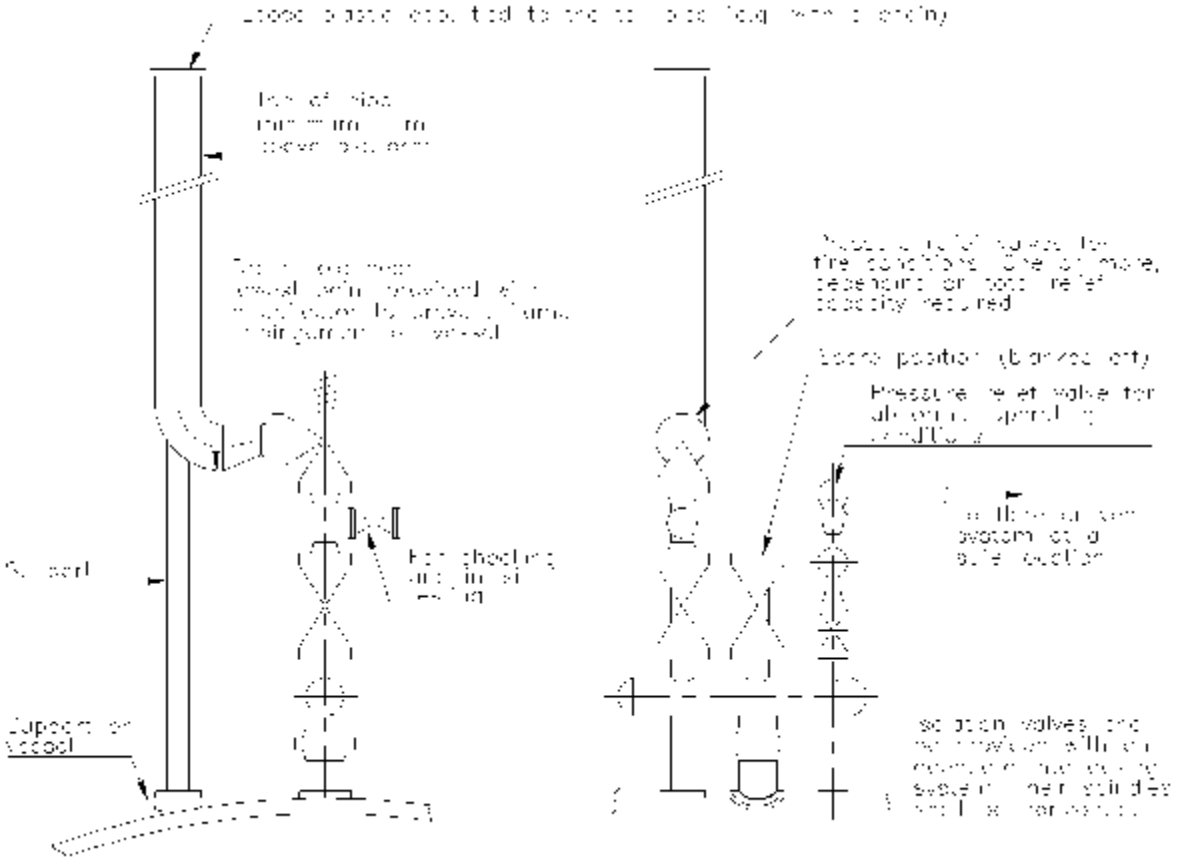


Figure 13 Arrangement of thermal expansion relief valves in cascade system

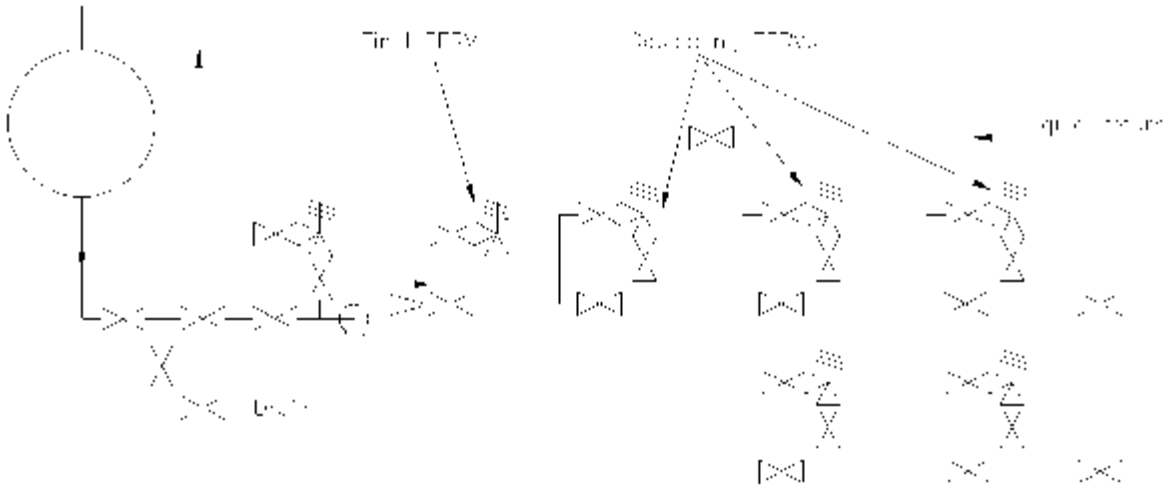
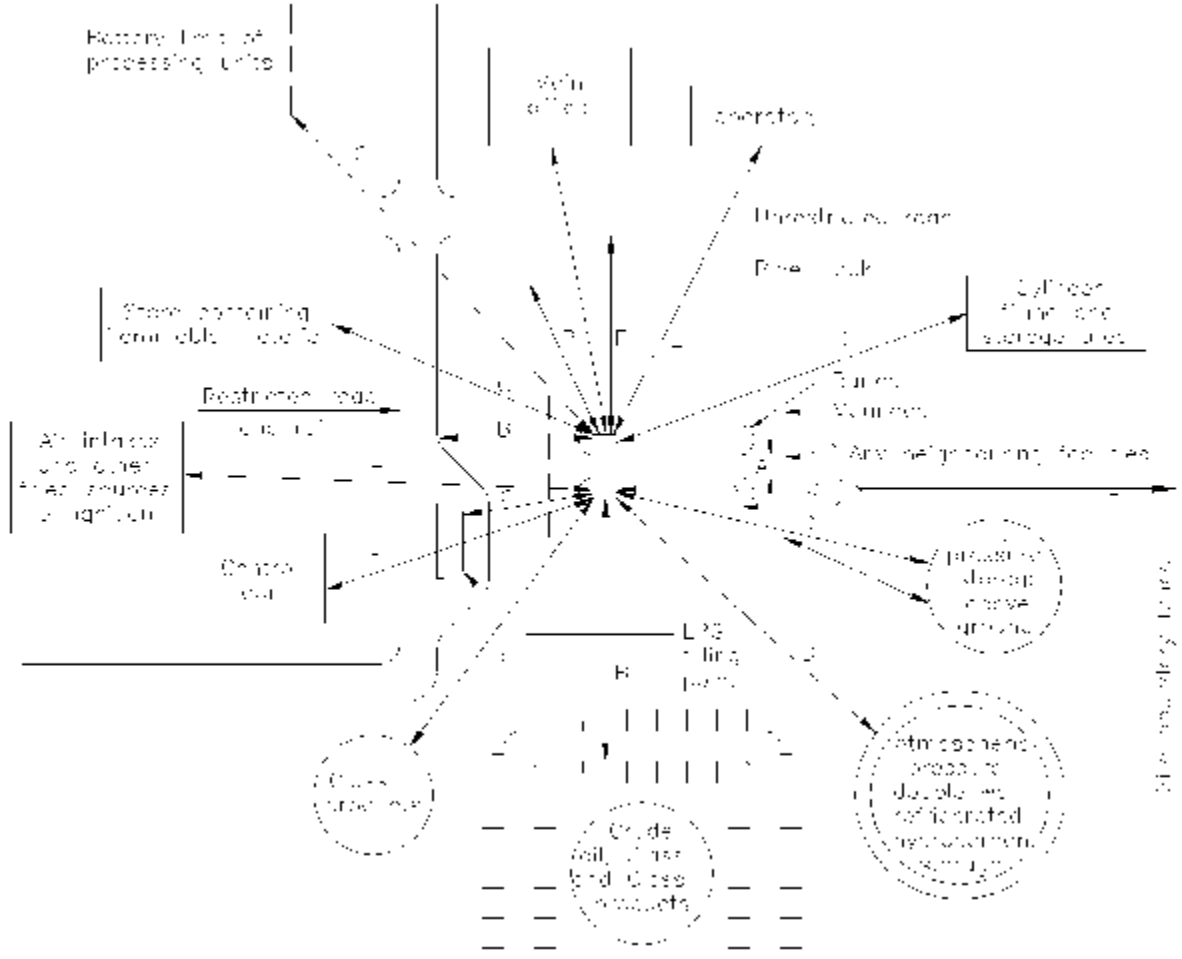


Figure 14 Safety distances for mounded LPG pressure storage vessels (capacity > 135 m^3)



Vessel capacity (m^3)	Safety distance (metres) (2)										
(1)	A	B	C	D (3)	E	F	G	H	I	J	K
135 < Capacity ≤ 265	1	7.5	15	D_r	22.5	22.5	25	22.5	15	1	3
265 < Capacity ≤ 500	1	7.5	15	D_r	22.5	22.5	25	22.5	15	1	3
Capacity > 500	1	7.5	15	D_r	30.0	30.0	25	30.0	15	1	3

NOTES: (1) For vessels with capacity not exceeding 135 m^3, see Table 6.

(2) All distances shall be verified by radiation assessment. See (3.1.2).

(3) D_r is the diameter of the outer tank of the refrigerated storage tank.