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MANUAL

LPG BULK TRANSFER AND TRANSPORTATION

DEP 30.06.10.13-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

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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.

When Contractors or Manufacturers/Suppliers use DEPs they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the DEPs. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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1. INTRODUCTION

1.1 SCOPE

This DEP specifies requirements and gives recommendations for transfer methods and systems for pressurised LPG. It also specifies requirements for the layout, location and safety and operability aspects of loading/discharging facilities used for the bulk transportation of LPG by pipeline, road, rail and water.

LPG includes commercial propane, commercial butane and mixtures thereof.

This DEP is a revision of the DEP with the same number dated November 1978.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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This DEP is intended for use in oil refineries, chemical plants, gas plants, exploration and 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, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this document 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 document as closely as possible.

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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 authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 ABBREVIATIONS

ADR	Act on the European Agreement on the transporation of Dangerous Goods by Road
ESD	Emergency Shut Down
EFV	Excess Flow Valve
ERC	Emergency Release Coupling
ERS	Emergency Release System

GVW	Gross Vehicle Weight
IMO	International Maritime Organisation
ISV	Internal Safety Valve
NRV	Non-Return Valve
OCIMF	Oil Companies International Marine Forum
PRV	Pressure Relief Valve
QCDC	Quick Connect/Disconnect Coupling
RID	Regulations on the International Transport of Dangerous Goods by Rail
ROV	Remotely Operated Valve
RTW	Rail Tank Wagon

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 in this DEP are listed in (7).

2. BULK TRANSFER AND TRANSPORTATION

2.1 TRANSFER METHODS

Loading and unloading involves transfers from one vessel to another and to achieve this different methods may be employed depending upon a number of factors such as:

- the distance and difference in elevation between supply and receiving vessels;
- the pressure differential;
- the characteristics of the product;
- the design characteristics of the supply and receiving vessels;
- the transfer rate required;
- the method of measurement, e.g. meter, weighing, tank gauging.

This section deals with the methods and equipment commonly used to transfer LPG into storage vessels. One of the main objectives in designing the liquid transfer system is to limit the build-up of pressure created by the transfer of LPG into the vessel. If a vapour return system is used between the supply and receiving vessels the pressure build-up in the receiving vessel will be considerably reduced. Transfer systems based on vapour return allow high flow rates but make accurate custody transfer measurement by metering difficult to achieve.

The transferring of LPG into the receiving vessel by filling into the vapour space is considered the best overall method. This may be done directly through a top connection or through a nozzle in the bottom of the vessel with internal piping to the vapour space.

There are two methods generally used in filling into the vapour space:

(i) Spray Loading
LPG is transferred to the receiving vessel through a pipe in the vapour space provided with spray nozzles, orifices or slots. The use of a spray header improves contact between the incoming liquid and the vapour in the vessel and thus reduces pressure build-up through condensation. In some cases spray loading may eliminate the need for a vapour return line.

(ii) Splash Loading
LPG emerges from the internal inlet pipe as a jet. This causes violent disturbance of the liquid surface and results in some evaporation and cooling. The system is not as effective as spray loading in limiting pressure build-up and should only be used if spray loading is not practicable.

If LPG is pumped directly into the liquid phase of a receiving vessel, with no vapour return line in operation, the rising liquid compresses the vapour above it and increases its temperature and pressure (see Appendix 3, Table A2).

The system back-pressure will continue to increase during the transfer thereby reducing the pumping rate and increasing the transfer time. The correct choice of pump, with due consideration being paid to performance at high differential pressures, is clearly important. The design of the transfer system shall take into account the maximum pressure generated during the transfer operation.

2.2 TRANSFER SYSTEMS

In designing transfer systems consideration should be given to performance over the full range of operating conditions likely to be experienced, e.g. due to climatic conditions and the type of storage in use. Product temperatures in mounded vessels could give rise to variations in differential pressures according to the season, thereby affecting pump and compressor performance.

The following systems are illustrated in Figure 1.

a) **Transfer by gravity**
LPG flows from one vessel to another under its own weight. The method is only practicable if there is a substantial difference in elevation between the vessels or product levels. A vapour return system enables higher flow rates to be achieved. The practical opportunities and economic advantages of making inter-vessel transfers by gravity are limited, e.g. decanting faulty cylinders in small filling plants, and should only be carried out under constant supervision.

b) **Transfer by pump**
LPG is pumped into vessels either into the vapour space (via a spray header or an open ended nozzle) or through a bottom connection into the liquid phase. Filling into the liquid phase produces higher pressures (refer to Appendix 3) as a result of very limited heat exchange between the liquid and vapour. It is therefore advisable for the LPG to enter the receiving container in the vapour phase via a spray header which results in a cooling effect in the vapour space thereby reducing back-pressure build-up. Bottom loading requires a vapour withdrawal facility from the receiving container to maintain an adequate loading rate; this is not needed for top loading but a higher loading pump discharge head may then be required.

c) **Bottom loading using a compressor**
The compressor draws vapour from the receiving vessel and introduces it as a compressed vapour into the vapour space of the supply vessel. As a consequence liquid is forced into the receiving vessel through a connection in the liquid phase. High transfer rates are possible but metering is not practicable because vapour is transferred back from the receiving vessel.

d) **Top splash/spray loading using a compressor**
Vapour is drawn from a third vessel and introduced into the supply vessel, forcing liquid from it into the top of the receiving vessel. A vapour return line is not used between the supply and receiving vessels and therefore metering is possible. This system is sometimes used to discharge tankers.

e) **Top splash/spray loading using a compressor and pump**
The difference between this system and that described in (d) is the addition of a pump in the discharge system. The compressor ensures that there is always sufficient net positive suction head (NPSH) at the pump inlet for an optimum transfer rate. Custody transfer measurement may be effected by metering the liquid volume discharged.

f) **Bottom loading using an eductor**
LPG is pumped into the receiving vessel through a bottom connection. An eductor (ejector) is fitted to the line and connects it to the vapour space of the receiving vessel. The liquid flow through the eductor draws vapour from the top of the vessel and carries it into the liquid phase, condensing the greater part in the process. The system limits back-pressure build-up but is no more effective in that respect than spray loading. A vapour return line is not required; metering is possible but eductor design is critical.

2.3 PUMPS AND COMPRESSORS

Refer to DEP 30.06.10.11-Gen.

2.4 METERS

Refer to DEP 30.06.10.11-Gen.

2.5 LOADING/DISCHARGING FACILITIES

2.5.1 General

The design layout and type of equipment for loading/discharging facilities is dependent on a number of factors such as:

- whether the facility is for loading or discharging, or both;
- the number of products and grades to be handled. Separate systems should be used for each product, although multi-product lines may be used. If multi-product piping is used up to the loading/discharging facility, the design shall ensure that inter-product mixing does not result in off-specification product. Interlocks shall be provided to prevent the flow of more than a single product through the loading/discharging facility. A product sampling system for monitoring product quality shall be provided at these facilities.

Precautions shall be taken against the hazards of static electricity see Shell Safety Committee publication “Static Electricity - Technical and Safety Aspects”.

2.5.2 Safety distances

The layout and design of installations 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).

Figure 2 (road and rail facilities) and Figure 3 (marine facilities) show safety distances which may be used for preliminary design purposes. The final spacing shall be determined after an assessment based on Report OH 96-30202 and FRED has been performed.

For further information, refer also to DEP 30.06.10.12-Gen.

2.5.3 Hoses

(a) General

All hoses and hose assemblies used in LPG operations shall be manufactured in accordance with an approved standard at least meeting the requirements of BS 4089.

(b) Materials

The materials used in the construction of hoses and hose assemblies shall be resistant to the action of LPG both as a liquid and a vapour. If woven wire braid (used to restrain the hose against elongation and dampen vibrations) and heavy steel wire reinforcement are used in the hose construction they shall be of stainless steel.

(c) Burst pressure and safety factors

Burst pressure (the pressure at which any part of the hose assembly fails) should be at least 100 bar (ga) and the safety factor (ratio of burst pressure to design pressure) shall be at least 4. The design pressure is equivalent to the maximum working pressure. Hoses supplied to BS 4089 will normally have a minimum burst pressure of 100 bar (ga) and the maximum working pressure may need to be limited to ensure that the safety factor is not reduced in a particular operation. For example, the International Maritime Organisation IMDG Code requires hoses to have a safety factor of 5 and therefore if standard BS 4089 type hoses manufactured to a burst pressure of 100 bar (ga) are used in IMDG operations the working pressure shall not exceed 20 bar (ga). If hoses have to comply with the requirements of the IMDG or similar codes the manufacturing specification shall clearly state the maximum working pressure and safety factor required.

(d) Markings

All hoses shall be marked at intervals of not less than one metre with the following:

- the standard to which the hose was manufactured;
- the hose type/specification within the standard or design pressure and operating temperature range;
- the Manufacturer's name or trade mark;
- the month and year of manufacture;
- the batch number;
- a torsion line along its entire length.

(e) Electrical continuity

Hoses shall be anti-static or conductive. Conductive hoses shall have a maximum resistance of 0.75 Ω/m or 10 Ω in total, whichever is lower. Electrical resistance (continuity) shall be measured in accordance with ISO 8031. For hoses used in marine operations, see (6.6).

(f) Thermal expansion relief

Hose assemblies which are not vented between operations and in which liquid may be trapped shall include a thermal expansion relief valve arranged to vent product to a safe location.

(g) Testing by Manufacturers

All hoses shall be tested in accordance with the standard to which they were produced and shall meet the requirements of MESC 73.12.30.

Type approval tests shall be carried out by Manufacturers on new types or modified designs of hose and hose assemblies and shall meet the requirements of MESC specification 73.12.30/001. The purpose of the type approval tests is to show that hoses in continuous or batch production comply with the manufacturing standard.

Testing of each hose or hose assembly as a routine during the manufacturing process (i.e. production proof testing) should be in accordance with the standard to which the hose is produced. Typical tests are hydrostatic pressure and elongation tests, leak tests, electrical continuity and vacuum tests.

Test certificates shall be in accordance with ISO 10474 Type 3.1.C for type approval tests and in accordance with ISO 10474 Type 3.1.B for production tests. The certificates shall be provided by the Manufacturers for each LPG hose and hose assembly supplied, indicating that they meet the requirements of the manufacturing standard/specification and are fit for purpose.

2.5.4 Loading arms

(a) General

The term “loading arm” refers to all metal self-supported loading and unloading arms with articulated swivel joints and also, if required by the operation, quick connect/disconnect couplings (QCDCs), power system (for large marine arms), control system, operational controls, range control system, purge system, emergency release system (ERS) and jacks (supports).

Loading arms should be used to transfer LPG into and from tankers, bulk vehicles and rail tank wagons. Hoses should be replaced by flexible arms wherever practicable, in order to improve safety. Compared to hoses, flexible arms:

- are often economically advantageous over the longer term, i.e. life of the arm;
- are less prone to damage;
- require less maintenance and less manpower for handling, particularly in the larger sizes;
- require less frequent testing.

(b) Design and construction standards and practices

For piping and fittings, refer to (3.3.1).

Structural steel work used in the loading arm assembly or supporting structure shall comply with DEP 34.00.01.30-Gen.

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

Painting and coating shall comply with DEP 30.48.00.31-Gen. and cathodic protection shall comply with DEP 30.10.73.10-Gen.

Marine loading arms shall also comply with the OCIMF "Design and construction specification for marine loading arms". Road and rail loading arms shall also comply with this OCIMF specification as far as practical.

(c) Materials

All materials used in loading arms shall be suitable for LPG service over the full range of pressures and temperatures likely to be experienced during testing and inspection and during normal operations including commissioning and decommissioning.

Materials shall correspond to those specified in the selected Piping Class for pipes, flanges, fittings, gaskets, etc. For equipment/fittings outside the scope of the Piping Class the appropriate standard, e.g. pressure vessel code, electrical equipment standard, etc., shall apply.

Swivel joints and LPG-carrying parts of couplers shall be constructed of materials which do not galvanically react with the pipe used in the arm.

The liquid seal shall have packing faces of austenitic stainless steel or of an equivalent material which is resistant to pitting corrosion in LPG service.

Metallic materials shall comply with DEP 30.10.02.31-Gen.

Aluminium components shall not be used in those parts of the arm in contact with LPG.

(d) Electrical continuity

Loading arms used for bulk road vehicle or rail tank wagon loading or discharge shall be electrically continuous. Arms used for ships and barges shall incorporate insulating flanges to ensure electrical discontinuity between ship and shore.

(e) Design

(i) Layout and arrangement

Operating envelopes for loading arms shall be determined for each application based on the location of the connections/manifold and the maximum possible movement of the connections during the loading/discharging operation. Arm lengths, clearances and location of the trunnion swivel joint shall be determined to ensure that the arm is suitable for operation to the boundaries of the envelope.

In stored position, the arm shall be immune from possible impact damage which could be caused by passing traffic, berthing ships, etc.

The range of arm movements and the layout of gantries, marine berths, etc., shall allow the outboard joint/coupling to be positioned on the platform/deck for maintenance with an adequate space (at least one metre) for safe access to the joint.

Depending on operational requirements arms shall be balanced for either the full or empty condition. If arms are to be left full of product, they should be balanced in the liquid-full condition. Arms normally emptied after use should be balanced in the empty condition. Arms equipped with emergency release couplings (ERCs) should be balanced for the specific conditions applying when this coupling has been broken, i.e. for the liquid-full condition. Consideration shall be given to the need to restore arms to the stored position in the event of an emergency release.

(ii) Design pressure and temperature

The design pressure of the loading arm shall be not less than the vapour pressure of the grade of LPG handled at the Assessed Temperature for Developed Pressure given in Table 1 plus the differential pump pressure at the arm and the effects of surge pressure caused by the closing of valves in the system.

The upper design temperature of the loading arm shall be not less than the assessed temperature.

The lower design temperature shall be the atmospheric boiling point (ABP) of the product.

(iii) Stress analysis

Manufacturers shall carry out analyses of stresses and deflections in the loading arm and in the connecting manifold in all appropriate arm conditions. Arm components should be analysed in their most highly loaded condition. Any type of load other than its own weight which reduces the total calculated stress level in any component of the arm shall be ignored for that component.

Wire ropes used for arm manoeuvring systems shall have a safety factor of 5 relative to the minimum breaking strength at the arm's maximum load condition.

The method of stress analysis detailed in the OCIMF “Design and construction specification for marine loading arms” should be followed.

(f) Swivel joints

Swivel joints shall be capable of being lubricated without dismantling. Lubrication points shall be readily accessible in both stored and maintenance positions. A lubricant relief port shall be provided to prevent overpressure.

For marine arms, all swivel joint assemblies except the outboard joint (triple) swivel shall have devices to permit repacking without dismantling major sections of the arms.

If there is an outboard joint (triple) swivel it shall be balanced (with its support device, coupling and valves) so that the outboard flange remains in the vertical plane for all arm attitudes.

Swivel joints shall have ball or roller bearings and shall be designed so that water cannot penetrate from the outside and freeze in the joints between rotating parts of the swivel. Swivel joints may be equipped with purge connections if required. Joints shall be designed for temporary vacuum conditions if ambient temperatures could fall to levels which could create pressures below atmospheric in the arm or if the use of a compressor could similarly reduce pressure.

Safety factors and swivel joint design loads shall follow the OCIMF “Design and construction specification for marine loading arms”.

(g) Quick connect/disconnect couplings (QCDCs)

If QCDCs are proposed, coupling/uncoupling operations should be made possible both from the central loading arm control panel (if provided) and from the local control point (which may be a portable or pendant control panel).

All coupler clamps shall operate simultaneously and in such a way that clamp mating forces shall be approximately equal and not overstress the mating flanges/connections while coupling or disconnecting.

In the event of a locking mechanism power failure the coupling shall fail safe and remain securely fastened to the tanker manifold flange or to the the rail tank waggon (RTW) or bulk road vehicle connection. A manual override shall be provided allowing release without power.

The flange end of the QCDC shall be ANSI rating class 300. In marine applications in which a variety of tankers may be loaded or discharged, consideration shall be given to using couplings able to connect up with flanges other than ANSI, e.g. BS and DIN.

If lubrication from an external source is a requirement it shall be possible to provide this without dismantling the coupling.

The design pressure of the coupling shall not be lower than that of the loading arm.

Safety factors shall be not less than those indicated in the OCIMF “Design and construction specification for marine loading arms”.

(h) Emergency release couplings (ERCs)

DEP 30.06.10.20-Gen. shall apply.

(i) Accessories

(i) Storm locks

For all marine applications, and in rail/road loading facilities in areas exposed to high winds, a mechanical tie-down device shall be provided to prevent the inboard arm from moving when in the stowed position. Either mechanical or hydraulic locks may be used. Interlocks shall be employed to prevent the attempted movement of the arm with the locks engaged and to prevent engaging the locks when the arm is in the operating mode.

(ii) Supports (jacks)

In marine applications, if the stress level at the ship’s manifold exceeds safe limits (refer to the OCIMF “Design and construction specification for marine loading arms”), a support or jack shall be fitted to the arm to provide support between the arm and the deck. The mounting of the support on the loading arm shall be such that the support is free to move with the pitching motion of the vessel.

(iii) Insulating flanges

In marine applications insulating flanges or joints shall be incorporated in the arm to isolate the vessel from the shore system (refer to 6.6).

(iv) Drain and purge connections

Connections for draining and purging should be provided as required for the loading/discharging operation and for maintenance purposes, to enable the arms to be cleared of liquid and their residual vapour content to be reduced by means of a compressor. Connections shall comply with the piping class of the arm, be flanged, be not less than nominal size DN 25, Schedule 80 and be protected by their location or mechanical means against possible impact damage.

(j) Expansion joints

Bellows and expansion joints shall not be fitted in loading arm systems.

(k) Operating and control design

Control power systems shall be either electro/hydraulic or all hydraulic.

In marine and block train applications consideration shall be given to combining all control modes at a console located on the loading jetty/gantry with local control on individual arms or sets of arms as required for operational and maintenance purposes. If both central and local control systems are installed, interlocks shall be fitted to prevent both systems from operating at the same time. Arms undergoing maintenance shall be capable of being isolated locally by a lock-out system which cannot be overridden.

Hydraulic systems shall be designed to handle maximum wind load on the arm during manoeuvring plus the resistance in swivels and rotating sheaves. The system design shall also be capable of handling loads produced by acceleration/deceleration of the arm. Hydraulic systems shall be protected by their location or other means against collision damage. Speed control mechanism shall be tamper-proof and adjusted to ensure the safe and proper control of arm movements under all operating conditions. Simultaneous powered movement of arms at the same loading location should not be possible during manoeuvring or flange/coupling connection.

Consideration shall be given to the possibility of moving powered arms in the event of an electrical or hydraulic failure, i.e. return to freewheel mode.

At marine terminals with frequent vessel movements consideration shall be given to fitting an audio-visual alarm and a system which automatically actuates ERCs if loading arm movements extend outside specified envelopes (see (6.5.2)).

(l) Inspection and Testing

(i) Pressure testing

Shop testing:
All arms shall be completely assembled and hydrostatically tested to at least 1.5 times the design pressure. The test pressure shall be maintained for at least 30 minutes to determine if there are any leaks. Testing shall take place with the arm fully assembled and placed in the hydrostatic test position. During hydrostatic testing the arm shall be restrained as necessary to reduce any stress from bending or other external source.
The hydrostatic test shall be performed in order to confirm that there is no deformation, damage or leakage. To avoid stress corrosion in austenitic stainless steel components, fresh water with a low chloride content (less than 200 mg/kg) shall be used for hydrostatic testing. Arms shall be dismantled and thoroughly dried after testing (refer to DEP 31.40.40.38-Gen.).
The above shop tests shall be carried out prior to painting.

Site testing:
Prior to initial operation the fully assembled arm shall be pneumatically leak tested using a soap solution or other suitable means of leak detection. Either nitrogen or dry air shall be used. The test pressure shall be 6 bar (ga) and shall be maintained for at least 30 minutes.

(ii) Working range and clearance check

One arm of a batch or series should be erected in the Manufacturer's workshop to verify that the working range of the arm is as specified.

After installation, checks shall be carried out to confirm that arm movements are sufficient to ensure that connecting flanges/couplings will reach the limits of the specified envelope at the correct attitude. Positions at which audio/visual alarms and emergency release signals are generated shall also be checked.

(iii) Swivel testing

Marine arms shall be shop proof tested by subjecting the swivel to a swivel test load as defined in the OCIMF "Design and construction specification for marine loading arms" without resulting in permanent deformation of any part of the swivel.

The swivel test shall be carried out as follows:

- hydrostatic test at an internal pressure of 1.5 times the design pressure or 28.5 bar (ga), whichever is the greater; then
- partial vacuum test at 0.5 bar (abs); then
- hydrostatic test at an internal pressure of 1.5 times the design pressure or 28.5 bar (ga), whichever is the greater.

(iv) Quick connect/disconnect coupling test

QCDCs should be tested for leakage, fail-safe capability and load capacity. If load capacity tests have been carried out in the form of a type approval test then no further load capacity testing of the coupling is required provided that changes have not been made to the model's specification.

Leak tests shall be carried out at ambient and at the lower design temperature.

Tests should be carried out in the power failure mode to demonstrate the fail-safe requirement of the QCDC. The ability of the coupling to disengage when the arm is both full and empty in varying positions within its operating envelope should also be verified.

Load tests shall be carried out in accordance with the OCIMF "Design and construction specification for marine loading arms".

(v) Emergency release coupling test

ERCs shall be tested for leakage, permanent deformation and release performance in accordance with the OCIMF "Design and construction specification for marine loading arms".

(vi) Resistance across any insulating flange shall be checked.

2.6 PORTABLE TANKS

IMO/ISO freight container tanks are specifically designed for multi-modal transportation of products, i.e. by road, rail or sea. LPG tanks are designed and constructed to comply with IMO Type 5 (IMDG code, Section 13) plus the requirements of other relevant codes, e.g. ISO standard for container tanks, ADR, RID and the US Government DoT specification. These tanks, if used for LPG, are usually equipped with pressure relief valves (PRVs), a maximum ullage gauge and liquid and vapour valves fitted with remotely operated internal safety valves (ISVs). Containers operated internationally by road or rail shall conform to ADR and RID specifications respectively; containers used in areas subject to US Coast Guard regulations shall also conform to DoT requirements. Most containers in international operation are owned by leasing companies who should ensure that tanks on hire meet all current regulations.

For LPG transportation, IMO/ISO containers shall be used only if more than one transport mode is used. An example of this type of movement is where IMO tanks (on road or rail units) are filled at a terminal or refinery, transferred to a dock for loading on to a container ship for transfer by sea to a receiving port, from where they are unloaded and transported by road or rail to a storage depot. At the depot, they should be discharged into fixed storage, ready for return to their point of origin.

Proposals to use demountable or skid tanks for distribution of LPG are subject to the approval of the Principal.

Figure 4 shows a typical layout of an IMO Type 5 container tank.

ISO containers shall not be used for providing fixed storage facilities as they do not fulfil requirements with respect to piping, ESD and fire fighting provisions.

2.7 ODORISATION FACILITIES

Refer to DEP 30.06.10.11-Gen.

2.8 SAFEGUARDING SYSTEMS - EMERGENCY SHUTDOWN

In view of the potential consequences of an LPG liquid/vapour spill, systems for safeguarding the integrity of the plant and equipment shall be incorporated in the design to limit the quantity of released product.

In fully automated systems, product flow shall not start unless all safeguarding conditions are met (e.g. earthing cable and loading arm connected properly) and shall be automatically halted during filling if one condition ceases to be acceptable (e.g. loading arm moves beyond safe limits).

There shall be remote controls to stop the loading/discharging operation and activate the emergency response procedure. These controls should be installed at the control room or centre, and near the loading point as well as at safe locations nearby. Consideration shall be given to installing gas detectors in product transfer areas where connections are regularly made and uncoupled. The detectors should be set to trigger audible and/or visual alarms in the control centres and operating areas.

The activation of the ESD controls should shut down the loading pump/compressor and close the ESD valves protecting the transfer points. Elaborate safeguarding features can be incorporated in plant safety systems and their degree of sophistication will need to be assessed according to local requirements and circumstances. For example, in terminals, refineries and large storage plants consideration shall be given to integrating fire alarms, fire pump start mechanisms, the opening of valves in fire mains/sprinklers/water curtains and ESD systems.

2.9 FIRE PROTECTION FACILITIES

The requirements for fire protection facilities shall be based on an assessment of the fire safety. Refer to Report OH 96-30302, DEP 80.47.10.30-Gen. and DEP 80.47.10.31-Gen.

3. TRANSPORT BY PIPELINES

3.1 GENERAL

A pipeline is a system of pipes and other components used for the transportation of fluids, between (but excluding) plants. A pipeline extends from pig trap to pig trap (including both pig traps) or, if no pig traps are fitted, to the first isolation valve within the plant boundaries or a more inward valve if so nominated.

3.2 PIPELINES

3.2.1 Pipeline engineering

Pipeline enginering shall be in accordance with DEP 31.40.00.10-Gen. and the DEPs and other standards specified by the Principal.

3.2.2 Product segregation

LPG grades should be segregated by providing each grade with its own dedicated facilities. Non-odorised grades shall be segregated in systems designed to prevent contamination.

3.2.3 Multi-product pipelines

LPG can be handled in appropriately rated multi-product white oil pipelines. The parcel size shall be both economical and practical, taking into account the requirements and costs of adequate storage at each end of the system as well as those of handling the interface at the receiving end.

- The ancillary fittings and equipment of a multi-product pipeline system shall be suitable for operation at the maximum foreseen pressure in the system.
- The pipeline system shall be equipped with pressure control valves to ensure that the product is under sufficient pressure to prevent LPG vaporisation in the pipeline.
- Mechanical separation of the different products in long pipelines will reduce the interface volume.
- Interface signalling equipment, e.g. gravitometer, will enable accurate interface cuts to be made thereby minimising the cuts to slops.
- A suitable pressure vessel (slops tank) and associated compressor to handle the interface cut are required.

Refer to (3.5) for information on a method of calculating interface volumes in multi-product pipeline operations and (3.6) for details on the use of mechanical separators.

3.2.4 Corrosion protection

Pipelines above ground shall be painted in accordance with DEP 30.48.00.31-Gen. to prevent corrosion. Buried and submerged pipelines shall be protected by a suitable coating and by cathodic protection. Polyethylene and polypropylene coating shall be in accordance with DEP 31.40.30.31-Gen. and fusion-bonded epoxy powder coating shall be in accordance with DEP 31.40.30.32-Gen.

Cathodic protection shall be in accordance with DEP 30.10.73.31-Gen. for buried pipelines and DEP 30.10.73.32-Gen. for offshore pipelines.

3.2.5 Access

Above ground pipelines (including pig trap installations) should be readily accessible for operation, maintenance and inspection purposes. Protection shall be provided against possible impact/collision damage where vehicle movements may occur in the vicinity of the pipeline. Buried pipelines shall be protected against the effects of superimposed loads.

3.2.6 Overpressure protection

The design and engineering of the overpressure protection systems shall comply with DEP 31.40.10.14-Gen.

3.3 PIPING

3.3.1 General

Piping is the assembly, within designated plant boundaries, of pipes, elbows, flanges, gaskets, fittings, valves and other components (e.g. expansion joints, strainers, devices for mixing, separating, distributing, metering and flow control). It also includes pipe supports and insulation.

DEP 31.38.01.11-Gen. shall apply.

3.3.2 Bonding/Earthing

To prevent the accumulation of static electricity, piping should be electrically continuous. Normal pipe fittings, bolted flanges, etc., are generally sufficient to ensure this.

3.3.3 Thermal expansion and flexibility

Piping systems shall have sufficient flexibility to allow for thermal expansion and contraction. Piping and pipe supports at pumps, compressors and other fixed equipment shall be designed to ensure that equipment nozzles are not subjected to stress which could adversely affect the performance of the equipment, e.g. alignment, internal clearance of moving components, etc.

Flexible connections in permanent piping shall be avoided unless their use is considered essential for the safe and trouble-free operation of equipment.

Provisions shall be made to prevent excessive pressure developing in sections of piping which are isolated by valves or other equipment. Refer to DEP 30.06.10.12-Gen.

3.4 LEAK DETECTION

Pipelines shall be provided with a suitable leak detection system in accordance with DEP 31.40.60.11-Gen.

3.5 PRODUCT INTERFACES

Multi-product operating procedures should cover the handling and subsequent disposal of product interfaces.

In a pipeline handling different products, or grades of product, the interface between them will be a mixture. If the interface does not meet either of the product specifications it should be diverted from the pipeline to a slops tank/pressure vessel.

The size of the interface, and thus the size of the vessel to be provided, depends on the size of the line, the pumping rate and the viscosities of the products involved. The size of the interface will also be affected by the sophistication of the instrumentation and/or the alertness of the operators concerned, i.e. the speed with which the necessary valves are actuated.

The theoretical interface, i.e. that due to the pipeline only (and not to the operators), may be determined by the Smith and Schulze (Shell Oil) formula, which gives 99% non-contamination outside the interface:

$$C = \frac{684.2}{Re^{0.87}} + 0.35\,(L^{0.62})$$

where

C = interface length (m)
L = pipeline length (m)
Re = average Reynolds number, Re = 0.5 (Re_1 + Re_2), where Re_1 and Re_2 are the Reynolds numbers of the two products.

The individual Reynolds numbers can be calculated by the equation:

$$Re = \frac{\rho V D_i}{\mu} \qquad \text{or} \qquad Re = \frac{V D_i}{\nu}$$

where

Re = Reynolds number (dimensionless)
ρ = density (kg/m^3)
V = average linear flow velocity (m/s)
D_i = inside diameter of pipe (m)
μ = dynamic viscosity (mPa.s)
ν = kinematic viscosity (m^2/s)

The arrival of the interface at the take-off point may be determined on a time basis (known pumping rates/flow speeds) or by instruments which detect such characteristics as change of relative density or colour.

3.6 MECHANICAL SEPARATION

Mechanical separators, such as pigs or spheres, may be used to physically separate different products in a pipeline if the line has been designed and constructed for their use.

Pigs and spheres utilise synthetic rubbers or plastic materials to make contact with the pipeline walls and provide the seal between the products. The materials shall be compatible with and resistant to the products being handled.

3.6.1 Pig trap systems

DEP 31.40.10.13-Gen. shall apply.

3.6.2 Bi-directional pipeline operation

Some LPG pipeline clearing operations require a pig or a sphere to travel in the reverse direction to normal. These operations could entail:

- replacing water with LPG vapour;
- replacing air or inert gas with LPG vapour;
- replacing LPG liquid with LPG vapour.

In these cases, the pipeline shall be designed and constructed to include pig/sphere launchers/traps capable of both launching and receiving.

4. TRANSPORT BY BULK ROAD VEHICLES

4.1 GENERAL

Bulk road vehicles generally perform one of the following roles:

- Bridging: the vehicle is used to move product in bulk between two plants and is usually loaded and discharged by plant facilities;
- Delivery: the vehicle is designed to make small volume drops to customers using its own pump and metering system.

Vehicle selection should take account of the following factors in order to determine the most suitable chassis type configuration for the job, e.g. articulated, rigid or rigid with drawbar trailer, while allowing for the capacity and composition requirements of the overall LPG fleet:

- payload and drop size;
- axle load constraints;
- gradability requirements (hill climbing ability);
- speedability (road speed through the gears);
- operational constraints, access restrictions;
- transport costs.

LPG vehicles shall comply with local design and construction regulations for the transport of flammable gases. If local regulations do not exist, or are not sufficiently comprehensive, then a recognised standard shall be followed, e.g. ADR, US Department of Transport MC331, LPGITA Code No. 2. The more stringent requirements of the local regulations (or the selected code) and this DEP shall be applied.

4.2 VEHICLE DESIGN

4.2.1 Engine, electrical system and chassis

a) Engine

The engine should be of the compression ignition type and should be located in front of the rear line of the cab. An external, readily accessible emergency engine stop should be fitted to the rear of the cab or other convenient location and be clearly labelled.

The point of entry to the air induction system should be at a high level and located so that any LPG released from the vehicle is unlikely to enter the engine.

The exhaust system should be located or shielded so that any spillage of LPG, or fuel from the vehicle's fuel tanks, will not leak onto a hot part of the exhaust. Modifications to the exhaust system should be approved by the vehicle Manufacturer. Add-on spark arresters should not be fitted to vehicle exhausts unless required by local regulations, in which case the spark arrester shall be approved by the vehicle Manufacturer and maintained fit for purpose throughout its life.

b) Electrical

The electrical system should be protected to minimise mechanical damage and the risk of electrical fires. The nominal circuit voltage shall not exceed 24 volts. Insulated return or robust single pole wiring conforming to ADR Appendix B.2 shall be used. Cables should be protected against impact and heat by their location and secured to prevent damage by vibration.

All cables should have heavy duty copper conductors (other than the starter which may be in aluminium provided that compression terminals are used). Cables should be insulated and protected in accordance with BS 6862-1 or equivalent.

Batteries should be protected against leakage of LPG and fitted with an insulated cover to prevent inadvertent contact across terminals and possible sparks.

A battery master switch to enable isolation of all electrical circuits shall be placed as close as possible to the battery. All wiring taken from the battery side of the master switch shall meet Zone 1 requirements of IEC 79-14. The master switch control should be readily accessible to persons outside the vehicle and its location clearly indicated. Means should also be provided to enable the driver to open the switch without leaving his seat.

Cigar/cigarette lighters and power offtake points shall not be fitted in the cab. Radios, telephones, etc., shall be permanently wired into a double pole circuit which can be isolated via the master switch.

Cab heaters, except those which take heat from the vehicle's engine, shall not be installed.

c) Chassis

Valves, piping and ancillary equipment shall be adequately protected against impact damage from side-on collisions either by their location or by mechanical means. Side guards should also be provided on articulated and long wheel-base vehicles for the protection of other road users in case of side-on collisions.

The rear of the vehicle shall have under-run protection and a rear bumper (fender) designed to protect the vessel and any rear mounted ancillary equipment in the event of a rear end collision. The bumper should be located at least 100 mm to the rear of any part of the vessel shell or fitting. It shall be designed to transmit the force of a rear end collision in a horizontal line to the chassis of the vehicle and to withstand the impact of the fully loaded vehicle with a deceleration of twice the acceleration due to gravity (2 g_n), using a safety factor of 4 based on the ultimate strength of the bumper material.

d) Stability

The height of the centre of gravity of the load (vessel and equipment plus payload) should not be greater than 95% of the width across the outer walls of the tyres on the vehicle's rearmost supporting axle.

e) Driver's cab

Cabs shall be provided with approved seat belts at all seat positions. The anchorage of the seat belts shall be of a type approved and installed by the chassis Manufacturer.

The shell of the cab shall be constructed of fire resistant materials and shall resist collapse and flame penetration for at least 15 minutes when tested in accordance with BS 476-20 and BS 476-22 (or equivalent standards). If windows are provided at the rear of the cab they shall be of toughened or safety glass (minimum 6 mm thick) and shall not be openable.

There should be a space of at least 100 mm between the back of the cab and the foremost point of the cargo vessel.

4.2.2 Vessel

a) Vessel capacity

The maximum carrying capacity of the vessel is determined by the Gross Vehicle Weight (GVW) and axle load limitations set by local regulations, by the chassis Manufacturer's maximum recommended GVW and axle loadings and by the minimum safe ullage requirements of the product grades transported.

b) Safe filling capacity

LPGs have high volumetric coefficients of expansion compared to other liquid hydrocarbons and water. For example, at 15 °C the volumetric expansion of butane is 0.210 % per °C and and the volumetric expansion of propane 0.273 % per °C.

The maximum quantity of LPG filled into a vessel used in road transport operations shall be such that the vessel will not become more than 97% liquid full (3% ullage) due to expansion of the product at the highest temperature the product may reach in normal operation. This temperature is called the Assessed Temperature for Safe Filling.

The assessed temperatures given in Table 2 shall be used unless local regulations dictate otherwise. Some authorities recognise that if sun shades are used assessed temperatures may be lowered. In Table 2 it is assumed that the vessel shell is not protected against solar radiation.

Notes: 1. In some publications, e.g. BS 5355, the Assessed Temperature for Safe Filling is referred to as the “reference temperature“.

2. The term assessed temperature is also used to define the developed vapour pressure for vessel design purposes (see (4.2.2(e))). As stated in a number of codes and standards, e.g. NFPA 58 and BS 5355, there is a difference between the Assessed Temperature for Safe Filling and the Assessed Temperature for Developed Pressure, the latter being set several degrees higher.

3. Some codes dictate that the maximum filling level should be set such that the vessel does not become liquid full at temperatures of up to 5 °C above the Assessed Temperature for Safe Filling. The 3% ullage safety factor referred to above always meets this requirement.

Bulk vehicles are loaded by measuring either the mass (weighbridge or mass meter) or the volume (volumetric meter or internally mounted ullage gauge). Whichever method is applied, a weighbridge shall be used both before loading (to assess the ullage available in the vessel) and after loading (to ensure that the maximum GVW is not exceeded).

Loading by mass:

To ensure that the vehicle is not overfilled the maximum permitted LPG load (W) when filling by mass shall not exceed the following:

$W = 0.97\ V\ \rho_i$

where: V = Water capacity (litres) of the vessel at 15 °C, allowing for internal fittings
ρ_i = Density of liquid LPG at assessed temperature (kg/m^3)

Example: Calculate the safe filling capacity of propane for a road tanker with a net water capacity of 19 812 litres. The assessed temperature is 45 °C, at which the density of propane is 461 kg/m^3.

$$\text{Safe filling capacity: } W = 0.97 \times 19\,812 \times \frac{461}{1\,000} = 8\,859 \text{ kg}$$

Loading by volume:

(i) If volume, density and temperature cannot be determined at the loading facility on a routine basis with a high degree of confidence, vehicles shall be loaded to the fixed ullage gauge set to allow for the maximum possible rise in product temperature that may occur in normal operations, i.e. the difference between the assessed temperature and the lowest possible product loading temperature.

A fixed ullage gauge normally consists of a simple valve assembly fitted into a boss in the top of the vessel shell. The assembly consists of a valve with a screw bleed, bleed vent and a small bore extension which extends downwards to the maximum safe liquid level of the vessel. The position of the gauge expressed as a volume is determined as follows:

$V_f = 0.97\ V\ \rho_i / \rho_m$

where: V_f = Volume (litres) of liquid at level of fixed ullage gauge
V = Water capacity (litres) of vessel allowing for internal fittings
ρ_i = Density of liquid LPG at assessed temperature (kg/m^3)
ρ_m = Density of liquid LPG at minimum loading temperature (kg/m^3)

If reliable meteorological data is not available the following temperature rises should be used to establish the position of fixed ullage gauges:

38 °C for vessels up to 5 000 litres water capacity
30 °C for vessels above 5 000 litres water capacity

Example: Calculate the volume and percentage of water capacity at which the fixed ullage gauges for propane and n-butane should be positioned in a road tanker with net water capacity of 19 812 litres. The assessed temperature is 45 °C and the minimum loading temperature 15 °C.

Temperature	15 °C	45 °C
Density of propane (kg/m^3)	509	461
Density of n-butane (kg/m^3)	584	548

Maximum safe fill volume of propane, V_f = 0.97 x 19 812 x 461 / 509
= 17 405 litres (or 87.8 %)

Maximum safe fill volume of n-butane, V_f = 0.97 x 19 812 x 548 / 584
= 18 095 litres (or 91.3 %)

(ii) If accurate measurements of volume, density and temperature are made routinely and consistently, vehicles may be loaded to a safe level using the density of the product at its loading temperature and its density at the assessed temperature according to the following formula:

$V_f = 0.97\ V\ \rho_i / \rho_a$

where: V_f = Volume (litres) of liquid at level of fixed ullage gauge
V = Water capacity (litres) of vessel allowing for internal fittings
ρ_i = Density of liquid LPG at assessed temperature
ρ_a = Density of liquid LPG at loading temperature

Example: Calculate the maximum safe volume of propane which may be loaded into a bulk vehicle with a net water capacity of 19 812 litres. The assessed temperature is 45 °C and the loading temperature is 30 °C.

Density of propane at 45 °C = 461 kg/m^3
Density of propane at 30 °C = 482 kg/m^3

Maximum safe filling volume, V_f = 0.97 x 19 812 x 461 / 482
= 18 380 litres (or 92.8 %)

(c) Vessel construction

The maximum overall width of any vessel and its service equipment shall not project beyond the overall width of the chassis/cab or the ISO frame in the case of a tank container.

Vessels shall be designed, fabricated and tested in accordance with a recognised pressure vessel code acceptable to the local licensing/inspecting authority. If no local regulations exist, the vessel shall be constructed to either BS 7122 or ASME VIII and shall incorporate the requirements of this DEP.

To limit the effect of product surge on the braking efficiency of vehicles, vessels may require baffle plates to be fitted. If local regulations covering this requirement do not exist, advice should be sought from the chassis supplier. Baffles should be fitted at intervals of not more than 7 500 litres water capacity.

The design of the baffle shall ensure unrestricted drainage of liquid and the interconnection of vapour spaces, and include a manway not less than 410 mm x 360 mm. The position of the drainage cut-outs in the baffle shall allow the flow of liquid and vapour across the baffle when the vehicle is on its side or upside down.

Baffle plate thickness should be at least 2 mm. If double plates or sealing rings are used to support baffles the enclosed spaces so formed shall be provided with plugged sockets for monitoring the atmosphere prior to carrying out hot work.

(d) Vessel nozzles and manholes

Connecting nozzles and manhole pads shall be manufactured from forged pads with studs for flanged fittings or internal threads as appropriate.

Threaded connections, if unavoidable, shall be kept to a minimum and should not be used on piping greater than 50 mm nominal diameter (refer to (4.2.2(n)) for size limitations on threaded connections on proprietary equipment, e.g. pumps, meters).

(e) Design pressure and temperature

The vessel design pressure shall be the vapour pressure of LPG at the Assessed Temperature for Developed Pressure plus the effects of the dynamic loads defined later. If assessed temperatures for the design of LPG transport vessels are not covered by local regulations, the temperatures given in Table 1 should be used. Refer to (4.2.2(b)) regarding the use of sun shades.

The design pressure of the vessel and the design load on its mountings shall include an allowance for absorbing the following dynamic loads under full load conditions:

- in the direction of travel: 2 x mass of payload;
- at right angles to the direction of travel: 1 x mass of payload;
- vertically downwards: 2 x mass of payload;

If vessels may be subjected to a vacuum, e.g. transport of butane in sub-zero temperatures, then vessels shall be designed to withstand full vacuum conditions.

The upper design temperature shall be not less than the Assessed Temperature for Developed Pressure.

The lower design temperature shall be in accordance with DEP 31.10.02.31-Gen..

(f) Mountings

Mountings should comply with the chassis and vessel Manufacturers' recommendations and take into account the additional stresses referred to in (4.2.2(e)). Mountings shall be fabricated in steel and designed as an integral attachment to the vessel. The point of attachment shall be continuously welded with local reinforcement as necessary to resist high stress concentrations at these points during transit. There shall be electrical continuity between vessel/fittings and the vehicle's chassis.

(g) Vessel connections - Primary shut-off systems

Valves which are directly connected to the vessel shell to control the flow of product into or out of the vessel and provide the means of stopping flow in emergency situations are referred to as primary shut-off systems.

Typical piping and equipment layouts for bulk delivery and bridging vehicles are shown in Figures 5 and 6.

The number of vessel connections, particularly those into the liquid phase, shall be minimised.

All connections in the vessel greater than 1.4 mm diameter (other than those for pressure relief valves), and bolted covers/blank flanges or screwed plugs which are permanently installed, should have a primary shut-off valve or series of valves installed as described below:

- Nozzles above 3 mm diameter in the liquid phase and 8 mm diameter in the vapour phase shall be fitted with:
  - either an internally mounted excess flow valve (EFV) or non-return valve (NRV) in combination with a fire-safe ball valve externally fitted as close as possible to the EFV/NRV,
  - or an internal safety valve (ISV) as described in the notes to Table 3.

- Smaller connections shall be fitted with fire-safe ball valves as the primary shut-off system except that equipment attached to a vessel nozzle and incorporating a controlling orifice not exceeding 1.4 mm diameter may rely upon the closing device provided, e.g. the bleed valve of a fixed liquid level gauge.

Table 3 indicates the type and the required characteristics of primary shut-off systems fitted to the main vessel connections.

Fire-safe ball valves shall meet BS 6755 Part 2, API 6FA or equivalent standard.

If the emergency uplift/drain is connected into the pump bypass as shown in Figure 5 then a type B valve should be fitted.

The closing rate of EFVs shall not be greater than the rate of flow which would result from failure of the piping or hose immediately downstream of the EFV or 150% of the nominal operating flow rate.

The ISV shall be provided with at least two remote actuation points, one located at the front of the vessel and the other at the rear. On long vehicles consideration shall be given to providing an additional actuation point at the front end of the vessel to enable closure of the ISV from both the offside and nearside. The actuator system shall include fusible links set to close the ISV in case of fire at or adjacent to the vehicle. Fusible links should have melting points not in excess of 120 °C. Each closing device should be clearly identified to show its purpose and means of operation.

A drain/emergency offtake connection, not greater than 50 mm diameter, shall be fitted into the bottom of the vessel or a suitable liquid connection, e.g. pump bypass (refer to Figure 5). Connections not exceeding 32 mm diameter may be fitted with an internally mounted EFV and a fire-safe ball valve. Larger nozzles shall be fitted with an ISV capable of remote actuation. The ISV shall be either blank flanged or plugged in normal operation. Consideration shall be given to the effective use of this connection particularly if rust and other fine grained deposits may build up in the vessel and collect in the outlet, possibly causing malfunction of the valves. To overcome this problem the drain/emergency offtake connection may be located in the pump bypass as shown in Figure 5. When draining to atmosphere, an extension pipe/hose at least 600 mm long with a dead-man type valve at its free end should be connected to the fire-safe valve.

All piping, valves and vessel connections shall be protected by their location from possible collision damage, e.g. between the wheels of the running gear of a semi-trailer outfit (where it is protected by the subframe) or alternatively by mechanical means in which case the protection, e.g. under-run bumper, shall have sufficient impact resistance to withstand typical collision forces (see (4.2.1(c))).

Primary shut-off systems shall be protected against collision and impact damage by their location and if necessary by additional mechanical means. The objective is to ensure that in an accident the primary shut-off system remains operable and in any collision which damages the piping system at least the internal valve, i.e. the NRV, EFV or the internal part of the ISV, will continue to operate safely.

All valves and fittings shall be manufactured to a recognised standard and approved for handling LPG over the range of service pressures and temperatures. Equipment shall be installed in accordance with the Manufacturer's instructions.

Jointing materials, thread sealants and gaskets shall be suitable for use with LPG and maintain satisfactory performance over the range of service conditions.

(h) Manual shut-off valves

Manual valves which are fitted in the piping system for operational and maintenance purposes are referred to as secondary shut-off valves. It is not a general requirement for secondary shut-off valves to be fire-safe.

Shut-off valves should be located in the liquid offtake piping immediately upstream of hose reels and hose couplings. Manual shut-off valves in drain/emergency uplift and other connections which are not in regular use shall be plugged or blank flanged.

All shut-off valves shall provide positive closure and shall be suitable for use in LPG operations over the design range of pressures and temperatures. If fire-safe ball valves are used, they shall meet BS 6755 Part 2, API 6FA or equivalent.

Vessel nozzles with fittings/equipment which have controlling orifices not exceeding 1.4 mm diameter shall be fitted with a suitable positive shut-off device, e.g. the proprietary equipment supplied with rotogauges, fixed ullage gauges, etc., is considered suitable because of the size of the controlling orifice.

(i) Couplings

Couplings shall be standardised throughout the distribution system to eliminate the use of adapters. Delivery vehicles and customer facilities should have standard types of couplings for liquid and vapour connections using differing sizes for the two phases. Odorised and non-odorised systems shall have totally incompatible couplings, e.g. by the selective use of right-hand and left-hand couplings.

If screw couplings are used they should have ACME threads to ASME B1.5 Class 2G. If self-sealing couplings are used they shall be compatible with mating couplings on fixed storage installations, in order to preclude the need for adapters.

For safe disconnection, a depressuring/bleed valve should be fitted close to, or in the connecting flange/coupling.

(j) Gauges

Pressure gauge
Each vessel shall have a suitable pressure gauge connected to the vapour space. The orifice size at the connection shall not exceed 1.4 mm, otherwise an EFV shall be fitted. In both cases, a shut-off valve shall be fitted.

Contents gauge
All bulk vehicles shall be fitted with a suitable contents gauge which may be of the float type or the capacitance type.

One or more fixed maximum liquid level gauges shall be fitted and set in accordance with (4.2.2(b)). Fixed ullage gauges bleeding LPG to atmosphere may be employed provided that the maximum orifice size at the connection to the vessel does not exceed 1.4 mm diameter and the operational bleed screw remains captive. Gauges in which it is possible to replace the sealing gland without withdrawing the vessel from service are recommended.

Thermometer
Thermometers shall be located so that they record the liquid temperature and shall be fitted in a sealed pocket in the form of a blind tube constructed to the vessel design code.

(k) Pressure relief valves (PRVs)

Unless prohibited by local legislation all vessels shall be fitted with PRVs.

Vessels shall be fitted with one or more PRVs connected directly to the vapour space. The set pressure shall be not greater than the design pressure of the vessel. The total relief capacity shall be sufficient to protect the vessel against overpressure in the event of liquid filling and fire engulfment, but should not be less than that specified in NFPA 58, Appendix E, E-2.2.

Valves shall be of the internal spring-loaded type, i.e. the operating mechanism shall be within the vessel and specifically designed for transport vessels. Weather caps should be provided to prevent water and solid particles from collecting in the outlet of the PRV.

Vapour discharging from the PRV shall not impinge on the vessel.

The design of the PRV connections shall ensure that the valve is protected in the event of collision or roll-over of the vehicle. Counter-sunk housings may be constructed in the vessel shell to provide such protection.

(l) Pumps

Pumps on typical rigid chassis delivery vehicles are usually driven direct from the engine power take off (PTO) which should be of the constant speed type. Alternatively, the PTO may be used to drive a hydraulic pump which powers a close coupled hydraulic motor on the product pump. The latter system gives designers greater latitude in positioning the pump on the chassis.

Materials used in pump construction shall be suitable for use with LPG at the service conditions required. Cast iron shall not be used unless the grade is known to have adequate ductility and resistance to brittle fracture over the full range of temperatures and pressures likely to be encountered in service.

A system of controlling the pump rotational speed and a means to prevent overspeeding should be provided.

In addition to any integral pump bypass the piping system downstream of the pump shall include a separate, suitably sized bypass with spring loaded differential pressure valve, to return product to the vessel when the delivery valve is closed. The bypass valve should be adjusted so that it opens before the integral bypass operates and that the difference in the pressure settings of the two valves is sufficient to hold the integral bypass closed under full flow conditions.

A strainer should be fitted immediately upstream of the pump inlet and should be effective for both normal discharge and uplifts using the vehicle's pump.

The piping arrangement should allow the vehicle to uplift product using its own pump.

(m) Meter

The meter assembly should include a vapour eliminator, a differential, diaphragm-operated, back-pressure valve and a temperature compensation unit. Normally these components are supplied as an integral unit with the meter.

The differential valve provides back-pressure on the meter and vapour eliminator, assisting the eliminator in functioning efficiently and also in keeping a sufficient pressure on the liquid in the metering system to prevent vaporisation.

The pressure balance side of the diaphragm of the differential back-pressure valve is connected to the vapour space of the vessel and the differential pressure is provided by a spring.

The design and materials used in the construction of meters shall be suitable for LPG service over the range of temperatures and pressures likely to be experienced in normal operations. If there is any chance of caustic being present in the product then aluminium components shall not be used.

(n) Piping

Piping shall be designed and fabricated in accordance with the standards referred to in (3.3).

The number of joints shall be kept to a minimum. Joints shall be welded or flanged except that screwed joints, if unavoidable, may be used for connections up to DN 50 (or DN 80 for proprietary equipment such as meters and pumps provided that threaded components are factory produced and certified by the supplier to be within the standard manufacturing tolerances).

Provision should be made for movement between the vessel and chassis. Flexible joints or hoses may be used for this purpose provided that the equipment is manufactured in accordance with BS 4089 or equivalent.

Sections of piping or hose in which LPG may be trapped shall have a thermal expansion relief valve (TERV) fitted to prevent excessive pressures from developing.

(o) Protection of vessel fittings and connections

All equipment which, if damaged, could give rise to a release of product shall be protected against collision, impact, overturn, etc., either by its location or by mechanical means.

(p) Marking

All the vessel's operational connections should be labelled to indicate their purpose. A flow diagram should be provided with each vehicle.

(q) Hoses

All hoses shall be suitable for propane service and should be constructed to BS 4089 or equivalent. Hoses greater than 50 mm internal diameter should be flanged and meet the requirements of (2.5.3).

Hoses wound on reels shall be a single, continuous length of hose. A suitably sized EFV should be fitted at the inlet to the hose reel to reduce the volume of leakage in the event of a hose failure. All transfer hoses shall have a manual shut-off valve located at the hose end. A bleed valve for depressuring the couplings may be incorporated in the valve body. Loose hoses should have a valve at each end of the hose.

(r) Earthing

Continuity shall exist between the vessel and its fittings/equipment and the chassis. Vehicles shall be provided with a separate bonding wire to ensure continuity between the vehicle and the fixed installation.

4.3 BULK VEHICLE LOADING AND UNLOADING

4.3.1 General

The system selected for loading bulk LPG vehicles shall be fully integrated in that the hardware (pumps, loading arms, ESD and alarm systems, instrumentation, measurement, data capture and product/security control systems, etc.) is optimised in accordance with the Principal's chosen software systems, loss control, invoicing, vehicle routing, stock control, etc.

Custody transfer into bulk vehicles shall be made via a weighbridge or a meter (mass or volumetric). Rotary gauges shall not be used for that purpose because of the difficulties of accurately calibrating and reading the gauge.

If measurement of the consigned volume is made by meter and vapour return systems are used, then both the liquid and returned vapour shall be metered in order to calculate the net quantity of product transferred.

4.3.2 Overfill protection

The loading of LPG should be automated to ensure that both the safe filling volume (4.2.2.6) and the GVW are not exceeded. This shall be achieved by flow metering and by using a weighbridge at the loading point.

In manually operated loading gantries, the liquid content shall be monitored carefully using the rotogauge or equivalent to verify that the maximum safe filling level (4.2.2(b)) is not exceeded. The GVW after loading shall be confirmed as safe by using of a weighbridge located either at the loading point or at the gate.

4.3.3 Driveaway prevention and protection

As the human element is involved in every filling and discharge operation there is a possibility that the vehicle could be driven away before the product transfer hose or arm has been disconnected.

Driving away with hoses or loading arms connected can cause damage to the plant and release of product with serious consequences. There are two ways of dealing with this situation. The first is to prevent the vehicle from moving until the hose or loading arm is disconnected and the second is to minimise the hazard if the vehicle moves away while connected. Consideration shall be given to using both systems at loading facilities.

(a) Driveaway prevention

This may be achieved by either lowering a barrier across the path of the vehicle, e.g. boom gate, or by immobilising the vehicle with an interlock blocking its control/drive system (e.g. by locking up the vehicle’s brakes).

If driveaway prevention is achieved by using boom gates there should be an interlock on the hose stowage or loading arm parked positions to prevent the boom gate from being moved before the hoses/arms are disconnected.

Vehicle immobilisation, e.g. by locking up the vehicle's braking system while the vehicle's hose is unstowed, provides protection against driveaway in delivery situations. The design of the system shall be such that the vehicle is immediately operational after the hose has been stowed and the vehicle cannot be inadvertently immobilised while in the drive mode.

Driveaway prevention systems shall not be capable of being bypassed.

(b) Breakaway couplings at loading and discharge points

Breakaway couplings which rupture before the hose or loading arm is damaged are the preferred method of minimising the consequences of a driveaway.

Breakaway couplings used on loading arms shall be of a type in which the breakaway action, i.e. the separation of the two halves of the coupling, occurs just before the arm is extended to the limit of its safe working envelope. The force causing the break shall not be applied directly via the piping components of the arm but through a separate mechanism (e.g. by a cable, which is tensioned by movement of the arm), applying sufficient force to break the coupling before the arm reaches the limit of its safe working envelope. Breakaway couplings actuated by tension in the piping sections of the arm can result in a progressive and non-instantaneous breaking of the coupling (if couplings are connected by notched or waisted bolts) with the possibility of a major spill occurring before the coupling finally separates. Also, arms under tension separate with a whiplash action when the coupling breaks and this could cause injury and damage.

4.3.4 Loading point

(a) General

The location of a loading point shall be determined with respect to the separation distances to the plant boundary and other parts of the plant and also with regard to safe traffic movement into and out of the facility. The equipment installed should be protected by kerbs or barriers to prevent accidental damage by vehicles. The principle of determining adequate separation distances between bulk loading points and storage is specified in DEP 30.06.10.12-Gen. The area shall be freely ventilated.

For preliminary design purposes, a safety distance of 15 metres between loading bays may be used. The final spacing shall be determined after an assessment of leakage scenarios and their consequences, based on Report OH 96-30202 and FRED, has been performed.

Hard standing should be graded and compacted to ensure that rain water, cooling water and any spillage will flow away from the loading area. The drainage system shall be designed so that an LPG spill will be properly contained. Refer to DEP 34.14.20.31-Gen.

If an operational parking area for empty and filled vehicles is provided it should be in a safe location in terms of distance from the filling points and other plant locations, and with regard to traffic flow and pedestrian movements. Adequate fire fighting facilities in the form of monitors and hose streams shall be provided in this area and vehicles shall be parked in such a way as to facilitate access for fire fighters and the movement of LPG vehicles if required.

(b) Piping systems

For product piping components refer to (3.3) and DEP 30.06.10.12-Gen.

Product piping shall be adequately supported and provisions made to cope with expansion, contraction and vibration. The end of fixed piping shall be securely anchored at the filling/discharging point. All piping and associated equipment shall be protected by barriers against possible collision damage.

Remotely operated ESD valves shall be fail-safe and fire-safe and shall be installed close to the loading point (typically 15 metres) to limit spillage in the event of equipment failure. Manual shut-off valves should also be installed in the fixed piping for operational purposes.

Excess flow valves alone shall not be used for ESD duties and shall be backed up by an ESD valve of the type described above.

Typical piping system layouts of LPG bulk vehicle filling installations are shown in Figure 7. Both layouts include vapour return systems. In loading facilities in which vapour return systems are not considered feasible or economically justifiable the liquid transfer system shall include the safeguarding features shown in Figure 7.

(c) Instrumentation

The instrumentation provided at loading points shall fully support the operating procedures and control systems. The specification of the measurement, product quality, product security and loss control systems, together with the instrumentation for data capture and automation (if applicable), should detail the type of equipment and its performance. For guidance refer to DEP 32.31.00.32-Gen.

(d) Loading arms/hoses and couplings

Loading arms should be used for LPG transfers (refer to (2.5.4)), although hoses may be used for infrequent operations (refer to (2.5.3)).

If the use of loading arms for both liquid and vapour is being considered, careful attention shall be paid to the configuration of connections on all bulk vehicles loading at the plant. It is not always possible to connect two hard arms (liquid and vapour) to a bulk vehicle because of the location of the couplings on the vehicle. In these situations it is necessary to make the vapour connection from the vehicle to the loading arm by means of a short flexible hose or by using a separate vapour hose instead of the arm.

Self-sealing breakaway couplings should be used at all loading points. Couplings shall be fitted in accordance with the Manufacturer's instructions.

Loading arms/hoses should be equipped with a close coupled shut-off valve and coupling. For safe disconnection, a depressuring/bleed valve should be fitted close to, or in, the connecting flange/coupling. If possible, the release shall be vented to a flare/vent system. Couplings on loading arms/hoses shall be compatible with those on vehicles loading at the plant. Adapters shall not be used.

The use of dry-break couplings should be considered for dedicated bulk vehicle fleets.

(e) Filling on weighbridges

Filling on a weighbridge is the preferred custody transfer system in large terminals and installations. This enables bulk vehicle filling time to be minimised by using high flow rates and a vapour return system whilst still achieving a high degree of measurement accuracy. Weighbridges equipped with load cells have proven to be reliable and accurate.

(f) Emergency showers and eye wash facilities

Loading gantries should be provided with emergency showers and eye wash units. The eye wash units shall be connected to a water supply able to deliver a minimum water supply pressure, as specified by the Manufacturer. The cold feed to emergency showers and eye wash units shall not be subject to unacceptable heat gains. In cold and moderate climates the emergency showers and eye wash units shall be connected to a warm water system, with an automatic mixing valve to keep the temperature acceptable, or to a separate lukewarm water system.

4.3.5 Unloading

(a) Unloading at depots

The requirements of (4.3.4) also apply to bulk vehicle discharge points at depots.

Bulk bridging vehicles are usually unloaded by the depot's pump or compressor. A benefit of using a compressor is that it enables the vessel to be depressurised after the liquid contents have been discharged, thereby increasing the quantity of product delivered.

(b) Consumer delivery

The requirements of (4.3.4(a)) also apply to consumer installations.

Pump performance should be compatible with the characteristics of the transfer system, the meter capacity/turndown and the following losses:

- the pressure drop in the hose and meter, etc.;
- the back-pressure developed in the customer's vessel;
- the drop in vapour pressure in the bulk vehicle's vessel as delivery proceeds.

Appendix 3 gives an example of a method to establish differential pressure requirements for a bulk vehicle pump.

4.3.6 ESD switches

ESD switches shall be provided at the filling point, at other locations in the vicinity which are safely accessible in an emergency and in the control room or areas which function as a control centre. They shall override all other controls, immediately stop product flow by stopping the loading pumps, closing ESD valves and flow control valves (if fitted) and actuate an alarm in the control room/area. The alarm may also be used to activate the fire pumps and open the water spray system to the loading area. If automated flow control is installed, the in-line valve should be of a type which closes automatically when the power is cut off, i.e. fail-safe.

4.3.7 Overturned vehicles

Consideration shall be given to the local availability of suitable means of safely recovering overturned bulk vehicles. If recovery equipment is not available, consideration shall be given to providing fittings and equipment in the vessel for transferring product in the event of a roll-over. Figure 9 shows an emergency product withdrawal system.

4.4 PRODUCT CONTROL - EQUIPMENT AND PROCEDURES

The operating functions and controls of a typical vehicle loading facility at a large LPG installation are shown in Figure 8.

(a) Interlocks

Interlocks shall prevent product from flowing until all the various checks are satisfied and the control system indicates that loading can safely commence. Only then shall they allow the product control valve to open and product flow to start. In the event of manual intervention, power failure, breakdown or defined irregularity the product flow shall be stopped by automatically closing the valve and subsequently stopping the relevant pumps.

(b) Earthing/bonding

Continuity between the bonding cable and the vehicle shall be maintained. The product flow control valve (solenoid type or electro-pneumatic) shall be interlocked into the earth circuit and shall only remain in a permissive flow condition while this circuit is closed.

(c) Filling

A solenoid-operated lock may be fitted to hold the loading arm/hose in the stowed position until the correct sequence of preliminary operations has been completed prior to start of loading.

A proximity switch should be fitted to indicate when the loading arm/hose has been removed or disconnected and is correctly stowed after loading is complete.

(d) Barrier arm

Before starting to load, the barrier arm shall be lowered to prevent the vehicle from being driven off. A traffic light or flashing light should also be used. Once this condition has been satisfied the loading operation can start.

As soon as the loading operation is finished, indicator lights at the loading bay should be used to signal that all past loading procedures have been correctly executed (e.g. loading arm properly stowed, hose disconnected, bonding link disconnected, etc.) and that the barrier arm may be raised.

(e) Weighbridge applications

A weighbridge should be used at the loading point to control directly the amount of product to be loaded. A typical procedure is as follows:

The driver or gantry operator earths the vehicle, connects the filling arm (and vapour return) and then slowly opens the manual product valve.

Tare weight is taken and displayed in the control room. If a vehicle loads regularly at the plant, the data system should include all relevant information on the vehicle, e.g. the water capacity of the vessel, tare weight, pressure rating. The load quantity is then calculated based on the procedure in place for the safe filling of LPG vehicles. In plants where reliable temperature and density information is available and is routinely monitored, the maximum safe filling quantity shall be based on the vehicle's vessel not being more than 97% full when the loaded product is at the Assessed Temperature for Safe Filling. The quantity ordered and the maximum GVW are also considered when calculating the load quantity.

Loading is initiated by the control room operator.

The computer controls the loading based on the predetermined weight, logs the transaction and, as a safeguard, highlights any discrepancy beyond a specified tolerance between the net weight calculated and the load as measured by the weighbridge. This system prevents overfilling of the vehicle.

(f) Product temperature

The temperature of the product being loaded can be measured accurately (to within 0.1 °C) by means of a platinum resistance probe inserted in the product supply line close to the loading bays or at the meters upstream of each loading arm. The loading control system monitors the probes (and all the other instrumentation devices) at regular intervals and can therefore relate the temperature to the volume flowing through the meter on a continuous basis, in order to calculate the average temperature, thence the volume at a standard temperature, and the safe filling volume.

(g) Meter applications

There are still meters fitted with a mechanical ‘stack-up’ including a vertical shaft drive to the recording head, a pre-set mechanism and optional ticket printer and in some cases a temperature compensation head.

To increase meter accuracy and reduce maintenance, mechanical stack-up devices should be gradually replaced by pulse units backed by a microprocessor. With the latter system the entire loading operation can be monitored via the gantry control system, i.e. pre-setting of a safe filling volume and closure of the flow control valve in the event of abnormally low flow rates.

Gantry control systems vary considerably in their design and in the extent of flow control provided. The flow of product may be ‘ramped up’ at the start of filling and ‘ramped down’ at the end of filling. On most systems, the level and duration of flow restriction are re-programmable.

Having recognised the driver and vehicle at the loading bay and the quantity of product to load, and having checked that the safety interlocks have been satisfied, the control system releases the correct meter to supply only the appropriate product. The flow of product may then be started (solenoid valve open and pump started).

The meter pulse unit transmits signals to the control system which records the volume metered and detects completion of the safe filling volume for loading, at which point the system shuts down.

After completion of loading, it shall be checked that the vehicle is not overfilled (see (4.3.1).

(h) Leaving the gantry

Correct disengagement of all equipment and proper placement of loading arms into a stowed position shall be completed before the vehicle can drive away.

5. TRANSPORT BY RAIL TANK WAGONS

5.1 GENERAL

In many countries it is usual for the railway companies to own the running gear and chassis of RTWs but the 'shipper' frequently owns the tank and its fittings because it is specialised equipment. Leasing or hiring RTWs from specialised companies is often found to be the most economic means of obtaining RTW capacity.

General arrangements of typical RTWs are shown in Figure 10.

The basic design and engineering criteria of the LPG vessels and their fittings are similar to those for road use. The main difference between the two transport units is that RTWs do not carry their own pumps or compressors. RTWs shall conform to the regulations of countries in which they will operate with respect to design loads, gauge, axle load, and any other requirements laid down by the railway authorities concerned.

The maximum weight of LPG for which the tank of the RTWs is designed should be such that the maximum gross weight permitted for that class of wagon under the appropriate railway regulations is not exceeded.

5.2 DESIGN OF PRESSURE VESSELS FOR RTWs

The design and construction of pressure vessels for rail transport use are generally subject to control by the railway authorities, augmented as necessary by international requirements such as RID. If comprehensive local standards do not exist, RTWs should conform to RID and also to the requirements of this DEP where they exceed RID.

The design of the pressure vessels for LPG transfer by rail follows the same general approach as for road use, i.e. it shall be to an acceptable design code such as ASME VIII. Dynamic and shunting loads, which may be as high as seven times the acceleration due to gravity (7 g_n) in the direction of travel, shall be taken into consideration. If block trains are utilised for dedicated journeys and shunting yards are avoided, a factor of 4g_n may be applied for these particular wagons, but the remainder of the fleet still requires 7 g_n.

The design pressure should be based on the Assessed Temperature for Developed Pressure for the area in which the RTW will operate, plus the effects of dynamic loads. The design of the pressure vessel should follow the requirements of (4.2.2).

In some countries top-filling connections are used on RTWs although, given the choice, bottom connections should be used as they are less vulnerable to damage and the connection/disconnection of couplings is easier.

Liquid filling/discharging connections should be equipped with remotely operated, internally mounted, positive shut-off valves. ESD valves can be connected to the rail track using a cable ensuring immediate closure if the wagon moves during loading or discharge.

PRVs shall be used to protect LPG vessels. PRVs should be of the internal type, fitted in recesses in the vessel shell, to provide protection in the event of a derailment and roll-over. For relief capacity, refer to (4.2.2(k)).

All fittings in the vessel shell should be protected from accident damage by their location or by mechanical means. A method frequently used is to recess fittings on both sides of the tank car so that loading/discharge may be effected on either side. Each set of fittings operates independently of the other. On large RTWs there may be two sets on each side of the vessel.

Local regulations may require RTWs with central couplers to be protected to reduce the risk of vessels being punctured by the coupling of a colliding RTW in a derailment. The Principal shall be contacted for advice on the type of protection which should be provided in such cases.

Figure 11 shows a diagrammatic layout of internal pipework for a typical RTW. The following comments refer to this layout:

- Liquid and vapour lines shall be equipped with self-sealing couplings to minimise the release of LPG during connection and disconnection.
- Opposite side sets of fittings shall be connected internally liquid-to-liquid, vapour-to-vapour. Both internal systems shall be fitted with remotely controlled valves. Hydraulically actuated valves are commonly used for this purpose, with fusible links and mechanical linkage to the track designed to close the hydraulic valve if the RTW is moved with the arm/hose still connected.

5.3 SUN SHIELDS

Local regulations may permit a decrease in the Assessed Temperature for Safe Filling (4.2.2(b)) and the Assessed Temperature for Developed Pressure (4.2.2(e)) if sun shields are fitted to RTWs. Proposals to use RTWs with sun shields are subject to the approval of the Principal.

5.4 INSULATION

Local regulations may require wagons to be insulated to reduce heat flux on the vessel shell when exposed to fire engulfment. Specifications for passive fire protection systems are subject to the approval of the Principal.

5.5 RTW LOADING AND UNLOADING

5.5.1 General

RTWs may be loaded/unloaded by using the methods referred to in (2.2).

A typical arrangement using a compressor is shown in Figure 12.

As the loading/unloading systems do not differ in principle from those for bulk road vehicles, refer to (4.3.4), (4.3.5) and (4.3.6).

For protection in the event of a RTW moving away while loading arms or hoses remain connected, see (4.3.3) with regard to breakaway couplings and (5.2) on the automatic closure of hydraulic safety valves.

ESD valves shall be installed at the RTW siding end of the permanent piping to contain spillage in the event of loading arm/hose failures.

Safety systems should be set up to prevent access by other rail vehicles to the sidings while RTWs are still connected to the loading or unloading facilities, e.g. by using barriers or gates.

For details on sidings, pulling equipment, e.g. capstans, mules and locomotives, etc., SIOP may be consulted.

5.5.2 Rail heads

Sites at which LPG transfers are made directly between RTWs and bulk road vehicles are referred to as rail heads. Figure 13 shows a typical rail head layout.

The standards of safety and engineering which are applied to storage plants handling the loading/unloading of bulk road vehicles and RTWs apply also to rail heads.

Refer to IP Model Code of Safe Practice, Part 9 for further guidance.

6. BULK TRANSPORT BY TANKERS AND OTHER WATERBORNE CRAFT

6.1 GENERAL

The following documents shall apply:

- “Liquefied gas handling principles (on ships and in terminals)”, by SIGTTO;
- “Safety guide for terminals handling ships carrying liquefied gas in bulk“, by OCIMF.

The design of the cargo carrying space and product transfer facilities in LPG tankers is based on handling either pressurised, semi-refrigerated/semi-pressurised or fully refrigerated product.

Tanks used in transporting ambient temperature product are conventional pressure vessels. Tankers designed to handle pressurised product are comparatively expensive to build and are generally less than 5 000 m^3 cargo capacity. They are commonly employed in coastal and short sea marketing distribution operations.

Tanks for holding fully refrigerated product are of much lighter construction, designed for pressures slightly above atmospheric and insulated to minimise heat inflow to the product. Tankers in this category are designed to carry cargoes between refrigerated and large pressurised storage terminals. Their cargo capacity ranges from around 20 000 m^3 to 150 000 m^3.

Semi-refrigerated/semi-pressurised tankers fill the capacity gap and meet operational needs between the small pressurised tankers and large fully refrigerated carriers. Their cargo tanks are designed to handle fully and partially refrigerated product at correspondingly reduced pressures.

6.2 TANKER LOADING AND UNLOADING

Pressurised LPG loading facilities shall be provided with vapour return systems to avoid releasing large quantities of vapours to the atmosphere (see Figure 14).

The two most common methods of unloading a pressurised LPG tanker are by ship's pumps or by ship's compressors and pumps. Although all pressurised ships should have their own means of discharging cargo, the occasional need may arise for shore-based compressors to be used in the vapour return line (see Figure 15).

6.3 VAPOUR HAZARDS AT THE SHIP/SHORE INTERFACE

The release of LPG vapour should only occur on board tankers laying alongside berths or in the onshore facilities under controlled and supervised conditions as, for example, when loading arms or hoses are disconnected. LPG carriers and terminals shall have stringent loading and discharging procedures in place.

For requirements and guidance, refer to:

- “Liquefied gas handling principles (on ships and in terminals)”, by SIGTTO;
- “Safety guide for terminals handling ships carrying liquefied gas in bulk“, by OCIMF;
- IMDG code, by IMO.

6.4 EMERGENCY SHUTDOWN SYSTEMS

6.4.1 General

Refer to DEP 30.06.10.20-Gen. for a detailed description of the various ESD systems.

Ship/shore ESD systems should be integrated according to the SIGTTO

"Recommendations and guidelines for linked ship/shore emergency shut-down of liquefied gas cargo transfer". The use of an alternative system is subject to the approval of the Principal.

The design of the ESD system and associated ship/shore link shall include a detailed operating procedure for use by shore personnel and shall meet the requirements of OCIMF "Ship/shore safety check list guidelines".

Figure 16 shows typical emergency situations that would give rise to system shutdown.

6.4.2 ESD-1

Terminals shall be equipped with at least an ESD-1 system to stop the transfer operation in a quick, safe and controlled manner. This system consists of:

(i) ESD valves (for details, refer to DEP 30.06.10.12-Gen.).

(ii) Push buttons located at various strategic locations on the jetty and on the shore which are unlikely to be affected by an incident at the berth.

(iii) A pendant box placed on board the ship prior to loading/discharging for ships which are not equipped with a compatible ESD system.

(iv) A ship/shore link to convey the shutdown signal for ships equipped with a compatible ESD system.

(v) The ESD-1 logic control system.

6.4.3 ESD-2

This system shall be installed if there is a risk of damage to the loading arms or the ship due to ship drift under adverse weather or current conditions. In an emergency, the ESD-2 system uncouples the loading arms quickly with minimum spillage. If the ship can be securely moored with minimal impact of wind, tide and current and if surge from other ship movements in the vicinity is not a problem, the installation of an ESD-2, also called the emergency release system (ERS), is not essential. The ESD-2 system consists of:

(i) The Emergency Release Coupling (ERC).

(ii) Two isolation valves (the ERS valves), one upstream and one downstream of the ERC.

(iii) The ESD-2 logic control system.

6.4.4 Pressure surge

The potential hazard of pressure surges resulting from sudden changes in flow by rapid closure of valves shall be considered when designing transfer systems. The hazard is greatest for transfers over long distances and at high velocity. The loading arm/hose is the component most vulnerable to failure in these circumstances.

Surge calculations shall be carried out at an early design stage to arrive at a proper selection of pumps and piping system (e.g. diameter and flange rating) and to prevent the need for unwanted measures to alleviate excessive surge pressures. In this evaluation the features of the ship manifold should be taken into account.

The minimum acceptable valve closure time at the design flow rate shall be calculated for each loading/discharging system. Actuators should be set to closure times marginally longer than the minimum theoretical figure. Refer to DEP 30.06.10.20-Gen. and SIGTTO "Guidelines for the alleviation of excessive surge pressures on emergency shut down".

To avoid creating excessive pressures in the ship/shore manifold and transfer equipment when loading a ship, the terminal ESD should complete its shutdown before the ship's ESD valves close. Similarly, when discharging tankers, the ship should complete its ESD before the terminal's ESD valves close.

6.5 LOADING ARMS/HOSES

6.5.1 Selection

Loading arms should normally be used rather than hoses (refer to (2.5.4)). Separate arms are usually provided for liquid and vapour, although arms which incorporate two integral booms ‘piggy back’ style are also available.

Hoses may be used at berths where tanker discharging operations are infrequent and discharge rates are low. Suitable submarine hoses should be used at conventional buoy mooring (CBM) berths. Floating hoses shall not be used.

6.5.2 Loading arm working envelope

Each loading arm has a safe working envelope (refer to Figure 17) and movements outside this envelope will give rise to damage to the arm and possible release of product. Arms should incorporate alarm systems to warn of excessive movement. For details, refer to DEP 30.06.10.20-Gen.

Loading arms are normally provided with an over-travel detection system. This should be a two stage system, particularly for the larger arms (150 mm diameter and larger), as follows:

(a) An alarm is actuated when the arm approaches predetermined limits based upon acceptable movements of the ship at the berth. The alarm sensor may also initiate an ESD-1.

(b) If the arm continues its movement in excess of the acceptable limits, a second alarm will be activated and, if an ERS is provided, an ESD-2 will be initiated.

If no alarms are fitted, precautionary measures should be agreed between the ship and the terminal to give early warning before a critical situation is reached. For guidance, refer to the OCIMF “Design and construction specification for marine loading arms”.

6.6 EARTHING AND BONDING

Hoses/loading arms shall be fitted with insulating flanges or joints to ensure electrical discontinuity between ship and shore. All metal on the shore side of the insulating flange/joint shall be electrically continuous to the jetty earthing system and all metal on the seaward side shall be electrically continuous to the ship.

Refer to DEP 33.64.10.10-Gen.

7. 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

DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Equipment in LPG installations	DEP 30.06.10.11-Gen.
Pressurised bulk storage installations for LPG	DEP 30.06.10.12-Gen.
ESD systems for loading and discharging refrigerated and pressurised LNG and LPG carriers	DEP 30.06.10.20-Gen.
Metallic materials - prevention of brittle fracture	DEP 30.10.02.31-Gen.
Cathodic protection	DEP 30.10.73.10-Gen.
Design of cathodic protection systems for onshore buried pipelines	DEP 30.10.73.31-Gen.
Painting and coating of new equipment	DEP 30.48.00.31-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
Pipeline engineering	DEP 31.40.00.10-Gen.
Design of pipeline pig trap systems	DEP 31.40.10.13-Gen.
Pipeline overpressure protection	DEP 31.40.10.14-Gen.
External polyethylene and polypropylene coating for line pipe	DEP 31.40.30.31-Gen.
External fusion-bonded epoxy powder coating for line pipe	DEP 31.40.30.32-Gen.
Hydrostatic pressure testing of new pipelines	DEP 31.40.40.38-Gen.
Pipeline leak detection	DEP 31.40.60.11-Gen.
Pipeline repairs (Supplements to ANSI/ASME B31.4 and B31.8)	DEP 31.40.60.12-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Minimum requirements for structural design and engineering	DEP 34.00.01.30-Gen.
Mounded horizontal cylindrical bulk storage vessels for pressurised gases at ambient temperatures	DEP 34.51.11.30-Gen.
Welding of pipelines and related facilities (Amendments/supplements to ANSI/API STD 1104)	DEP 61.40.20.30-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

Shell Safety Committee publication	"Static electricity - technical and safety aspects"

AMERICAN STANDARDS

ACME screw threads	ASME/ANSI B1.5
Chemical plant and petroleum refinery piping	ASME/ANSI B31.3
ASME Boiler and Pressure Vessel Code Section VIII, Rules for construction of pressure vessels	ASME VIII

Issued by:
American Society of Mechanical Engineers
345 East 47th Street
New York NY 10017
USA.

Specification for fire tests for valves	API 6FA

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

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

Issued by:
National Fire Protection Association
470 Atlantic Avenue
Boston Massachusetts, 02210
USA

Specifications for containers for motor vehicle transportation. Specification MC 331 cargo tanks constructed of steel, primarily for transportation of compressed gases as defined in the Compressed Gas Section	MC 331

Issued by:
US Department of Transportation
400 Seventh Street SW
Washington DC 20590-0001,
USA

BRITISH STANDARDS

Fire tests on buildings and structures:

Part 20: Method for determination of the fire resistance of elements of construction (general principles)	BS 476-20
Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction	BS 476-22
Hose and hose assemblies for liquefied petroleum gas	BS 4089
Filling ratios and developed pressures for liquefiable and permanent gases	BS 5355
Testing of valves: Part 2: Specification for fire type-testing requirements	BS 6755-2

Specification for cables for vehicles:

Part 1: Cables with copper conductors	BS 6862-1
Welded steel tanks for the road transport of liquefiable gases	BS 7122

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

IP Model code of safe practice	IP Code
Part 9: Liquefied petroleum gas	

Issued by:
Institute of Petroleum
61 New Cavendish Street
London W1M 8AR, United Kingdom.

Code No. 2: Safe handling and transport of LPG in bulk by road	LPGITA

Issued by:
Liquefied Petroleum Gas Industry Technical Association UK
17 Grosvenor Crescent
London SW1X 7ES, United Kingdom.

INTERNATIONAL STANDARDS

International maritime dangerous goods code	IMDG code

Issued by:
International Maritime Organisation
4 Albert Embankment
London SE1 7SR, United Kingdom.

Safety guide for terminals handling ships carrying liquefied gases in bulk	OCIMF
Design and construction specification for marine loading arms	OCIMF
Ship/shore safety check list guidelines	OCIMF

Issued by:
The Oil Companies International Marine Forum
6th Floor, Portland House, Stag Place,
London SW1E 5BH, United Kingdom.

Guidelines for the alleviation of excessive surge pressure on emergency shut-down	SIGTTO
Liquefied gas handling principles (on ships and in terminals)	SIGTTO
Recommendations and guidelines for linked ship/shore emergency shut-down of liquefied gas cargo transfer	SIGTTO

Issued by:
Society of International Gas Tanker & Terminal Operators Ltd.
17 St. Helen's Place
London EC3A 6DE
United Kingdom.

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.

Act on the European agreement on the transporation of dangerous goods by road	ADR
Regulations on the international transport of dangerous goods by rail	RID

Issued by:
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Information Office
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1211 Geneva, Switzerland

Rubber and plastic hose and hose assemblies - Determination of electrical resistance	ISO 8031
Steel and steel structures - Inspection documents	ISO 10474

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 Assessed Temperature for Developed Pressure

		Vessel size (water capacity) (litres)	
		up to 5 000	above 5 000
Climatic Area	Maximum shade temperature t_S (°C)	Assessed Temperature for Developed Pressure (°C)	
1	$t_S < 35$	47.5	42.5
2	$35 \leq t_S < 37.5$	50	45
3	$37.5 \leq t_S < 42.5$	55	50
4	$42.5 \leq t_S < 47.5$	60	55
5	$47.5 \leq t_S < 52.5$	62.5	60
6	$52.5 \leq t_S$	67.5	65

Notes:
1. Source: BS 5355
2. For maximum shade temperatures, refer to Appendix 4.

Table 2 Assessed Temperature for Safe Filling of bulk vehicles

		Vessel size (water capacity) (litres)	
		up to 5 000	above 5 000
Climatic Area	Maximum shade temperature t_S (°C)	Assessed Temperature for Safe Filing (°C)	
1	$t_S \leq 35$	42.5	38
2	$35 < t_S < 37.5$	42.5	40
3	$37.5 \leq t_S < 42.5$	47.5	45
4	$42.5 \leq t_S < 47.5$	50	47.5
5	$47.5 \leq t_S < 52.5$	52.5	52.5
6	$52.5 \leq t_S$	55	55

Notes:
1. Source: BS 5355
2. For maximum shade temperatures, refer to Appendix 4.

Table 3 Type of primary shut-off systems to be fitted in vessel connections

Product phase / Connection size	Liquid fill		Liquid outlet	Pump bypass	Emergency uplift/drain	Vapour return
	L	V				
Liquid						
≤ 32 mm	A	-	C	A	C	-
> 32 mm	B	-	B	A	B	-
Vapour						
≤ 32 mm	-	A	-	-	-	C
> 32 mm	-	A	-	-	-	B

NOTES:

1. 32 mm is equivalent to 1¼ in NPT.

2. Pump bypass connections should not normally be larger than 32 mm diameter.

3. Description of codes:

   L: means that the connection terminates in the liquid phase;

   V: means that the connection discharges into the vapour phase, e.g. a spray header.

   A: Internally mounted NRV with a fire-safe ball valve, fitted externally as close as possible to the NRV.

   B: Remotely operated ISV with mechanical, hydraulic or pneumatic operation incorporating a thermal closure device, e.g. fusible link, which operates at temperatures of not more than 120 °C. The valve may incorporate an excess flow shutdown facility. The main seat of the valve shall remain in place and shall be operable in the event of an accident.

   C: Internally mounted EFV (in which the pressure equalising bypass is not greater than 1.4 mm diameter) with a close coupled fire-safe ball valve, fitted externally as close as possible to the EFV.

APPENDIX 2 FIGURES

Figure 1 Typical transfer systems

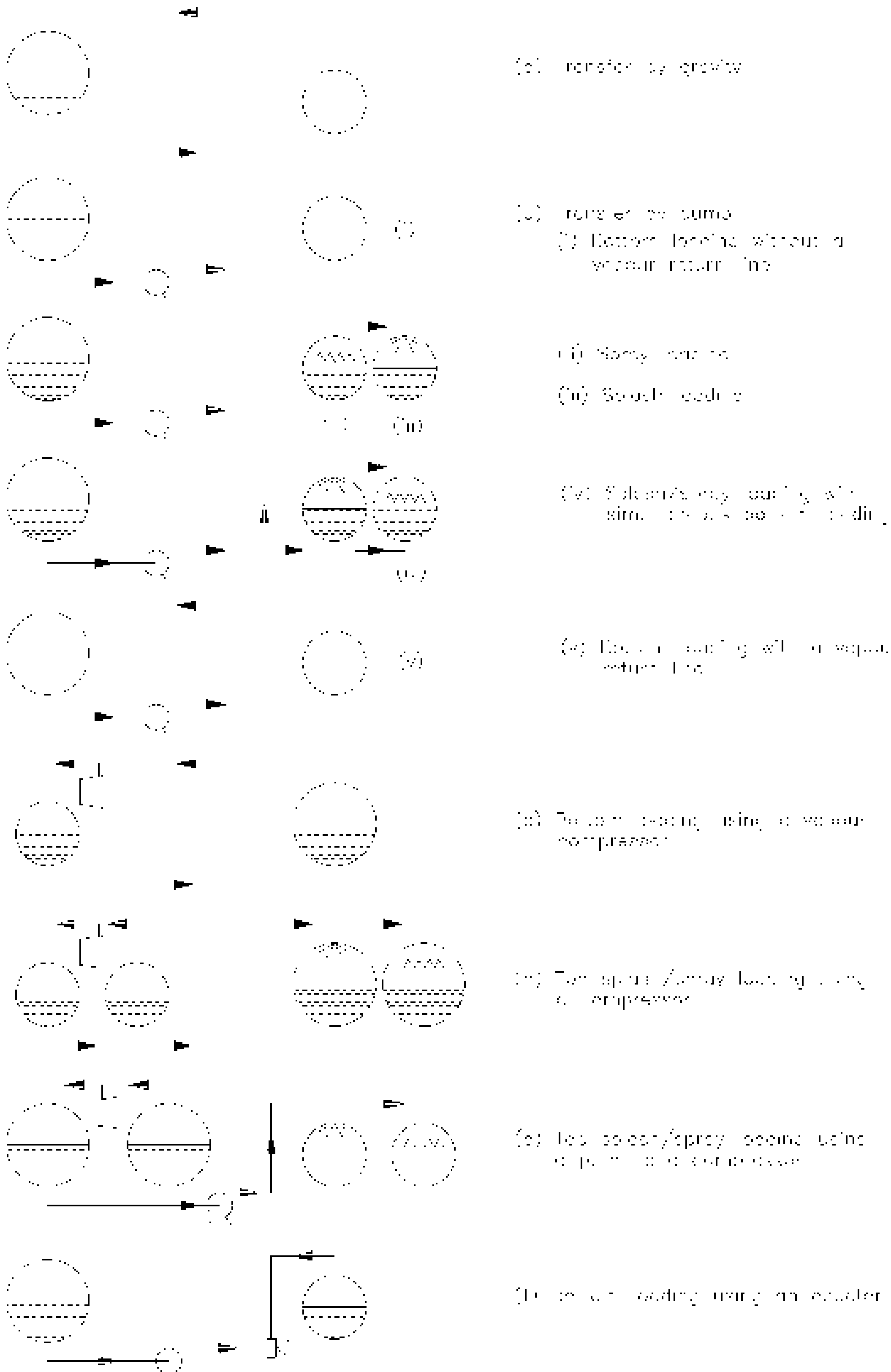
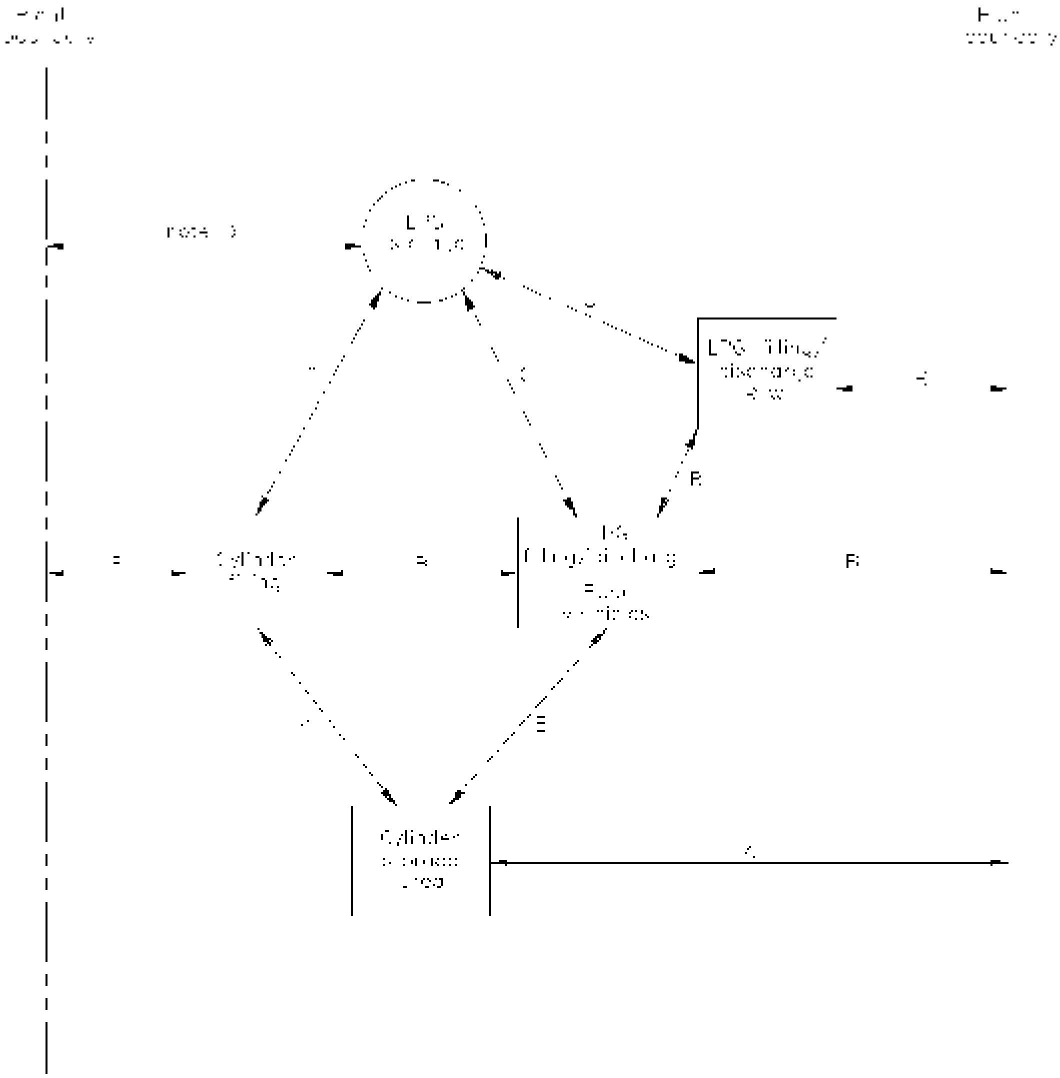

(a) Transfer by gravity
(b) Transfer by pump
(i) Bottom loading without a vapour return line
(ii) Spray loading
(iii) Splash loading
(c) Bottom loading using a vapour compressor
(d) Top splash/spray loading using a compressor
(e) Top splash/spray loading using a pump and a condenser
(f) Bottom loading using an eductor

Figure 2 Safety distances for preliminary design purposes - Road and Rail



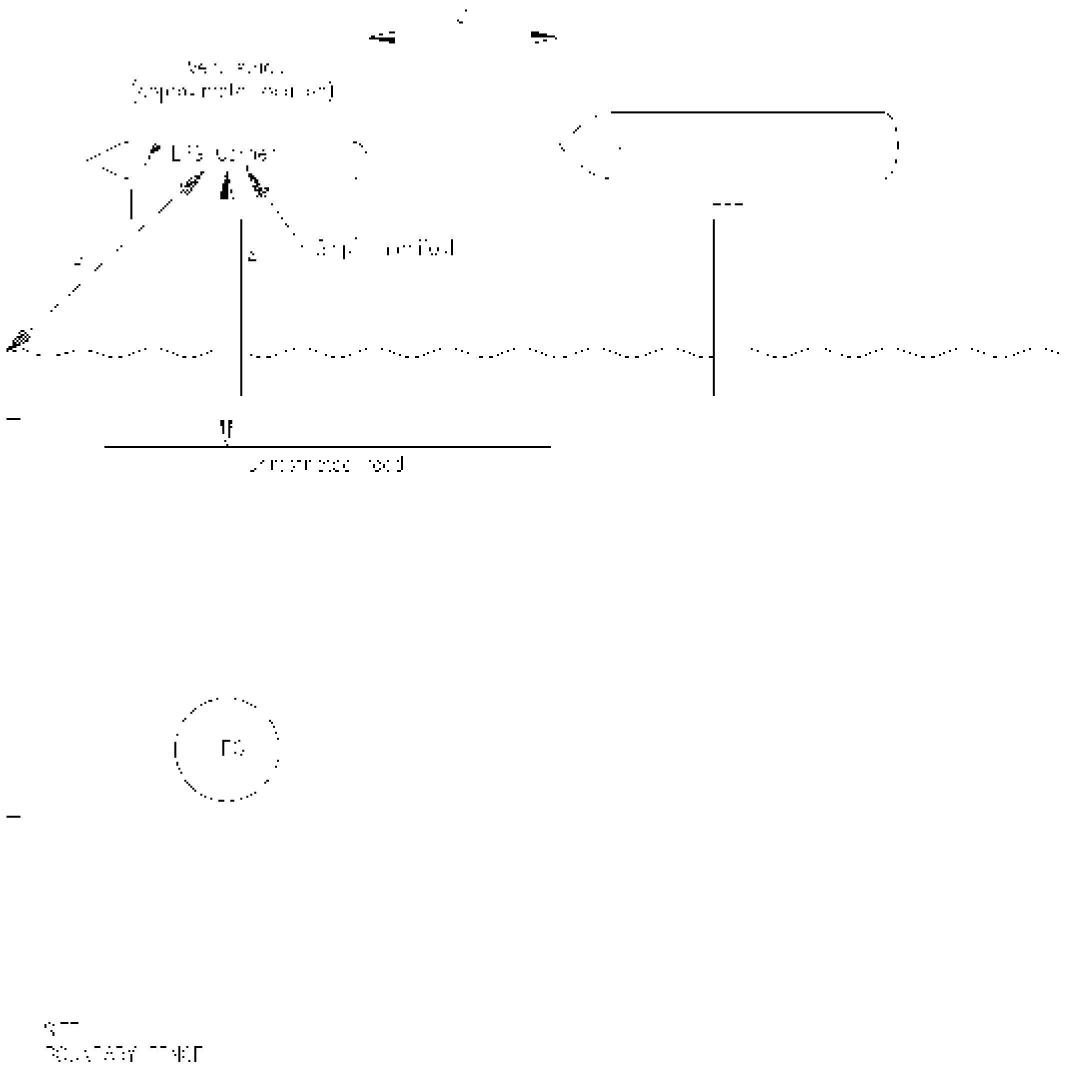
	Safety distance (metres)		
	A	B (2)	C (2)
Above-ground vessels	(1)	15	25
Mounded vessels	(1)	15	15

NOTES:
(1) Distance depends on the total quantity of LPG stored (from 1 metre for quantities up to 400 kg to 20 metres for quantities above 250 000 kg).

(2) Distances shall be verified by a radiation assessment. Refer to (2.5.2).

(3) Distance related to the size of LPG vessel. Refer to DEP 30.06.10.12-Gen.

Figure 3 Safety distances for preliminary design purposes - Tankers



Code	Description	Safety distances (metres)
	Between LPG carrier and:	
A	- the edge of unrestricted plant/depot roads	30
B	- the site boundary	60
C	Clearance between moored vessels	40

NOTE: All distances shall be verified by radiation assessment. Refer to (2.5.2).

Figure 4 Diagrammatic layout of an IMO Type 5 container tank

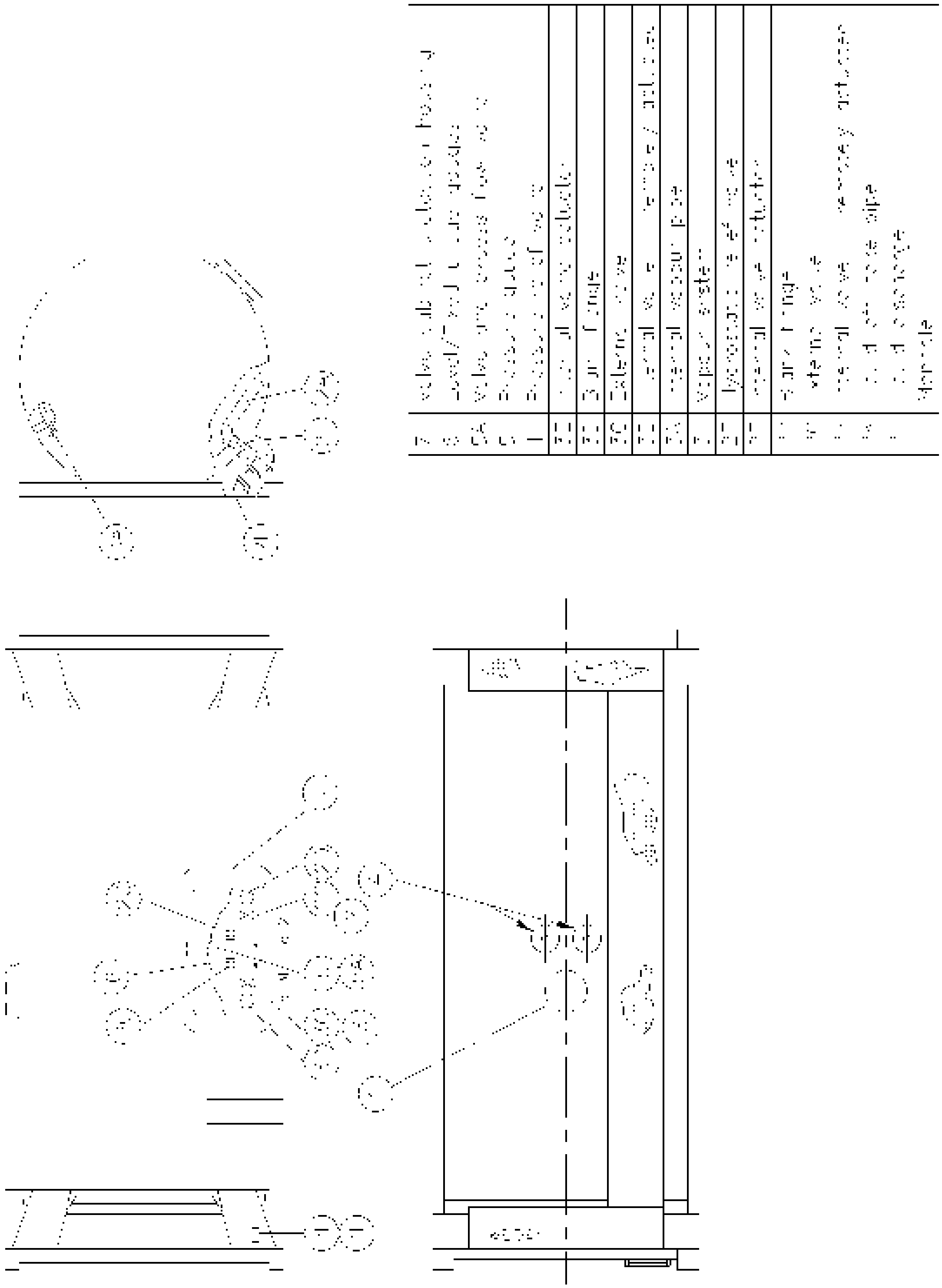
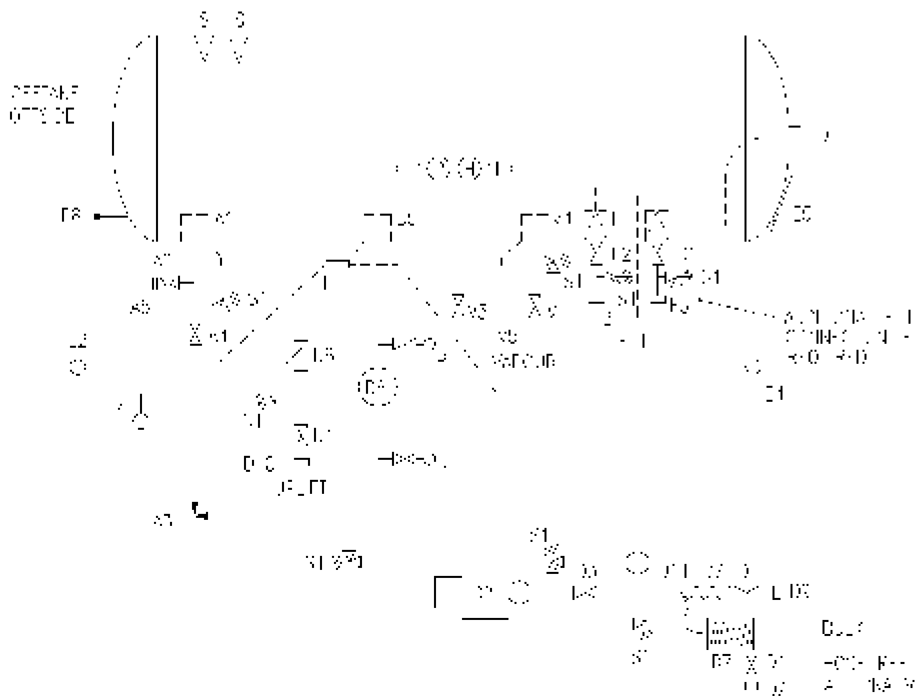


Figure 5 Diagrammatic layout of piping and equipment for a bulk delivery vehicle



DELIVERY SYSTEM
- D1 [illegible] ball valve
- D2 Meter c/w strainer, vapour eliminator & temperature compensator
- D3 [illegible] ball valve
- D4 [illegible] ball valve
- D5 [illegible] valve c/w [illegible]
- D6 Pump
- D7 Delivery hose [illegible]
- D8 Filter
- D9 [illegible] coupling
- D10 Adaptor c/w [illegible]
- D11 Excess flow valve

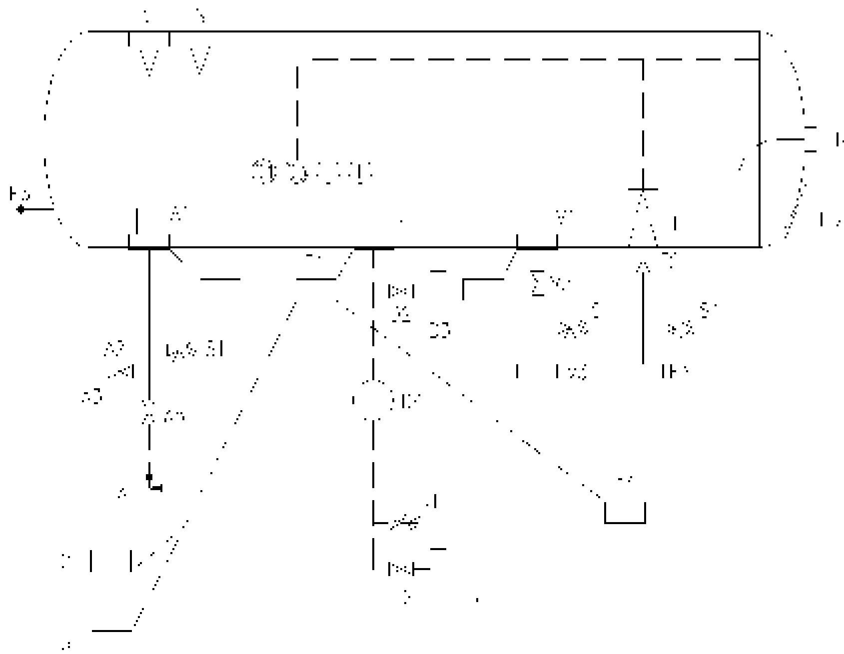
FILLING SYSTEM
- F1 Back check valve (inside vessel)
- F2 [illegible] safe ball valve
- F3 Double check filler valve & cap

VAPOUR SYSTEM
- V1 [illegible] safe ball valve
- V2 Fire safe ball valve
- V3 Internal safety valve c/w actuator
- V4 Vapour equalising valve & cap

EMERGENCY OFFTAKE & PUMP BYPASS
- A1 Internal safety valve c/w [illegible]
- A2 Fire safe ball valve
- A3 Differential pressure bypass valve
- A4 Fire safe ball valve
- A5 Blank flange or plug

TANK EQUIPMENT
- S Safety relief valve
- [illegible] Hydrostatic relief valve c/w cap
- T Dial 'C' type thermometer
- T2 Thermowell
- Pressure gauge c/w excess flow valve & isolation valve
- [illegible] Rotogauge
- [illegible] Level gauge butane
- Level gauge propane
- [illegible] Fixed [illegible]
- L1, L2, L3 [illegible] sequence control
- [illegible] Manway
- [illegible] Earth connection facility

Figure 6 Diagrammatic layout of a bulk bridging vehicle



LIQUID DISCHARGE
D1 Internal safety valve & actuator
D2 Fire-safe ball valve
D3 Hose coupling and cap
D4 Pump (as required)

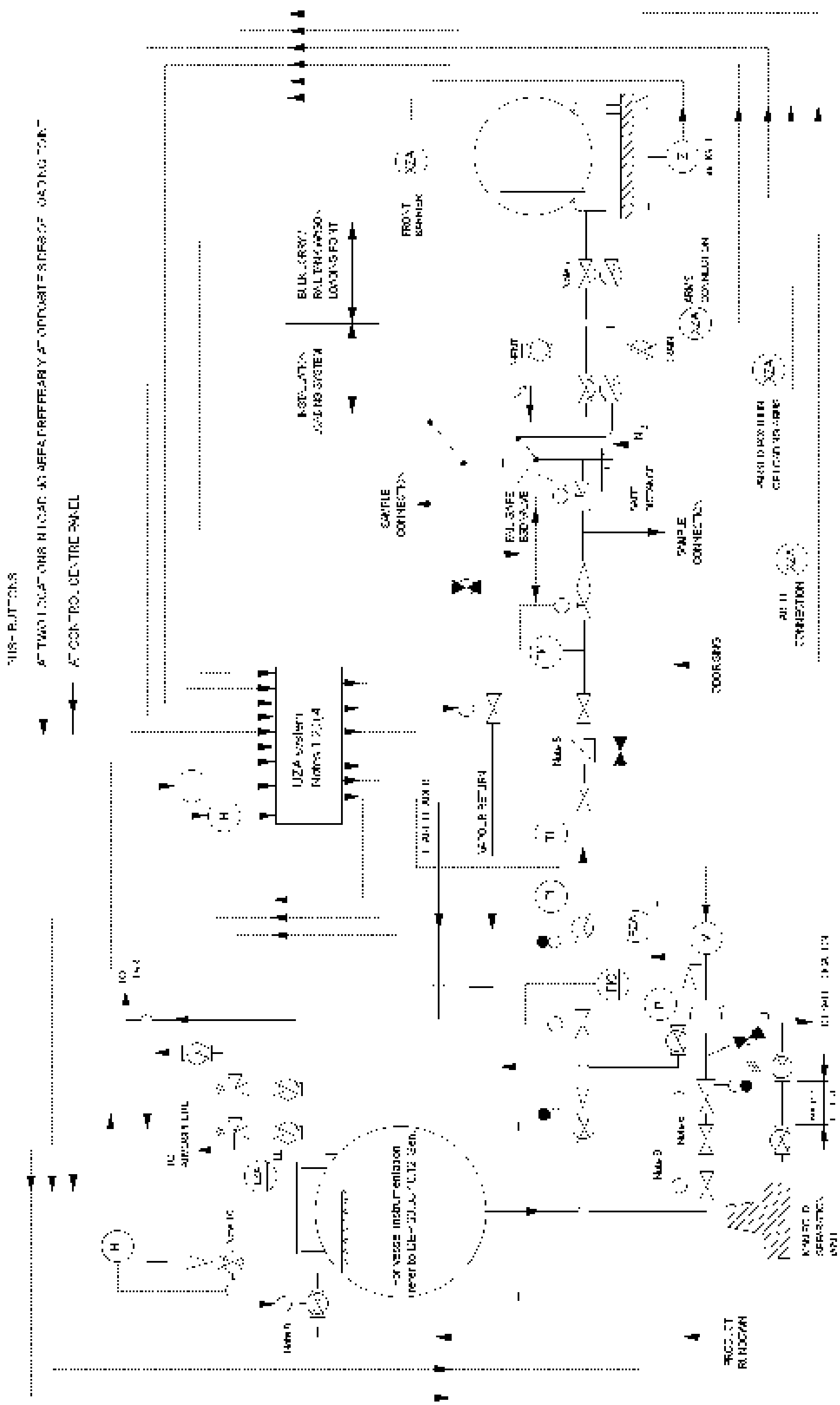
FILLING
F1 Back check filler valve (internal)
F2 Fire-safe ball valve
F3 Double check filler valve & cap

VAPOUR SYSTEM
V1 Fire-safe ball valve
V2 Internal safety valve & actuator
V3 Vapour equalising valve & cap

[illegible] & PUMP BYPASS
A1 Internal safety valve & actuator
A2 Fire-safe ball valve
A3 Blank flange or plug
A4 Differential bypass relief valve (as required)
A5 Fire-safe check valve (as required)

OTHER FITTINGS
S Safety relief valve
S1 Thermal expansion relief valve (hydrostatic relief valve)
T Thermometer
Pressure gauge c/w excess flow valve and [illegible]
R Rotogauge
L3 [illegible] gauge
L4 [illegible]
E Internal safety valve (ISV) actuation points
E2, E3, E4 Remote shut-off for ISVs
L2 Manway
E3 Earth connection point

Figure 7 Typical safeguarding scheme for bulk road vehicle/rail tank wagon loading system



Notes on Figure 7

1. The UZA system as indicated represents the arrangement (with optional features) of the automatic safeguarding functions envisaged.
2. Loading shall be possible only if all of the following conditions are satisfied:
   - driveaway prevention (e.g. front barrier) active;
   - proper earth connection made;
   - loading arms properly connected;
   - loading controller properly pre-set.
3. If any one of these conditions is not fulfilled, commencement of loading shall not be possible. If during loading any one of these conditions is no longer met, an emergency shutdown shall result.
4. Loading arms shall be operable only after proper earthing is established and driveaway prevention system is active.
5. Filter is optional.
6. Need for this ROV/ESD valve depends on volume of upstream line, taken from the storage vessel outlet ROV/ESD valve.
7. Dry-break couplings may be used in addition to block valve arrangement shown. Rear barrier with XZA signal to control and safeguarding system to be considered for additional protection.
8. These valves are activated by control and safeguarding system in case of overfill only and are not related to the loading operation proper.
9. For arrangement of storage vessel bottom ROV/ESD valve and downstream block valve, refer to DEP 30.06.10.12-Gen.
10. For valving arrangement on the vessel inlet nozzle of vapour return, refer to DEP 30.06.10.12-Gen.

General:

- For bulk road vehicle or rail tank wagon loading systems without a vapour return the typical arrangement shown can be adhered to but excluding the vapour return system, i.e. vapour return arm and line.
- Thermal expansion relief valves are not indicated. They should be provided on pump suctions and on line sections which can be blocked-in in liquid full condition, refer to DEP 30.06.10.12-Gen.
- Gas detectors shall be installed near critical points in loading line systems, e.g. near loading system/bulk road vehicle/rail tank wagon connection and loading pump. Consideration shall be given to tying in the gas detector signal to the ESD system.
- Refer to (4.3.2) for further details.
- Refer to Figure 8 which indicates typical loading control arrangements for a large LPG installation.

Figure 8 Schematic for bulk road vehicle loading controls procedures

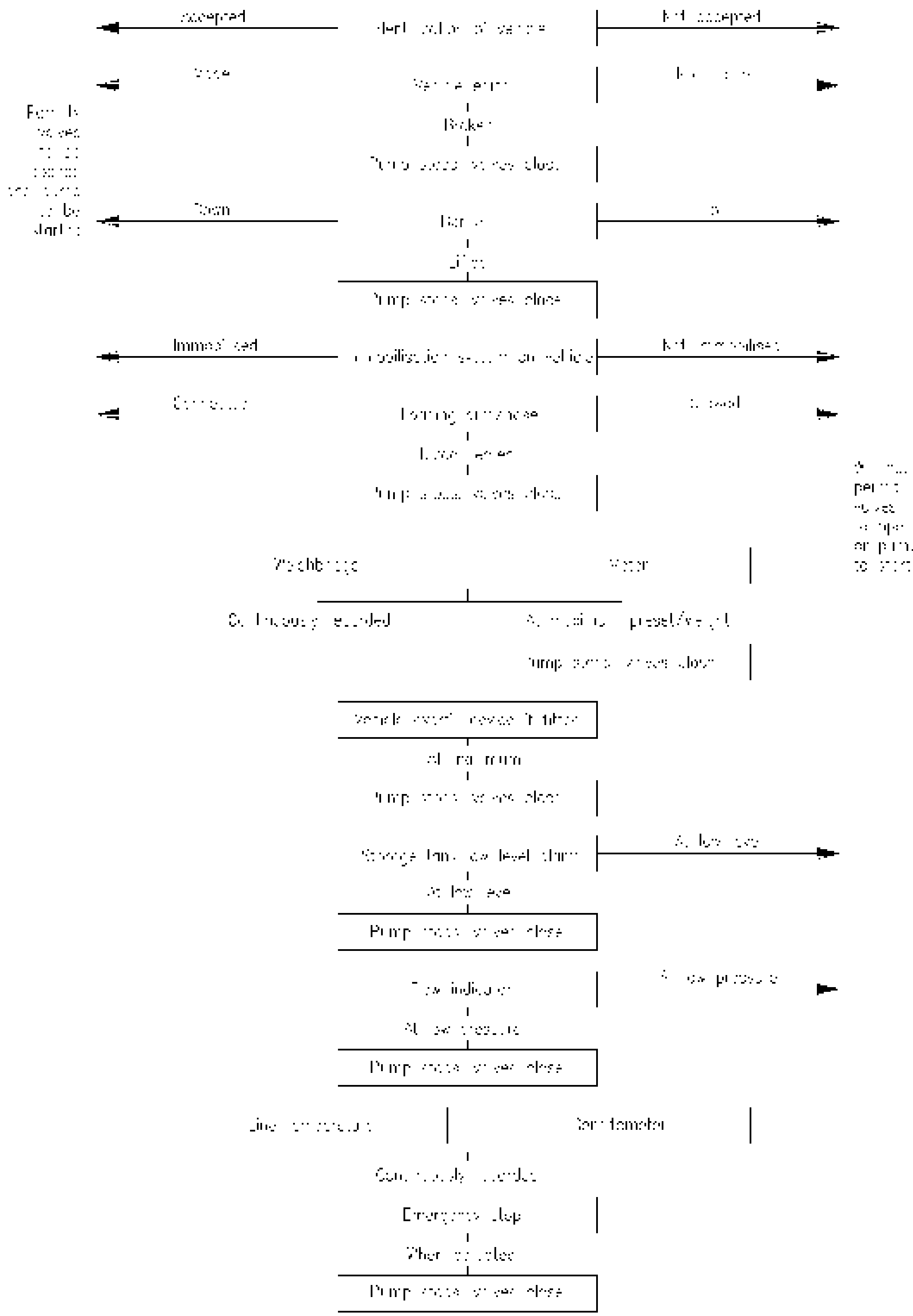


Figure 9 Emergency off-loading facility for discharging overturned bulk road vehicles

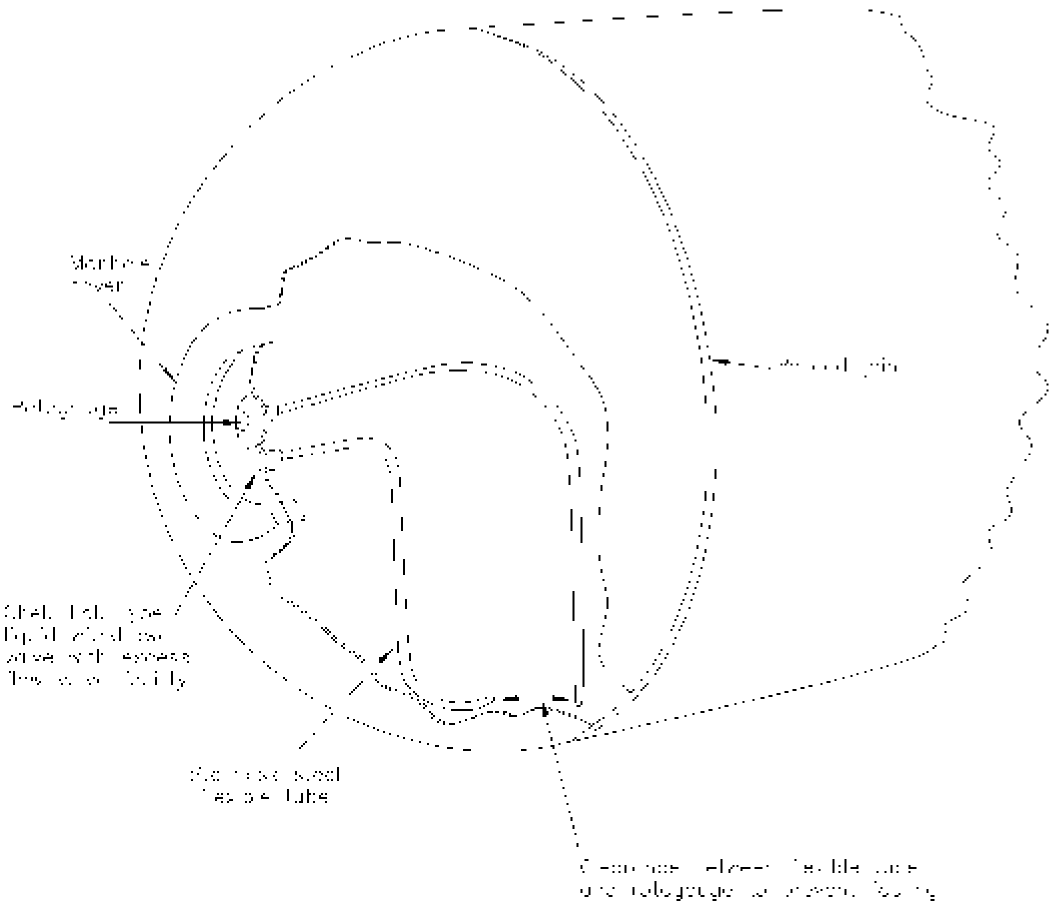


Figure 10 Typical rail tank wagon valves and instrumentation

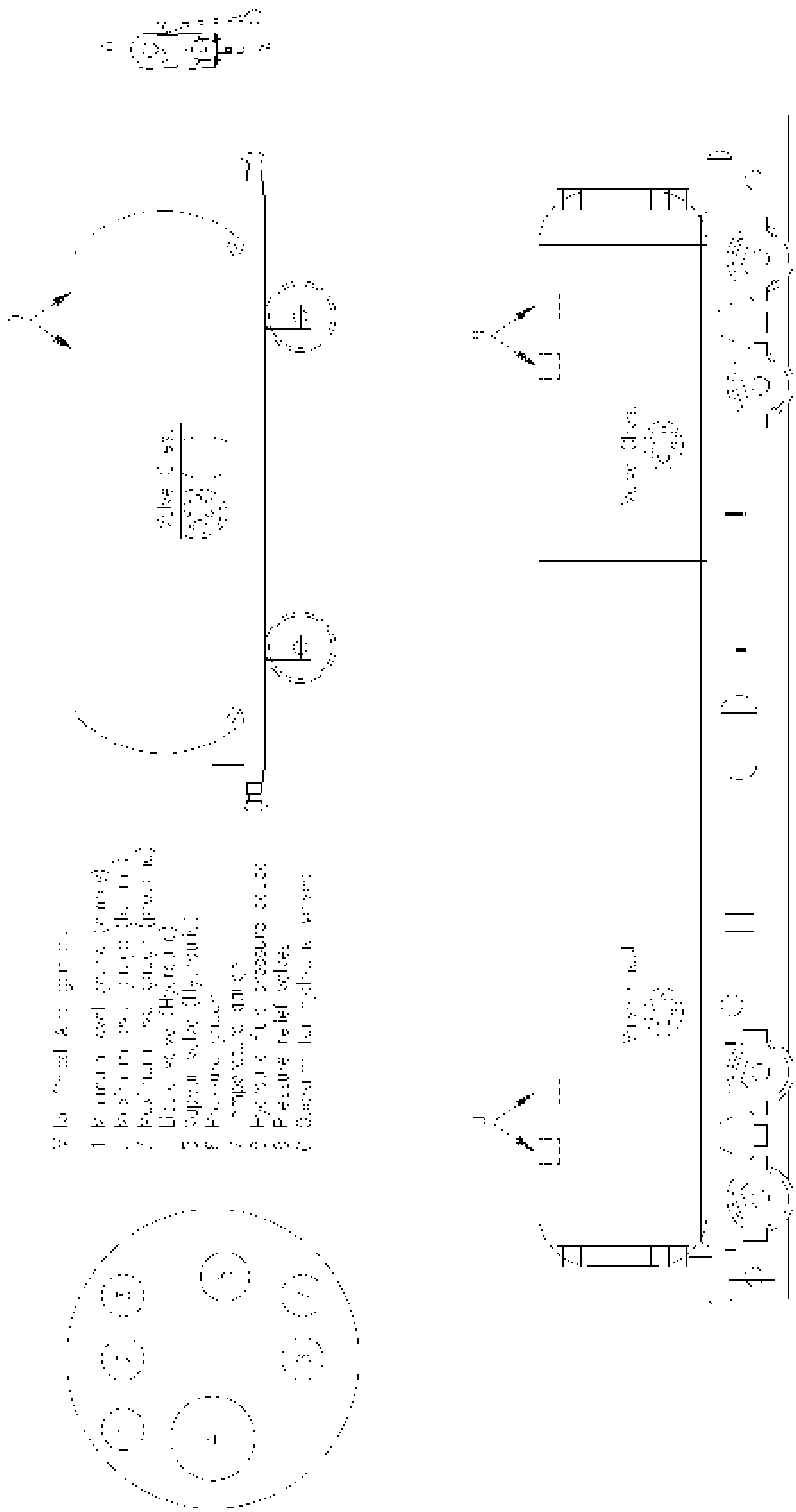
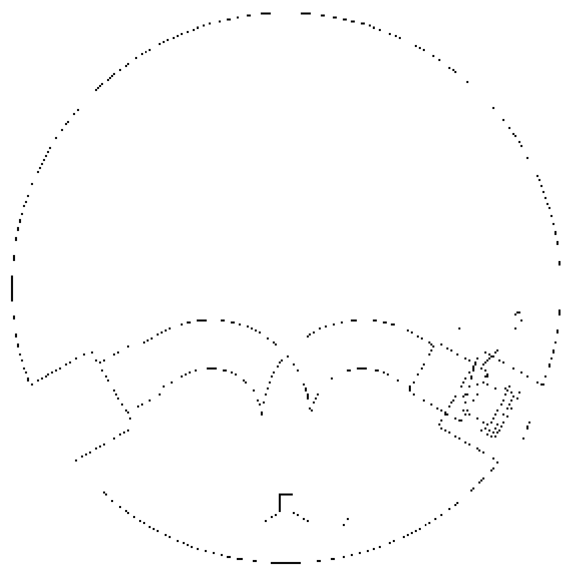
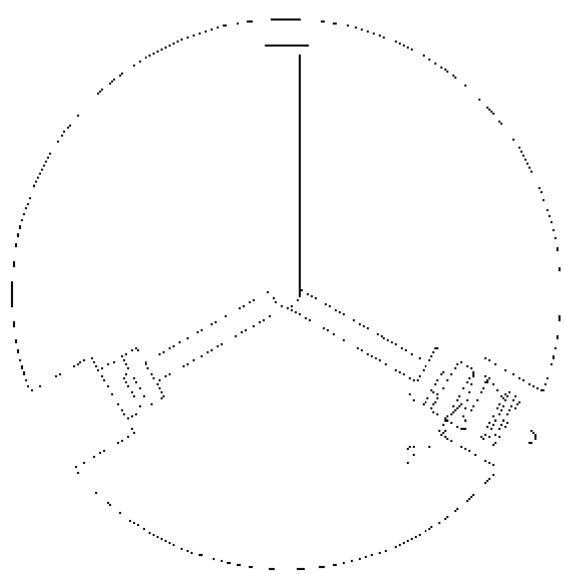


Figure 11 Typical design of internal valves and pipework for an LPG rail tank wagon

[illegible]



[illegible]



1 [illegible]
2 Ball Valve
3 [illegible]
4 Excess Flow Valve

Figure 12 Typical arrangement for loading/unloading an LPG rail tank wagon using a compressor

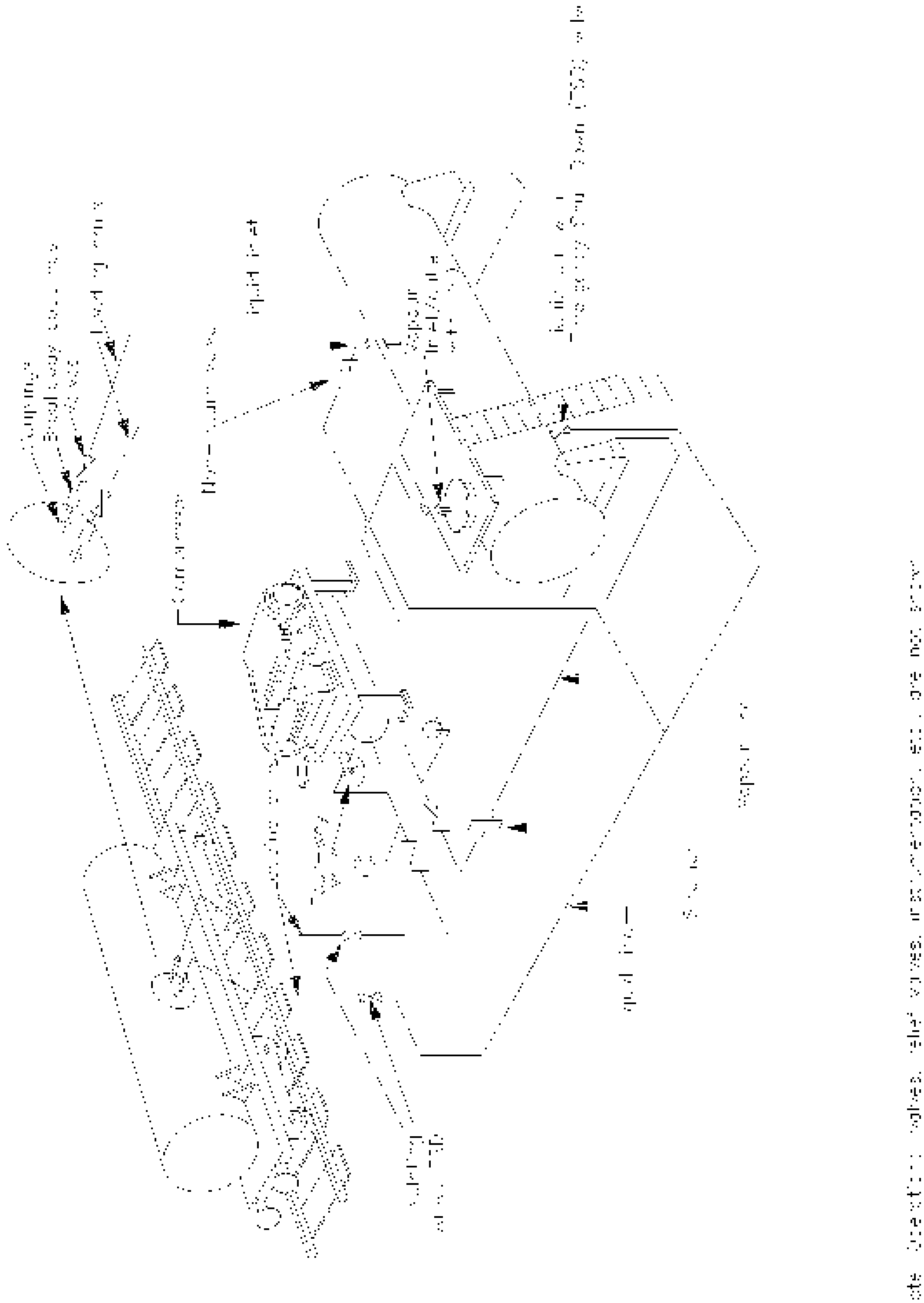


Figure 13 Typical arrangement at an LPG rail head using pump and compressor

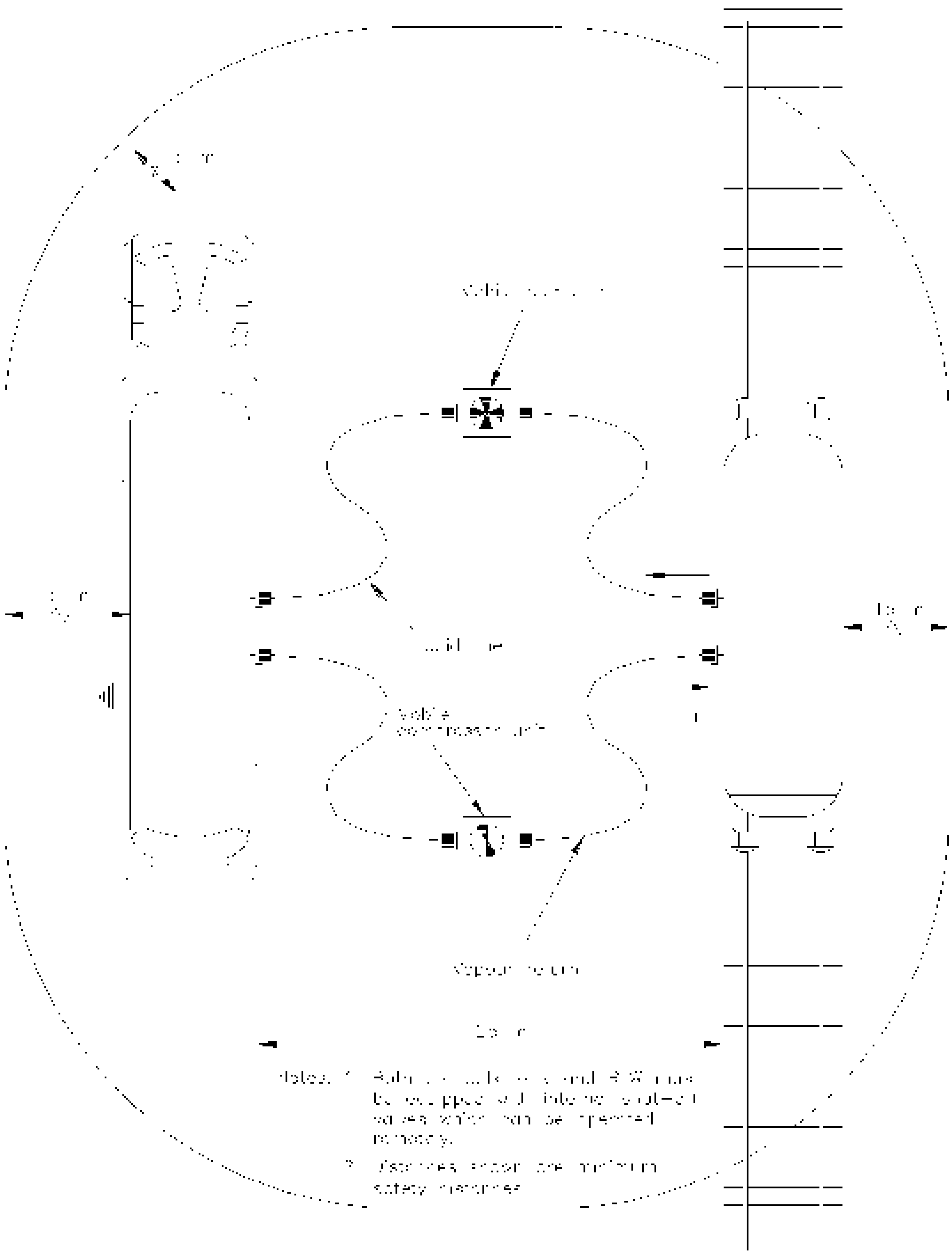


Figure 14 Diagrammatic tanker loading arrangement with vapour return

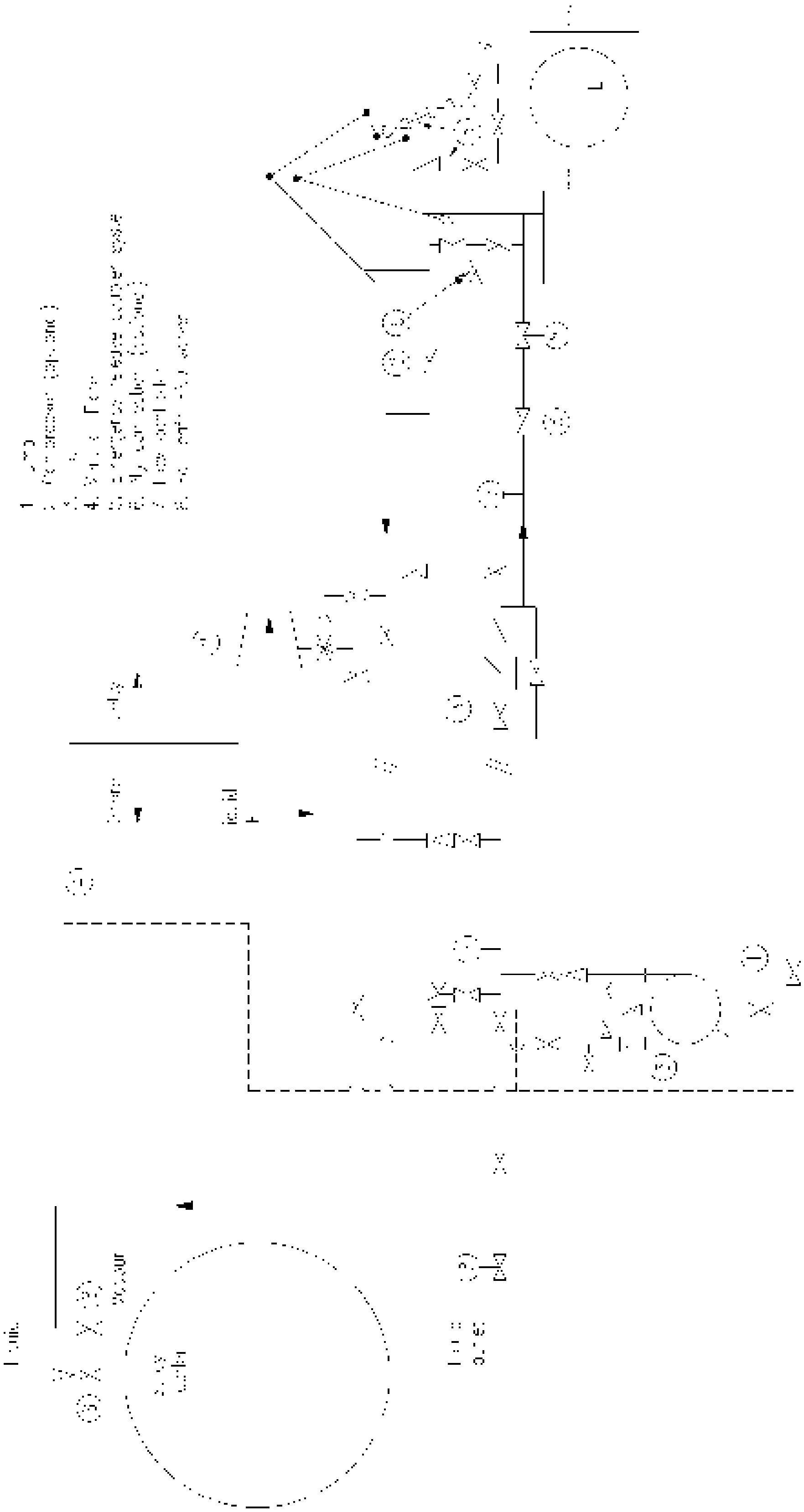


Figure 15 Diagrammatic tanker discharge arrangement using shore-based compressor

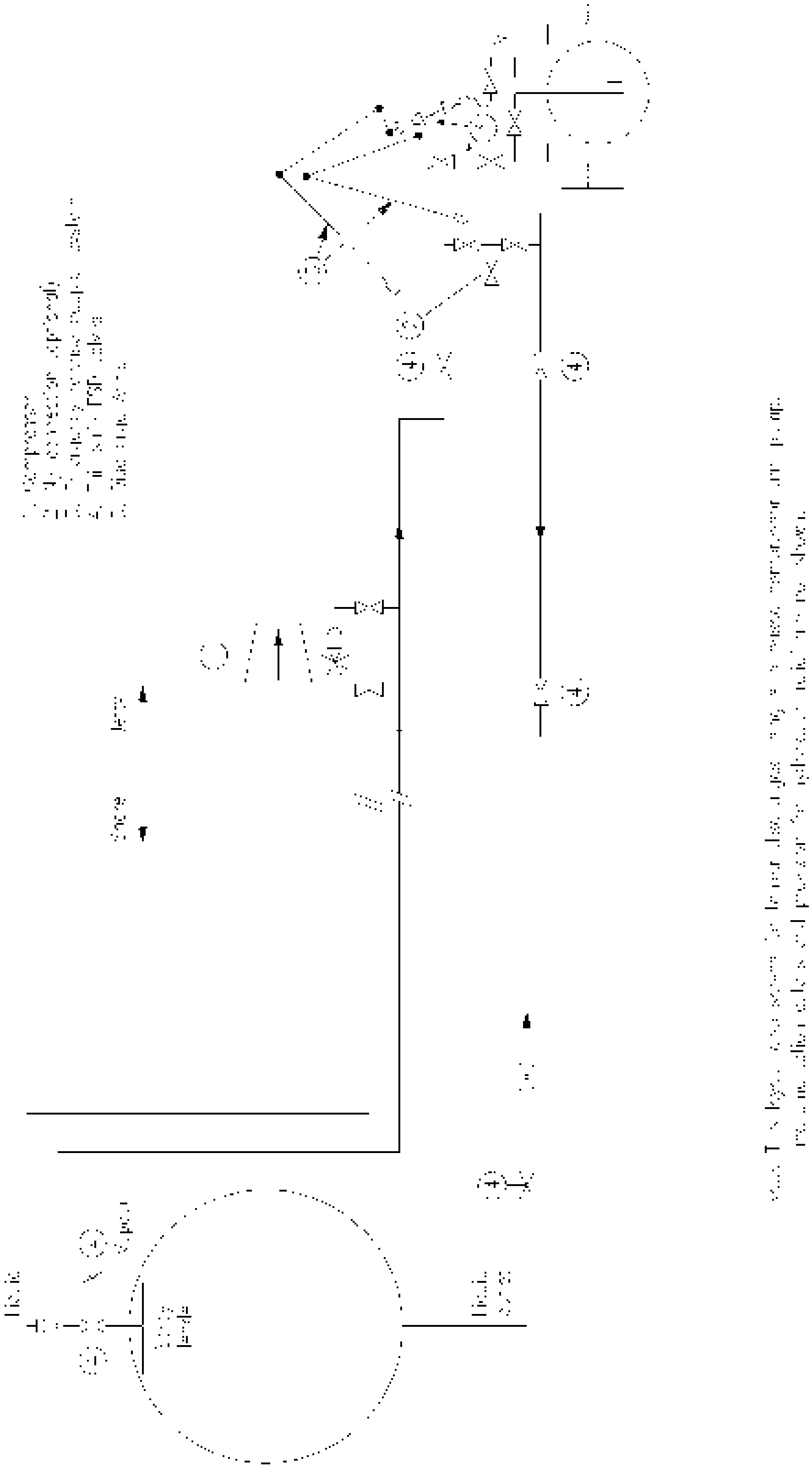


Figure 16 Responses to emergency situations - Marine

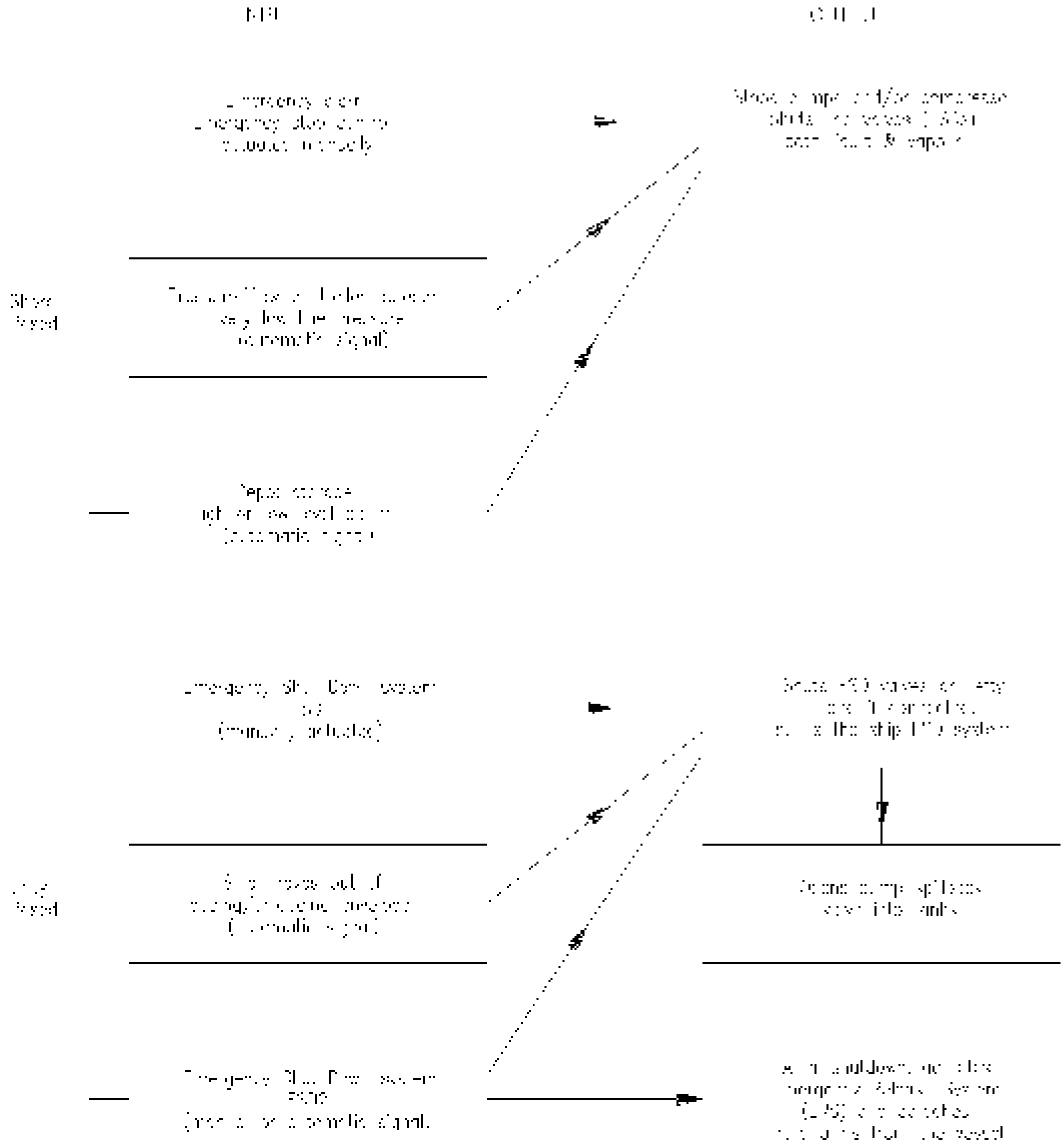
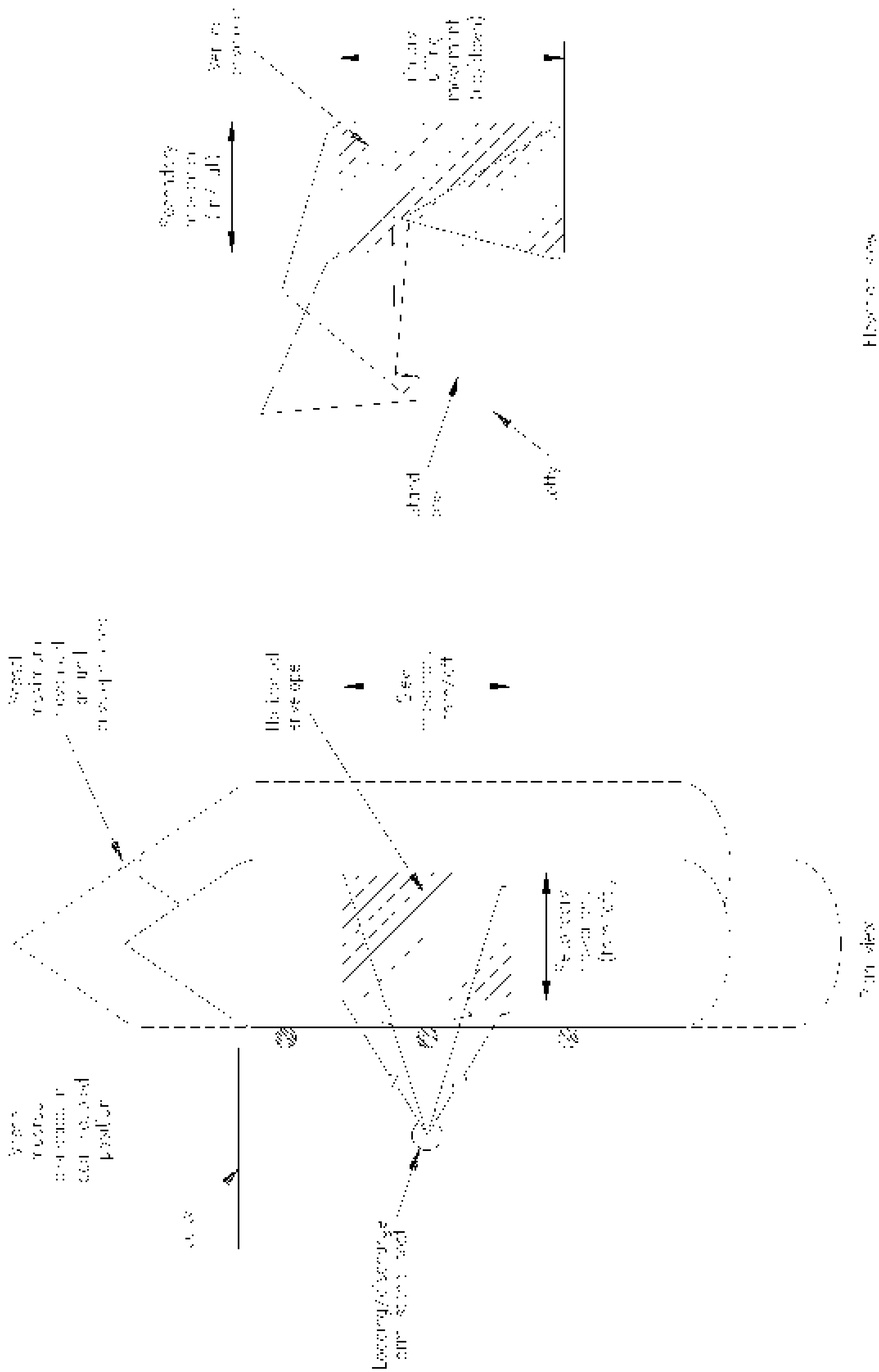


Figure 17 Marine loading arms - Operating envelopes



APPENDIX 3 METHOD OF ESTABLISHING THE DIFFERENTIAL PRESSURE REQUIRED FOR A BULK ROAD VEHICLE PUMP

Table A1 Pressure decrease in vessels being discharged - no vapour return - propane

Initial Product Temperature (°C)	Percentage of volume discharged			
	25%	50%	75%	100%
	Pressure drop (bar)			
38	0.58	1.29	2.38	5.30
21	0.30	0.69	1.26	2.75
4.5	0.14	0.29	0.64	1.46

Table A2 Back-pressure build-up in vessels being filled

Product	Initial temperature (°C)	Back-pressure bar (ga)	
		Filling into Vapour Space	Filling into Liquid
Propane	38	2.14	8.60
	21	1.17	4.66
	4.5	0.61	2.45
	-12	0.28	1.12
	-29	0.11	0.44
Butane	38	0.26	1.04
	21	0.12	0.50
	4.5	0.06	0.21

Table A3 Resistance to flow of average LPG meters

Delivery Rate (litres/minute)	Nominal diameter and delivery rate		
	32 mm 20 - 110 l/min	40 mm 50 - 225 l/min	50 mm 73 - 300 l/min
	Pressure drop (bar)		
38	0.034	*	*
76	0.097	0.076	0.020
114	0.210	0.170	0.055
151	*	0.280	0.080
189	*	0.430	0.120
227	*	0.620	0.180
265	*	*	0.255
303	*	*	0.340
341	*	*	0.430
379	*	*	0.540

* = Do not use

Table A4 Resistance to flow of average globe valves

Delivery rate (litres/minute)	Nominal diameter (mm)					
	15	20	25	32	40	50
	Pressure drop (bar)					
38	0.11	0	0	0	0	0
76	0.44	0.14	0.08	0	0	0
114	1.00	0.31	0.19	0.07	0	0
151	1.77	0.54	0.30	0.13	0	0
189	2.76	0.83	0.46	0.20	0.07	0
227	3.97	1.10	0.66	0.28	0.10	0
265	*	1.45	0.90	0.36	0.14	0.07
303	*	1.93	1.14	0.46	0.17	0.09
341	*	2.41	1.45	0.57	0.22	0.10
379	*	3.24	1.72	0.70	0.28	0.14

***** = Pressure drop too high

Table A5 Resistance to flow of 15-metre lengths of delivery hoses

Delivery rate (litres/minute)	Nominal diameter (mm)					
	15	20	25	32	40	50
	Pressure drop (bar)					
38	2.07	0.28	0.06	0.02	0.01	0
76	*	1.00	0.23	0.07	0.03	0.01
114	*	2.14	0.51	0.17	0.06	0.02
151	*	3.72	0.87	0.29	0.11	0.03
189	*	*	1.31	0.44	0.17	0.04
227	*	*	1.82	0.62	0.24	0.06
265	*	*	2.44	0.82	0.32	0.08
303	*	*	3.19	1.07	0.41	0.10
341	*	*	3.90	1.31	0.51	0.12
379	*	*	4.81	1.61	0.61	0.15

***** = Pressure drop too high

Table A6 Resistance to flow of tank filler valves

Delivery Rate (litres/minute)	Nominal diameter (mm)	
	20	32
	Pressure drop (bar)	
38	0.17	0.02
76	0.70	0.08
114	1.55	0.17
151	2.76	0.30
189	4.31	0.48
227	*	0.69
265	*	0.94
303	*	1.23
341	*	1.53
379	*	1.92

***** = Pressure drop too high

Example:

Delivery rate: 227 litres/minute

Product: Commercial Propane

Ambient/product temperature: 21 °C

Receiving vessel: filling into vapour space

No vapour return line used

Bulk road vehicle does a complete drop in one operation

Pressure drop through 50 mm diameter meter	:	0.18 bar
Pressure drop through 50 mm diameter globe valve	:	Negligible
Pressure drop through 32 mm diameter globe valve	:	0.28
Pressure drop through 32 mm diameter filler valve	:	0.69
Pressure drop through 15 m of 32 mm diameter hose	:	0.62
Back-pressure build-up in tank being filled	:	1.17
Drop in pressure tank being discharged	:	2.75
TOTAL	:	5.69 bar

The total differential pressure head varies considerably with product temperature because of the significant effect of the pressure build-up in the vessel being filled and the pressure drop in the vehicle's vessel, both of which are affected by the temperature of the product (see Tables A1 and A2).

For example, if the temperature was 38 °C instead of 21 °C the differential pressure would rise to 9.21 bar.

APPENDIX 4 CLASSIFICATION OF COUNTRIES INTO CLIMATIC AREAS IN RELATION TO OBSERVED MAXIMUM SHADE TEMPERATURES

Source: BS 5355. The maximum shade temperatures are quoted for guidance only, as in many areas they may be somewhat higher than the maximum temperature experienced.

Values marked ***** are assumed, by relation to adjacent countries, in the absence of data for the country in question.

Values marked **^** are the recorded maximum for the country but due to relative insufficiency of observations and the proximity of high recorded maxima in bordering countries, the classification has been raised to avoid anomaly.

Class 1: Maximum shade temperatures less than or equal to 35 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
American Samoa	34	Mauritius	35
Antarctica	6	Nauru	35
Ascension	35	New Hebrides	34.5
Azores	31	Norway	35
Barbados	35	Peru	34
Bhutan	31.5 *****	Pitcairn Is	34
Cape Verde Is	34.5	Puerto Rico	34.5
Channel Is	34	Reunion	29
Costa Rica	33.5	St Helena	34
Denmark	35	Sao Tome and Principle Is	33
Easter Is	31	Seychelles & dependencies	33.5
Falkland Is	29	Sikkim	25 *****
Fernando Po	33	Society Is	35
Greenland	30	S Georgia	29
St Pierre and Miquelon	28	Spitzbergen	15.5
Guam	34.5	Sweden	34.5
Guatemala	33	Tibet	31.5
Hawaii	32	Tokelau Is	35
Iceland	30.5	Tristan Da Cunha	24
Irish Republic	30.5	United Kingdom	35
Mariana Is	34.5	Western Samoa	34

Class 2: Maximum shade temperatures above 35 °C and less than 37.5 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
Andaman and Nicobar Is	36.5	Jamaica	36
Antigua	36.5	Laccadive, Minicoy and Admindivi Is	37
Aruba	35.5 *		
Bahamas	35.5	Leeward Is	36.5
Bermuda	37	Malaysia	37
Belize	36	Maldives Is	36.5
Bonaire	35.5 *	Marshall Is	36.5
Canton Is	35.5 *	Martinique	35.5
Caroline Is	36.5	Montserrat	36.5
Cayman Is	36 *	Nepal	36
Chile	37	Netherlands Antillies	35.5
Christmas Is	36.5 *	New Caledonia	37
Colombia	36	New Zealand	36.5
Cook Is	35.5	Nicaragua	36 *
Cuba	35.5	Niue Is	36.5
Curacao	35.5	Panama	36
Dominica	36	Panama Canal	36
Dominican Republic	36.5	Poland	36.5
Ecuador	36.5	St Christopher, Nevis, Anguilla	36.5
Fiji Is	36.5	St Vincent	36 *
Finland	36	St Lucia	36
French Guyana	36	Singapore	36
Galapagos Is	35.5 *	Solomon Is	35.5
Gilbert & Ellis Is	35.5	Surinam	37
Grenada	35.5 *	Tonga Is	36.5
Guadeloupe	36	Turks and Cacos	35.5
Guyana	37	Virgin Is (UK)	36.5 *
Haiti	36.5	Virgin Is (USA)	36.5 *
Honduras	36	Windward Is	36.5 *
Hong Kong	36		

Class 3: Maximum shade temperatures equal to or greater than 37.5 °C and less than 42.5 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
Alaska	37.5	Liechtenstein	38.5 *
Austria	37.5	Luxembourg	37
Belgium	38.5	Madeira	39.5
Bolivia	38.5	Malta	40.5
Brazil	42	Mongolia	38.5
Burundi	35.5 ^	Netherlands	37.5
Canada	42	New Guinea	39
Comoros Is	37.5	Papua	39 *
Congolese Rep	39.5	Philippines	40.5
Czechoslovakia	37.5	Rumania	40.5
El Salvador	40.5	Rwanda	35.5 ^
Gabon	38.5	Sierra Leone	39
Gambia	41.0	Sri Lanka	40
Germany	39.5	Switzerland	39
Gibraltar	38.5	Taiwan	38.5
Guinea Bissau	41	Tanzania	39
Hungary	39.5	Thailand	42
Indonesia	39	Timor	38.5
Ivory Coast	41	Trinidad and Tobago	38.5
Japan	39	Uganda	39.5
Kenya	40.5	Venezuela	40
Korea	39.5	Zaire	41
Liberia	40.5		

Class 4: Maximum shade temperatures equal to or greater than 42.5 °C and less than 47.5 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
Albania	36.5 **^**	Lebanon	41.5 **^**
Andorra	34 **^**	Lesotho	44.5
Angola	43	Malawi	44
Argentina	46.5	Monaco	34 **^**
Bahrain	45	Mexico	47
Balearic Is	40 **^**	Namibia	42 **^**
Bangladesh	44 *****	Nigeria	47
Benin	45	Oman	47
Botswana	44	Paraguay	44
Bulgaria	43.5	Portugal	45.5
Burma	44	Qatar	45 *****
Cameroon	45.5	San Marino	45.5 *****
Canary Is	43	Senegal	47
Central African Republic	47	Somalia	47
China	46	S Africa	44.5
Corsica	39.5 **^**	S Yemen	41 **^**
Cyprus	46.5	Spain	47
Djibouti	47	Swaziland	37 **^**
Ethiopia	46	Syria	47
Equatorial Guinea	45.5 *****	Togo	45 *****
France	44	Turkey	46
Ghana	43	USSR (former)	45
Greece	45.5	Uruguay	43
Guinea	43	Vietnam	43
Israel	46.5	Yemen	41 **^**
Italy	45.5	Yugoslavia	42 **^**
Jordan	43	Zambia	44.5
Kampuchea	40 *****	Zimbabwe	45.5
Laos	45 *****		

Class 5: Maximum shade temperatures equal to or greater than 47.5 °C and less than 52.5 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
Afghanistan	44 **^**	Mali	49 *****
Australia	51.5	Mauritania	49
Burkina Faso	48	Mozambique	49
India	49.5	Morocco	48
Iran	50.5	Niger	46.5 **^**
Iraq	51.5	Saudi Arabia	48.5
Kuwait	48.5	United Arab Emirates	48.5
Malagasy Republic	48.5		

Class 6: Maximum shade temperatures equal to or greater than 52.5 °C

Country	Maximum shade temperature °C	Country	Maximum shade temperature °C
Algeria	53	Pakistan	53
Chad	49.5 **^**	Sudan	53
Egypt	51 **^**	Tunisia	55
Libya	58	USA	56.5