

DEP SPECIFICATION

FULL CONTAINMENT REFRIGERATED LPG TANKS

DEP 34.51.01.34-Gen.

February 2012

DESIGN AND ENGINEERING PRACTICE

DEM1



© 2012 Shell Group of companies
All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, published or transmitted, in any form or by any means, without the prior written permission of the copyright owner or Shell Global Solutions International BV.

PREFACE

DEP (Design and Engineering Practice) publications reflect the views, at the time of publication, of Shell Global Solutions International B.V. (Shell GSI) and, in some cases, of other Shell Companies.

These views are based on the experience acquired during involvement with the design, construction, operation and maintenance of processing units and facilities. Where deemed appropriate DEPs are based on, or reference international, regional, national and industry standards.

The objective is to set the standard for good design and engineering practice to be applied by Shell companies in oil and gas production, oil refining, gas handling, gasification, chemical processing, or any other such facility, and thereby to help achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to Shell companies 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 Units 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 such use, including the quality of their work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will typically expect them to follow those design and engineering practices that will achieve at least 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.

The right to obtain and to use DEPs is restricted, and is granted by Shell GSI (and in some cases by other Shell Companies) under a Service Agreement or a License Agreement. This right is granted primarily to Shell companies and other companies receiving technical advice and services from Shell GSI or another Shell Company. Consequently, three categories of users of DEPs can be distinguished:

- 1) Operating Units having a Service Agreement with Shell GSI or another Shell Company. The use of DEPs by these Operating Units is subject in all respects to the terms and conditions of the relevant Service Agreement.
- 2) Other parties who are authorised to use DEPs subject to appropriate contractual arrangements (whether as part of a Service Agreement or otherwise).
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) or 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, Shell GSI disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any DEP, combination of DEPs or any part thereof, even if it is wholly or partly caused by negligence on the part of Shell GSI or other Shell Company. The benefit of this disclaimer shall inure in all respects to Shell GSI and/or any Shell Company, or companies affiliated to these companies, that may issue DEPs or advise or require the use of DEPs.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, DEPs shall not, without the prior written consent of Shell GSI, be disclosed by users to any company or person whomsoever and the DEPs shall be used exclusively for the purpose for which they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of Shell GSI. The copyright of DEPs vests in Shell Group of companies. Users shall arrange for DEPs to be held in safe custody and Shell GSI may at any time require information satisfactory to them in order to ascertain how users implement this requirement.

All administrative queries should be directed to the DEP Administrator in Shell GSI.

TABLE OF CONTENTS

1.	INTRODUCTION	6
1.1	SCOPE.....	6
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	6
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	7
1.5	COMMENTS ON THIS DEP	7
1.6	DUAL UNITS.....	7
2.	GENERAL.....	8
2.1	DESCRIPTION OF THE TANK	8
2.2	TECHNICAL SCOPE INCLUSIONS	8
2.3	CODES AND INDUSTRY STANDARDS.....	9
3.	FOUNDATIONS, PAVING AND DRAINAGE.....	10
3.1	SOIL INVESTIGATIONS.....	10
3.2	FOUNDATIONS.....	10
4.	DESIGN CONSIDERATIONS.....	11
4.1	GENERAL	11
4.2	CONSTRUCTION LOADING.....	11
4.3	WIND LOADS AND SNOW LOADS	11
4.4	EARTHQUAKE (OBE and SSE).....	11
4.5	HEAT LEAK	13
4.6	HAZARD DESIGN CONDITIONS.....	13
5.	CONCRETE COMPONENTS	15
5.1	GENERAL	15
5.2	DESIGN STANDARD	16
5.3	ANALYSIS REQUIREMENTS	16
5.4	LIMIT STATE CHECK AND MINIMUM REQUIREMENTS	18
5.5	LOAD COMBINATIONS	19
6.	METALLIC COMPONENTS	22
6.1	GENERAL	22
6.2	INNER TANK	22
6.3	LINERS (VAPOUR BARRIER)	22
6.4	SUSPENDED DECK.....	24
6.5	TANK INTERNAL AND EXTERNAL PIPING.....	24
6.6	STRUCTURAL STEEL	26
7.	MATERIAL REQUIREMENTS	27
7.1	CONCRETE TANK	27
7.2	INNER TANK	28
7.3	WELDING CONSUMABLES.....	29
7.4	IMPACT TESTING REQUIREMENTS.....	29
7.5	VAPOUR BARRIERS, BOTTOM, WALL AND ROOF	29
7.6	SUSPENDED DECK.....	30
8.	MANUFACTURE AND CONSTRUCTION	31
8.1	STEEL COMPONENTS.....	31
8.2	CONCRETE COMPONENTS	36
9.	INSULATION SYSTEMS.....	39
9.1	GENERAL	39
9.2	BOTTOM INSULATION	39
9.3	WALL INSULATION.....	40
9.4	INSULATION MATERIAL HANDLING AND STORAGE	42
10.	INSTRUMENTATION	43
10.1	GENERAL	43
10.2	COOLDOWN SENSORS.....	43
10.3	INNER TANK LEAK DETECTION SYSTEM	44

10.4	THERMAL SENSORS FOR HEATING SYSTEM	44
10.5	LIQUID LEVEL INSTRUMENTS.....	45
10.6	LIQUID STRATIFICATION MONITORS.....	46
10.7	FIRE AND GAS DETECTION SYSTEM.....	46
10.8	FLAMMABLE GAS DETECTION.....	46
10.9	FIRE DETECTORS.....	46
10.10	MANUAL CALL POINTS.....	47
10.11	CCTV CAMERAS	47
10.12	PA/GA SYSTEMS.....	47
10.13	WATER MONITORS.....	47
10.14	PRESSURE RELIEF PROTECTION.....	47
10.15	INSTRUMENT CONNECTIONS.....	48
10.16	INSTRUMENT WIRING AND ELECTRICAL WIRING.	48
11.	ELECTRICAL	49
11.1	GENERAL.....	49
11.2	PUMP ELECTRICAL INSTALLATION/HOOKUP	49
11.3	LIGHTING	49
11.4	EARTHING AND BONDING.....	50
11.5	LIGHTNING PROTECTION.....	50
11.6	AIRCRAFT WARNING LIGHTS	50
11.7	BASE SLAB HEATING SYSTEM	50
11.8	CABLING, WIRING AND ACCESSORIES.....	51
11.9	ELECTROMAGNETIC COMPATIBILITY (EMC).....	52
11.10	FLAMEPROOF EQUIPMENT.....	52
11.11	INSTALLATION AND COMMISSIONING.....	52
12.	PRESSURE AND VACUUM RELIEF SYSTEMS	53
12.1	GENERAL.....	53
12.2	PRESSURE RELIEF VALVES.....	53
12.3	RESERVE CAPACITY RELIEF VALVES	53
12.4	VACUUM RELIEF VALVES.....	53
13.	ACCESSORIES.....	55
13.1	ROOF PLATFORM	55
13.2	ACCESS TO PLATFORM AND ROOF	55
13.3	CRANES/HOISTS.....	56
13.4	MONORAILS	56
14.	PAINTING AND COATING	57
14.1	INNER TANK STEEL PLATES.....	57
14.2	METALLIC VAPOUR BARRIER	57
14.3	STRUCTURAL STEEL	57
15.	TESTING AND CALIBRATION.....	58
15.1	HYDROSTATIC TESTING OF INNER TANK.....	58
15.2	TESTING MEDIUMS	58
15.3	HYDROSTATIC/PNEUMATIC TESTING OF PUMP WELLS	59
15.4	PRESSURE AND VACUUM TESTING	59
15.5	CALIBRATION	59
16.	SETTLEMENT MONITORING.....	60
16.1	SURVEY MARKERS	60
16.2	INCLINOMETERS	60
17.	PRE-COMMISSIONING	61
17.1	DRYING AND INERTING	61
17.2	COOLDOWN	61
18.	COMMISSIONING-GENERAL	62
19.	REFERENCES	63

APPENDICES

APPENDIX A	FIRE SCENARIOS	68
APPENDIX B	ULTRASONIC INSPECTION	69
APPENDIX C	SPECIFICATION FOR PUF INSULATION SYSTEM	71
APPENDIX D	FULL SCALE TRIALS AND MOCK UPS	81
APPENDIX E	CONSTRUCTION TOLERANCES CONCRETE STRUCTURES	83

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the design, supply, fabrication, construction, inspection, testing, purging, cooling-down and commissioning of above ground refrigerated propane and butane tanks.

All requirements shall be applicable to both propane and butane, unless otherwise specified.

This DEP contains mandatory requirements to mitigate process safety risks in accordance with Design Engineering Manual DEM 1 – Application of Technical Standards.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by Shell GSI, the distribution of this DEP is confined to Shell companies and, where necessary, to Contractors and Manufacturers/Suppliers nominated by them. Any authorised access to DEPs does not for that reason constitute an authorisation to any documents, data or information to which the DEPs may refer.

This DEP is intended for use in facilities related to oil and gas production, gas handling, oil refining, chemical processing, gasification, distribution and supply/marketing. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process shall be implemented; this is of particular importance when existing facilities are to be modified.

If national and/or local regulations exist in which some of the requirements could 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 with regards to the safety, environmental, economic and legal aspects. In all cases, the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned, the objective being to obtain agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party that 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 that manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party that initiates the project and ultimately pays for it. 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 capitalised term **SHALL [PS]** indicates a process safety requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Term	Definition
AGA	American Gas Association
ALARP	As Low As Reasonably Practicable
CCR	Central Control Room
DCS	Distributed Control System

Term	Definition
EPC	Engineering Procurement and Construction
HAZ	Heat-Affected Zone
LPG	Liquefied Petroleum Gas
OBE	Operating Base Earthquake. See EN 1473.
PAS	Process Automation System (combination of SIS, DCS and other systems)
PLC	Programmable Logic Controller
PRV	Pressure Relief Valves
RCRV	Reserve Capacity Relief Valves
SIS	Safety Instrumented System
SLS	Serviceability Limit State
SRSS	Square Root Sum of the Squares
SSE	Safe Shutdown Earthquake, See EN 1473.
TMS	Tank Monitoring System
TPI	Third Party Inspection
ULS	Ultimate Limit State
VCE	Vapour Cloud Explosion
WPQ	Welding Procedure Qualification
WPQR	Welding Procedure Qualification Record
WPS	Welding Procedure Specification
XLPE	Cross Linked Polyethylene.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets (). Other documents referenced by this DEP are listed in (19).

1.5 COMMENTS ON THIS DEP

Comments on this DEP may be sent to the Administrator at standards@shell.com, using the DEP Feedback Form. The DEP Feedback Form can be found on the main page of "DEPs on the Web", available through the Global Technical Standards web portal <http://www.shell.com/standards> and on the main page of the DEPs DVD-ROM.

1.6 DUAL UNITS

This DEP contains both the International System (SI) units, as well as the corresponding US Customary (USC) units, which are given following the SI units in brackets. When agreed by the Principal, the indicated USC values/units may be used.

2. GENERAL

2.1 DESCRIPTION OF THE TANK

The Tank(s) SHALL [PS] be as per the "Full Containment" concept specified in EN 14620 and the requirements of this DEP.

The Full Containment Tank(s) (FCT) SHALL [PS] comprise a liquid tight inner steel tank and a liquid and vapour tight concrete outer tank, both capable of independently containing the stored product.

The inner and outer tanks shall be as per EN 14620 and the requirements of this DEP and associated datasheets.

The roof and base of the outer tank SHALL [PS] be of reinforced concrete whilst the walls SHALL [PS] be post tensioned in both horizontal and vertical directions.

The tanks SHALL [PS] be designed and constructed such that:

- a) In normal service:
 - Accumulation of product in the interspace shall not occur.
 - Vapour tightness of the secondary container is achieved through the incorporation of a metallic vapour barrier to the walls, roof and base.
- b) In upset or emergency conditions where product accumulates in the interspace (the zone between the inner and outer tank):
 - The outer tank and secondary bottom contains the liquid product and prevents leakage.
 - Product losses due to outer container permeability are acceptable (under these conditions and determination of absolute rates is not required).
 - Controlled venting of the product vapour is permitted.

2.2 TECHNICAL SCOPE INCLUSIONS

The Contractor shall design, procure, install and construct the following:

- a) The foundation, including soil improvement, deep foundations (or otherwise).
- b) A reinforced concrete base slab with under tank heating system, designed to prevent frost heave and support the inner tank, outer tank and appurtenances.
- c) An open topped inner steel tank designed and constructed in accordance with EN 14620 (without anchor straps). Material specifications shall be as stated in this DEP.
- d) A concrete secondary outer container consisting of a post tensioned concrete wall rigidly connected to the outer tank concrete bottom slab and a roof constructed of reinforced concrete. The inside of the secondary container shall be lined with a carbon steel vapour barrier.
- e) A steel roof liner which forms an integral structure with the reinforced concrete roof.
- f) A flat plate suspended inner deck constructed of aluminium, stainless steel, improved toughness steel supported by hangers from the steel roof structural members.
- g) A tank insulation system including insulation located between the inner tank and outer tank bottoms; insulation on top of the suspended deck and PUF applied to the outer tank walls.
- h) Columns for the installation of submerged product pumps.
- i) Platform, staircase, stairs, walkways, caged ladders, monorails, cranes, handrails, etc.

- j) Instrumentation for level, pressure and temperature recording, leak/gas detection, and cool-down control, and any other instrumentation specified for supply by the Contractor.
- k) Pressure relief and vacuum relief valves for protection.
- l) A fire detection and control system for the relief valves.
- m) Design, installation, NDE and testing of all pipe work and pipe work insulation associated with the tank to the Battery Limit.

The Contractor shall model and design the piping systems within his scope and determine loads that the pipe supports should accommodate. The Contractor shall consult with the Principal on surge and slug design considerations when establishing piping system anchor point requirements within the battery limit. Battery Limit shall be defined in the contract documentation.

All piping within the tank, on the tank roof and wall is within the Contractor's Battery Limit. Piping termination points and battery limits shall be identified within interface documentation.

Submerged pumps shall be designed, supplied and installed by the tank Contractor and conform to DEP requirements.

For the pump power cables, the Contractor shall supply and install the cables from grade to a Junction Box (JB or JB's) at the top of the Pump wells. For other electrical items, the Contractor shall supply, detail, locate, and install all electrical components or equipment in or on the tank, and between the tank and the nearest JB, Substation, or Auxiliary Room as designated for each component.

Contractor shall design, supply and install:

- The base slab heating system including all associated control and protective devices.
- Lighting, earthing and lightning protection systems on and around the tank area.
- Electrical equipment and devices for MOV's, and any installed crane.

The Contractor shall supply, detail, locate, and install all instrumentation and its associated wiring and components which are in or on the tank, and from the tank to the nearest JB or designated termination point for each component.

All trays, racks, supports, etc. for the electrical and instrumentation are within the scope of the Contractor when in or on the tank or tank wall, but for cabling exiting the tank area, the Contractor (if required) will utilise cabling trays supplied and installed by others.

The Contractor shall design, furnish, and install external pipe work and insulation materials for external pipe work within the Contractor's Battery Limit and any special support components and any non-standard insulation materials required at any pipe support or guide.

Inspection by an independent subcontracted inspection agency for all shop fabricated sub components may be used. The qualifications of all inspectors shall be acceptable to the Principal.

2.3 CODES AND INDUSTRY STANDARDS

A detailed list of applicable codes and standards is included in (19). All codes and standards shall be the latest edition, including revision, addenda, supplements.

3. FOUNDATIONS, PAVING AND DRAINAGE

3.1 SOIL INVESTIGATIONS

Soil investigations for the tank site shall be conducted to establish ground characteristics and variability of the underlying strata. Factual reports based on these investigations shall be made available to the Contractor.

The Contractor shall review the factual reports and verify that the data available is sufficient for his design and construction purposes. If the Contractor requires additional information on ground conditions, including ground improvement, then the Contractor shall carry out the additional work at his own expense.

The final interpretation of the factual data provided to the Contractor and the factual data obtained by the Contractor shall be the Contractor's sole responsibility.

3.2 FOUNDATIONS

The Contractor shall design and build the tank foundation in such a way that, during all stages of the tanks' lifetime (construction phases, hydrotest, operation phases and all emergency situations):

- All credible combinations of loads are safely transferred to the subsoil;
- Deformations (differential) along any line in radial or circumferential direction are within acceptable limits from a structural and tank operational point of view. (In the absence of deformation limits being specified in the factual report, limits specified in BS 7777-3, Table 3 may be used).

The tank foundation shall be designed such that drainage is provided for removal of ground and rainwater.

The Contractor shall select and optimise the foundation concept based on the content of the interpretive geotechnical report. Due consideration shall be given to the potential liquefaction of the soil in accordance with the requirements of DEP 34.11.00.12-Gen.

4. DESIGN CONSIDERATIONS

4.1 GENERAL

The inner and outer tank shall be designed for all specified loading conditions/combinations which may occur during construction, testing, commissioning, operation, de-commissioning, and maintenance of the tank.

The following specific design loading shall be taken into account:

- Full hydrotest of the inner tank as specified in EN14620-5.
- Normal operation of the tank containing LPG at Maximum Normal Operating Liquid Level (Max. NOL).
- OBE and SSE Earthquake as per Tank Datasheets.
- Predicted maximum differential centre to edge settlements of the concrete bottom slab based on interpretation of the geotechnical data. The design shall allow for total differential settlement through construction, hydro-testing and operational lifetime.

Where piles are included in the design, the tank aspect ratio shall be selected so as to avoid tension in all piles under normal, OBE and SSE conditions.

4.2 CONSTRUCTION LOADING

The roof liner may be used as formwork for the construction of the concrete roof. Internal air pressure may be utilised to offset the structural demands of fresh concrete during temporary load combinations.

Load and material variability factors shall reflect the temporary nature of the load and ability to control the placement and thickness of the concrete.

4.3 WIND LOADS AND SNOW LOADS

The outer tank and associated structural components shall be designed to withstand the basic wind speed stated in the Tank Datasheet. Design wind speed and wind loads shall be calculated from this basic value in accordance with EN 1991-1-4.

Snow loads shall be as per the Tank Datasheet.

4.4 EARTHQUAKE (OBE and SSE)

Seismic design of the inner and outer tank shall be in accordance with the requirements of EN 14620 respectively and the following additional requirements/amendments.

The inner and outer tanks shall be designed for two levels of seismic ground motion, the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE). Return periods for OBE and SSE events and spectral construction shall be as per requirements of EN14620-1 (§7.3.2.2.13, §7.3.3.3) and as stated in the Tank Datasheets.

The OBE ground motion shall be the motion represented by 5% damped response spectra having a 10% probability of being exceeded within a 50 year return period (mean recurrence interval of 475 years).

The SSE ground motion shall be the motion represented by a 5% damped acceleration response spectrum having a 1% probability of exceedance within a 50 year period (mean recurrence interval of 4975 years).

The complete tank system shall be designed so as to:

- Be re-operable after an OBE event and all components including piping, structures, attachments and appurtenances shall be designed so as to remain essentially elastic. In this regard force reduction (ductility) shall not be permitted under the OBE event.
- Survive the SSE event. In this regard, ductility is permitted as per code

requirements based on the structural classification for all structural and non structural components and attachments. Where ductility is adopted for the outer tank design including roof, wall and (where provided) piles, a detailed pushover analysis shall be undertaken to demonstrate/validate the force reduction factor selected.

In accordance with EN 14620-1 (§7.3.3.3), the spectral acceleration of the SSE response spectrum shall not exceed twice the corresponding OBE spectral accelerations.

The inner tank shall be designed for the OBE and SSE conditions while filled with LPG to the Maximum Design Liquid Level (MDLL). The outer tank shall be designed to contain 100% of the gross volume pertaining to the MDLL while subjected to an OBE event.

The outer tank shall be designed using dynamic lateral force procedures with due consideration of the affects of the inner tank, outer tank and foundation interaction. Specific combinations of components may be modelled and analysed separately.

For structural appendages such as platforms, etc. an appropriate analysis shall be undertaken to assess the amplification/attenuation of motion seismic action to be applied.

Fixed period damping ratios for the inner, outer and fluid contents shall be as per Table 1.

Table 1 Damping ratios

Component	Damping Factors in %	
	OBE	SSE
Steel	2.0	4.0
Horizontal Impulsive	2.0	5.0
Horizontal Convective	0.5	0.5
Vertical Flexible	2.0	5.0
Vertical Rigid ¹	0.0	0.0
Prestressed Concrete	2.0	5.0
Reinforced Concrete	4.0	7.0

NOTE: 1. The vertical rigid component is the motion portion of the liquid that moves in phase with the ground. It shall be assumed to be at the zero period acceleration. For the purposes of the analysis, it shall be taken as 33Hz.

Soil Structure Interaction (SSI) method (where used) shall conform to the requirements of EN 1998-4 A7. The effects of soil structure interaction (SSI) and settlement shall be analysed and the foundations, including piles (if used), should be designed, using a range of design soil profile parameters.

An acceptable method to account for uncertainties in SSI analysis is to vary the low strain soil shear modulus. Low strain soil shear modulus should be varied between the best estimate value times $(1 + C_v)$ and the best estimate value divided by $(1 + C_v)$, where C_v is a factor that accounts for the uncertainties in the analysis and soil properties. If sufficient and adequate soil investigation data are available, the mean and standard deviation of the low strain shear modulus should be established for every soil layer. The C_v should then be established so that it covers the mean $\pm$ one standard deviation for every layer. The minimum value of C_v should be 0.5. When insufficient data are available to address uncertainties in soil properties, C_v should be taken as no less than 1.0.

Maximum modal damping shall be limited to 15% and 20%, respectively, for the OBE and SSE horizontal modes. The Contractor shall propose modelling methodology and ranges of dynamic impedances used within analysis for review by Principal.

The horizontal and vertical response spectra for both the OBE and SSE shall be input to the model as acceleration spectra. The responses of the composite tank structure for each

mode shape shall be determined from the appropriate response spectrum, modal frequency and composite damping.

For the outer tank individual modes (for a given excitation direction) shall be combined using the "Square Root Sum of the Squares" (SRSS) method. The total seismic demand shall be determined using a 40% spatial combination and be the maximum of:

- 100% horizontal + 40% vertical
- 40% horizontal + 100% vertical

For the inner tank, the impulsive and convective components shall be combined using the absolute sum methods (for a given excitation direction). The total seismic demand shall be determined using a 40% spatial combination as per the above.

4.5 HEAT LEAK

The total heat-in leak shall be such that the boil-off rate will not exceed the percentage (as stated in the Tank Datasheets) of the gross tank contents per day. Boil-off calculations shall be based on the following information listed in the Datasheets;

- 95th percentile ambient air temperature.
- 5th percentile wind speed.
- 90% Relative Humidity
- Solar radiation as per Tank Datasheet

The Contractor shall make allowances for heat gain from pumps, stilling wells and appurtenances.

For exposed surfaces during a period of 12 h, global solar radiation shall be taken into account. Thermal inertia of the concrete outer tank may be considered for the effect of solar radiation on boil-off rate. The Contractor shall provide calculations during the detailed engineering phase demonstrating that the insulation fulfils the heat in-leak requirements.

4.6 HAZARD DESIGN CONDITIONS

4.6.1 LPG spill protection

No specific provisions for spill collection are required.

4.6.2 Fire exposure

The outer tank roof and side walls shall be capable of withstanding fire exposure and heat radiation from the following relief valve discharge fires:

- A single PRV fire by ignition of vapour relieved as a result of a failed pilot system. It is assumed that remedial action to stop a single PRV fire can be taken within 2 hours. The heat radiation shall be determined based on the total design flow rate of a single PRV discharging through the tail pipe.
- Multiple PRV fires by ignition of vapour relieved as a result of upsets in operation. It is assumed that the fire can be stopped by operational action within 10 minutes.

Main steel structural members, located on LPG tank roof, supporting vital equipment shall be protected both for fire and for cold splash

Requirements for the fire cases are included in (Appendix A).

4.6.3 LPG major leak

The post-tensioned concrete tank wall and its connection to the base slab shall be designed to withstand the thermal affects of LPG in the annular space. All intermediate liquid levels shall be considered in conjunction with maximum design internal pressure.

It shall be demonstrated that no irreversible deformations or damage will take place on the secondary containment (concrete) following a major leak event and major leak + OBE.

4.6.4 Local cold spot

The effects of a local cold spot equal to 1 m (3.3 ft) diameter shall be considered on the walls.

4.6.5 Impact loads

The outer tank walls and roof shall be designed to withstand without spalling the impact of a 50 kg (110 lb) projectile travelling with a velocity 45 m/s (150 ft/s) impacting perpendicular to surface with an impact diameter 100 mm (4 in).

NOTE: Effects of missile impact may be analysed using the Winfrith Model as described by M.Y.H Bangash, Impact and Explosion, Blackwell, CRC Press 1993.

In order to account for uncertainty, the concrete elements shall be at least 20% thicker than the minimum thickness to prevent perforation or scabbing. Perforation thickness is defined as the thickness required to reduce the projectile velocity to zero, without impairing or damaging the inside surface of the outer tank (vapour barrier).

4.6.6 Blast loads

Blast load shall be applied to the tank and shall have a simplified pressure distribution on the tank wall, roof and platform, according to the distribution indicated in the Tank Datasheets. This loading shall be regarded as quasi-static with a dynamic load factor.

5. CONCRETE COMPONENTS

5.1 GENERAL

Thicknesses of the bottom slab, wall, and roof are to be selected by the Contractor to meet the performance requirements documented herein. The thickness of the wall shall be selected so that in normal operating conditions, the shear forces are absorbed by the wall without the need for shear reinforcement.

5.1.1 Tank base slab

Tank concrete base slab/foundation design shall incorporate the recommendations of the geotechnical report. Horizontal surfaces where rain water may accumulate shall be laid to a grade of 1:40 to enable generation of free draining surfaces.

Where a temporary construction joint is provided in the slab to allow for differential movement during construction, the same shall be closed after partial post-tensioning of the wall.

For the base slab to wall junction, 'kicker-less' construction shall be permitted provided the Contractor can demonstrate the ability to restrain and control the wall forms during pouring.

5.1.2 Tank wall

The wall shall be designed with monolithic connections between the base slab and wall and wall to roof.

All openings used for construction purposes shall be considered within the design and limited to a height of 4.0 m (13 ft) measured above the top of the base slab.

Vertical construction joints in the outer tank wall shall not be permitted above the construction openings, i.e., the outer tank wall be cast by complete 360° pours.

The Contractor shall determine the post-tensioning requirements, stressing sequence, location of temporary openings and methodology used to permanently seal the openings prior to pneumatic test of the outer tank. The analysis and design of the wall shall reflect the effects of reduced axial demands due to the construction sequence in the vicinity of the access opening. Pre-stressing of the wall shall be achieved with an impermeable duct and tendon system.

Mechanical couplers qualified for LPG service shall be used to connect rebar in the vicinity of the construction openings.

5.1.3 Tank roof

The roof shall be spherical in shape, and made of reinforced concrete with an interior carbon steel vapour barrier (liner). The roof radius shall be selected so as to enable concrete compaction without the use of a top shutter.

The roof liner including the compression ring shall be anchored into the concrete. The steel liner located on the inside of the roof may be used as formwork for concrete placement. The concrete may be poured in two layers to limit structural demands on the roof liner. The Contractor shall demonstrate by analysis that the roof plates and framing are adequately designed for non-symmetrical loading due to the concrete pouring sequence. Offsetting of the reinforcement in the roof is not permitted through consideration of composite action.

The roof shall be designed to withstand a blanket loading of 1.2kN/m^2 (25 lb/ft²) projected across the whole roof area and a point load (non concurrent) of 5kN (1100 lb) distributed on an area of 0.1 m² (1 ft²).

5.1.4 Ring beam under inner tank shell

A ring beam shall be installed under the inner tank shell. The ring beam shall be designed such that the shell loads are properly distributed onto the bottom insulation under the ring beam. Horizontal frictional forces, eccentricity of the shell and uplift caused by movements of the annular plate shall be taken into account.

A finite element model shall be used which incorporates large displacement and considers the rotation of the tank shell and subsequent the uplift (contact) of the annular plate as a result of the hydrostatic condition.

Where concrete ringbeams are used (as opposed to foamglass) reinforcing bars shall be suitable for use at the design minimum temperature of the product stored. The width of the ring beam will be such that the primary bottom annular plate is fully supported.

The design of the inner tank ring beam shall allow gas flow between the bottom insulation space and annular space, so that differential pressure resulting in uplift of the inner tank bottom cannot occur during:

- Pressure testing of the tank (depressurisation) including in-situ performance testing of tank safety devices such as pressure and vacuum relief valve.
- Decommissioning

In addition the ring beam shall be either:

- Foamglass blocks selected so as to comply with the requirements of this DEP.
- Segmental ring beam; For this the gaps between annular ring concrete segments shall be minimum 25 mm (1 in) and maximum 50 mm (2 in) and filled with resilient fibreglass, or
- Continuous ring beam; provision shall be made to promote and assure unrestricted equalisation to occur.

5.2 DESIGN STANDARD

The reinforced and pre-stressed concrete elements of the tank wall shall be designed in accordance with the requirements of DEP 34.19.20.31-Gen. All applicable sections of the DEP shall be followed except when supplemented or modified by provisions of this DEP.

5.3 ANALYSIS REQUIREMENTS

Normal and abnormal loads structural demands shall be determined using a combination of 2D and 3D Finite Element Modelling (FEM) techniques. Local models shall be used to determine the impact of structural discontinuities.

Both linear and non-linear (cracking) analyses are permitted for the determination of structural demands for SLS and ULS combinations. Where cracked analyses are adopted by the Contractor full verification (of software/method) shall be provided for company review.

The Finite Element Method software, which will be used for modelling of the concrete tank, shall be demonstrated to produce reliable results by comparison with a set of benchmark problems (e.g., those published by the UK National Agency for Finite Element Methods and Standards), relevant for the type(s) of analysis carried out for the tank model.

Where proprietary software is used by the Contractor, full validation and verification shall be provided for company review and approval.

For combinations including the major spill, a non-linear analysis shall be undertaken using an axi-symmetric model. Constitutive concrete models shall be in accordance with the requirements of EN 1992-1.

In the absence of a defined spillage rate, the Contractor shall examine the outer tank (secondary container) full with product to the maximum level along with intermediate levels to capture maximum structural demands. Particular attention shall be paid to spills in the immediate vicinity of the embedment.

The outer tank shall be designed to contain 100% of the gross volume pertaining to the MDLL while subjected to an OBE event.

The model(s) shall include thermal affects arising from steady state heat transfer conditions. In addition, transient thermo-mechanical analyses shall be carried out where

appropriate (e.g., for liquid spill) to ensure maximum structural demands are captured prior to the establishment of steady state conditions.

As a minimum, spring elements shall be used to represent the sub-soil. The Contractor shall determine the spring stiffness's from the soil investigation commensurate with short term and long term behaviour. More advanced models of the sub-soil may be used to adequately represent tank-foundation interaction.

Loads due to pre-stressing may be simulated by axi-symmetrical loads, acting perpendicular to the tank wall. Local stress concentrations occurring at structural discontinuities such as buttresses shall be considered within the design.

Long term and short term behaviour shall be considered including the effects of creep and shrinkage of the concrete along with pre-stress losses, relaxation and foundation stiffness.

5.3.1 Foundation stiffness

Long and short term foundation flexibilities shall include the effects of upper and lower bound soil parameters to enable the determination of bounded structural demands.

Where piles are provided, specific considerations shall be given to the representation of foundation flexibility and to determination accurate prediction of pile loading.

Where 'smeared' stiffness's are used in the finite element model, benchmarking shall be provided to demonstrate accuracy of the final pile loadings. This phenomenon occurs when representing an orthogonal pile layout in 'axi-symmetric space'.

5.3.2 Thermal analysis

5.3.2.1 Normal and emergency conditions

Structural demands due to temperature affects shall be determined from semi coupled thermo-mechanical finite element analyses using 2D axi-symmetric solid or 2D Fourier models.

Surface temperatures shall be determined from a heat transfer analysis. Film coefficients shall be correlated to the surface temperatures, object size and flow characteristics. For the purpose of analysis, the tank shell shall be considered as a cylinder in cross flow. In addition, the analysis shall consider:

Summer and winter design temperatures commensurate with 95th and 5th percentile temperatures.

Wind speed for the determination of film coefficients shall be based on the 5th percentile mean hourly wind speed.

Solar gain shall be determined using the Solar Radiation data contained in the Tank Datasheet. Where appropriate, solar distribution shall be scaled from ASHRAE (2009 ASHRAE Handbook—Fundamentals) or other recognised standards to determine the total gain on horizontal and vertical surfaces.

Base heating demands shall be commensurate with the condition under consideration.

The initial temperature (stress free) T_0 should be taken as the temperature of a structural element at the relevant stage of its restraint (completion). Where necessary, upper and lower bound T_0 's shall be selected so as to maximise the differentials for 'summer' and 'winter cases'. Due to the construction schedule period T_0 for the base, wall and roof may adopt different values. Such temperature differences shall be included within construction and test load cases.

5.3.2.2 Heat of hydration analysis

The Contractor shall demonstrate by analysis using test data from the proposed concrete mix that the construction sequence and environmental condition will not cause restraint cracking in the base, wall or roof during construction.

From a full scale mock-up, the Contractor shall measure and record the adiabatic temperature rise of the concrete mix for use in the hydration analysis. The Contractor shall

provide analysis methodology to meet the target performance level of 'no cracking' under construction conditions.

5.4 LIMIT STATE CHECK AND MINIMUM REQUIREMENTS

The Contractor shall design the concrete structures on Ultimate Limit State (ULS) and Serviceability Limit State (SLS) for all normal situations.

- a) The Serviceability Limit State (SLS) shall be utilised to limit concrete crack widths and/or limit stresses for all load conditions including construction, testing and normal operation.
- b) The Ultimate Limit State (ULS) shall be utilised to verify the strength capacity for all load conditions with the exception of those containing spill cases for which specific analysis and acceptance criterion are stated herein.

Material partial safety factors for SLS and ULS conditions shall be in accordance with DEP 34.19.20.31-Gen.

5.4.1 SLS limit state (SLS)

For normal operation, and construction and testing, the following shall apply:

Crack width on inside and outside faces of prestressed concrete members shall be limited to $w_k < 0.2\text{mm}$ (0.008 in).

Crack width on inside and outside faces of reinforced concrete members shall be limited to $w_k < 0.3\text{mm}$ (0.012 in).

Tensile reinforcement stresses for crack controlling members shall be $\leq 300\text{MPa}$ (43.5 ksi) for reinforced concrete and prestressed concrete members.

For the OBE condition the following shall apply:

Crack width control is not required on inside and outside faces of prestressed concrete and reinforced concrete members, provided the tensile reinforcement stresses for crack controlling members are $\leq 300\text{MPa}$ (43.5 ksi).

5.4.2 Ultimate limit state (ULS)

ULS checks shall be in accordance with the requirements of EN 1992-1.

For load caused by a fire, stresses in the pre-stressing tendons and in the reinforcing bars shall be limited to the yield stress. In addition, the compressive stress in the concrete shall be limited to $0.6f_{ck}$ to avoid crushing and spalling of the concrete.

5.4.3 Spillage acceptance criterion

The acceptance criterion for all spillage conditions shall be as follows:

- a) The Residual Compression Zone (RCZ), i.e., the distance between the compressive face and the position of zero stress shall be $\geq 80\text{mm}$ (3.0 in)
- b) The average compressive stress (RCZ_{avg}) in the RCZ shall be $\geq 1.5\text{MPa}$ (220 lb/in²).
- c) The characteristic crack width (w_k) calculated in accordance with EN 1992-1 on the inside face of the concrete in contact with product shall be $\leq 0.2\text{mm}$ (0.008 in).
- d) Tensile strain in the reinforcing bars calculated on the basis of a cracked section shall be less than 1%.
- e) Tensile strain in the prestressed reinforcement calculated on the basis of a cracked section shall be less than the initial jacking strain (ϵ_{pm})
- f) Extreme compressive stress in the concrete cracked section shall be $\leq 0.6f_{ck}$.

Constitutive models for concrete and steel shall comply with the requirements of EN 1992-1 §3.1.5. Where tensile capacities are incorporated in the concrete constitutive model, upper and lower bound values pertaining to $f_{ck0.05}$ and $f_{ck0.95}$ shall be used to demonstrate compliance with the requirements of this clause.

Shear capacities under spillage conditions shall be verified against ULS requirements using material variability factors commensurate with the abnormal (accidental) nature of the loading.

Shear links shall be permitted to resist the shear demands under the spillage cases and where provided shall be appropriate for the minimum anticipated temperature.

5.5 LOAD COMBINATIONS

All appropriate load cases and combinations shall be incorporated in the design of the concrete outer tank. A detailed loading summary table shall be prepared to cover all phases of the tank life.

Favourable and unfavourable effects of all permanent, pre-stress, creep and shrinkage, temperature, hydrostatic and pressure actions shall be considered for all normal conditions including construction, normal operation and maintenance.

In all cases, the design shall take into account the effects of the load action, shrinkage strains, and pre-stressing forces during and after tensioning with due consideration of edge restraint at the wall junctions with the base slab and roof.

5.5.1 Serviceability limit state combinations

Load factors for normal conditions shall be in accordance with EN 1990 pertaining to reversible limit states except as modified herein. Shrinkage, creep and temperature shall be included within all SLS cases including locked in stresses arising from construction and loading history.

$$E_d = \sum_{j \geq 1} G_{kj} + P + Q_{sc} + Q_t + Q_f + \varphi_{1,1} Q_{k,1} + \sum_{(i \geq 1)} \varphi_{2,i} Q_{k,i}$$

Factors for $\varphi_{1,1}$ and $\varphi_{2,i}$ are presented in Table 3 below.

$\varphi_{1,1}$ shall be taken as 1.0 for the OBE condition.

5.5.2 Ultimate limit state combinations

Load factors for normal conditions shall be in accordance with EN 1990 except where modified herein. Shrinkage, creep and temperature need not be included within ULS combinations provided that they are included at Serviceability Limit State.

NOTE: Where a cracked analysis is undertaken at the SLS for a specific combination, a ULS compliance check shall be carried out using factored loads and appropriate stress strain curves.

For design situations with one variable action;

$$E_d = \sum_{j \geq 1} \psi_{Gj} G_{kj} + \psi_P P + \psi_{sc} Q_{sc} + \psi_t Q_t + \psi_f Q_f + \psi_{Q,1} Q_{k,1}$$

For design situations with two or more variable actions;

$$E_d = \sum_{j \geq 1} \gamma_{Gj} G_{kj} + \gamma_P P + \gamma_{sc} Q_{sc} + \gamma_t Q_t + \gamma_f Q_f + \gamma_{Q,1} Q_{k,1} + \sum_{(i \geq 1)} \gamma_{Q,i} \varphi_{0,i} Q_{k,i}$$

For design situations containing the OBE condition with one or more variable actions;

$$E_d = \sum_{j \geq 1} \gamma_{Gj} G_{kj} + \gamma_P P + \gamma_{sc} Q_{sc} + \gamma_t Q_t + \gamma_f Q_f + \gamma_1 A_{k,1} + \sum_{(i \geq 1)} \varphi_{2,i} Q_{k,i}$$

$\gamma_f = 1.35$, all other actions and factors for the above combinations, including leading, accompanying and quasi permanent factors are contained in Table 2 and Table 3 below.

Table 2 ULS partial load factors for G_k , P , Q_{sc} , Q_t and Q_f actions

Action	Description of action	Factor	Unfavourable	Favourable
G_k	Permanent actions	γ_{Gj}	1.35	1.00
P	Pre-stressing actions	γ_P	1.20	0.90
Q_{sc}	Shrinkage and creep actions	γ_{sh}	1.20	0.0
Q_T	Temperature actions	γ_T	1.20	1.0
Q_F	Fluid actions	γ_f	1.20	1.0
$Q_{k,1}$	Leading variable action	$\gamma_{Q,1}$	See Table 3 for leading and accompanying variables	
$Q_{k,i}$	Accompanying variable(s) action	$\gamma_{Q,i}$		

Table 3 ULS leading, accompanying, frequent and quasi permanent factors

	Leading Variable factor	Factor	Accompanying Variable factor	Factors for frequent and quasi permanent factors	
Variable Action $Q_{k,i}$	$\gamma_{Q,1}$	$\gamma_{Q,i}$	$\gamma_{Q,1} \gamma_{Q,i}$	$\gamma_{1,1}$	$\gamma_{2,i}$
Imposed Loads	1.5	0.70	1.05	0.5	1.00
Snow Loads	1.5	0.67	1.00	0.5	0.30
Wind Loads	1.5	0.67	1.00	0.5	0.30

NOTE: (Imposed + Wind) and (Imposed + Snow) actions need not be considered as acting simultaneously.

5.5.3 Accidental load combinations

Load factors and load combinations for accidental conditions shall be in accordance with **Error! Reference source not found.** below.

Table 4 Abnormal load factors and load combinations accidental conditions

G_k , P , Q_{sc} , Q_T and Q_F	Variable Loads			Accidental Loads		
	Imposed	Snow	Wind	SSE, Spill, Impact, Blast	Spill + OBE	Fire
Unfavourable 1.05 Favourable 1.00			0.5	1.0		
		0.5		1.0		
	1.05			1.0		
					1.0	
			0.5			1.0

NOTE: Multiple 'accidental load' shall not occur in the same combination, i.e., SSE or Spill or blast, etc.

Operational loads shall be combined, a single variable load and a single accidental load, (as shown).

6. METALLIC COMPONENTS

6.1 GENERAL

The inner tank, secondary bottom, suspended deck, bottom liner, wall liner, and the roof liner shall be designed, fabricated, supplied, erected, inspected and tested in accordance with the standards, guidelines, specifications, documents specified herein and additional requirements as given in this DEP.

6.2 INNER TANK

Maximum allowable stresses for the inner tank design for normal and testing conditions shall be in accordance with EN 14620-2.

Maximum allowable stresses for the inner tank design for OBE conditions shall be in accordance with EN 14620-2.

- Response at the OBE level shall be essentially elastic and the force reduction factor shall be taken as 1.0.
- Earthquake definition for the OBE shall be as per Tank Datasheet.
- Sliding shall not be permitted under the OBE and a minimum factor of safety of 1.5 shall be provided against sliding.

Maximum allowable stresses for the inner tank design for SSE conditions shall be in accordance with EN 14620-2.

- Force reduction factors greater than 1.0 shall be demonstrated explicitly via a pushover analysis or similar approved analysis.
- Earthquake definition for the SSE shall be as per the Tank Datasheet.
- Sliding shall not be permitted under the SSE and a minimum factor of safety of 1.0 shall be provided against sliding.

Shell and bottom annular plates shall be butt welded. Welding of the inner tank bottom annular plates, shell to annular plate welds shall conform to EN 14620.

Temporary access through the inner tank shell, using 'door sheets' or manways, is permitted. All temporary construction openings shall be closed prior to hydrostatic testing of inner tank

All permanent structural welded attachments shall be of the same material as that to which they are welded.

Minimum plate thickness shall be as per EN 14620.

Anchorage of the inner tank is not permitted under the seismic event(s), tank aspect ratio shall be modified accordingly and/or isolators introduced.

Attachments, including circumferential stiffeners, shall be welded with continuous fillets on all sides.

Stud-welded attachments are not permitted.

Structural attachments or appurtenances shall be located no closer than 150 mm (6 in) to all vertical and horizontal weld seams and any other attachment welds or discontinuities.

6.3 LINERS (VAPOUR BARRIER)

6.3.1 Bottom Liner

A vapour tight bottom liner, connected to the wall liner shall be installed on top of the concrete base slab. The design shall account for all normal and emergency loading conditions including the upset condition when the interspace fills with liquid product. The design shall also consider the mechanical, thermal loadings along with the deformation

fields imposed from the temperature effects, pre-stressing, creep and shrinkage of the outer tank.

The bottom liner minimum thickness shall be 5 mm (3/16 in), and it may be lap welded. In the area underneath the concrete ring beam, annular plates of at least 10 mm (3/8 in) thickness shall be used to limit weld distortions. For the joints between these thicker plates, butt welds shall be used, for which the use of backing strips shall not be allowed. The Contractor shall propose in his bid an installation procedure for the liner, the cellular glass and the concrete ring beam, based on this requirement.

The liner shall remain liquid-tight in the event of contact with LPG. To this end, the liner shall be anchored into the concrete base slab to avoid direct contact between LPG and the concrete structures. The anchor plates shall be located around the periphery of the outermost. A fillet weld shall be used to join the bottom liner plates to the anchor plates.

All welded joints and anchors shall be designed to resist the forces occurring during construction, testing and operation including strain based loading induced by creep, temperature and shrinkage effects.

The design minimum temperature of the bottom liner and anchor system shall be the design minimum temperature of the product stored.

Liner deformations shall be such that they do not impair the liquid tightness of the PUF insulation system.

6.3.2 Wall liner

A vapour tight steel wall liner shall be installed on the inner surface of the outer concrete wall. This liner is intended to act as a vapour barrier and shall not be to the substitute for any reinforcing bars in the concrete wall.

The liner shall have a minimum thickness of 5 mm (3/16 in) and shall be butt welded. The inside surface of the liner plates shall be flush and free of permanent attachments (i.e., backing bars shall not be on the side to which PUF will be applied). The extent of the liner shall be over the entire surface of the wall. The wall liner shall be made continuous with the roof and bottom liners by full penetration welding. Liner deformations shall be such that they do not impair the liquid tightness of the PUF insulation system.

The liner shall be designed to act as an integral part of the concrete wall and shall be provided with anchors for that purpose. Those shear anchors and all welds shall be designed for all relevant forces occurring during construction, testing, operation including strain based loading induced by creep, temperature and shrinkage effects. Anchor details shall be subject to acceptance by the Principal.

The spacing of the anchors shall be determined so as to minimise the amount of distortion of the liner caused by concrete creep and shrinkage and eventual welding of seams. As the liner plate will essentially become a part of the formwork, it is fixed into position at the same time as the formwork and is used as one of the reference points for installing the reinforcing steel work.

6.3.3 Roof liner

A steel roof liner shall be installed at the inside face of the concrete roof. The liner shall function as an integral part of the concrete roof using shear anchors for load transfer.

The roof liner may be used as formwork for the concrete during construction. The liner shall be at least 5 mm (3/16 in) thick and lap welded. The design temperature shall be -20 °C (-4 °F). A structural framing design temperature shall be selected by the Contractor appropriate to the use and design considerations of the framing.

The strength of all welded joints and anchors shall be adequate to transmit the forces that may occur during construction, testing and operation, including those induced by temperature variations.

The Contractor shall submit methodology for stress analysis and shear studs distribution on the roof for review.

6.4 SUSPENDED DECK

The suspended deck shall be a flat plate deck; trough decks shall not be permitted. Open vents shall be provided to ensure equilibrium of gas pressure on both sides of the suspended deck.

Piping penetrations through the suspended deck shall be provided with sleeves, which permit thermal movement of the suspended deck without applying load to the pipes for all load cases (including seismic).

The minimum plate thickness of the deck shall be 5 mm (3/16 in). Minimum design temperature shall be -50°C (-58 °F) and -10°C (14 °F) for propane and butane, respectively.

The suspended deck shall be designed for a minimum live load of 1.2 kN/m² (25 lb/ft²) or a concentrated live load of 1.5 kN (330 lb) at any place, or any higher load if required for erection purposes. Walkways where supported from the suspended deck shall be subjected to the same loading.

Vents between the upper and lower deck shall be provided to enable pressure equalisation between the two spaces during normal and upset conditions including roll over.

To enable entry into the inner tank, a removable cover to serve as an access hatch shall be installed. A deck walkway shall be provided from the outer tank roof manhole to the access hatch facilitating access to internal tank stairway.

6.5 TANK INTERNAL AND EXTERNAL PIPING

6.5.1 General

The internal piping and roof nozzles shown on the P&ID's shall be designed and supplied by the Contractor. External piping shall be installed and properly supported/guided.

Tank mounted internal and external piping shall be designed in accordance with standard ASME B31.3 and comply with DEP 31.38.01.11-Gen.

External flanges up to and including 600 mm (NPS 24) shall conform to ASME B16.5. Flanges larger than 600 mm (NPS 24) shall conform to ASME B16.47.

The Contractor shall determine the final detailed location of all internals and nozzles.

All piping to the inner tank shall be through the tank roof. Penetrations through the outer wall, inner tank shell or tank bottoms are not permitted.

All roof nozzles shall have vertical axes, with the flange boltholes straddling the north-south centreline of the nozzle and shall be designed in accordance with ASME B31.3.

Primary flanged connections shall be of either the welding neck or long welding neck type.

The minimum design temperature of internal piping for butane tank shall take into account the possible impingement by subcooled droplets from spray rings.

6.5.2 Pump wells

The tank shall be equipped with inner tank pump wells and a single annular space pump well each having a foot valve and filter box. Refer to Tank Datasheet(s) for number of pump wells. The pumps, pump wells, and foot valves shall be supplied and installed by the Contractor.

The pump wells shall be supported from the concrete tank roof and guided from the inner tank bottom. Fixed anchorage from the tank bottom is not permitted. The guide system must provide for differential movement of the pump column (well) inside the tank relative to its support point on the tank roof. A filter box shall be made around the bottom guide to avoid debris entering the pump wells, in accordance with the pump Manufacturer's requirements. The filter box shall be removable, to allow for hand check of pump shaft rotation before commissioning.

The minimum clearance between the underside of the foot-valve (in the open position) and tank bottom plate shall be as recommended by the pump Supplier and not less than 100 mm (4 in) in the warm condition.

The pump wells shall be sized and fabricated in accordance with the pump Manufacturer's requirements and designed for full vacuum conditions. A vibration analysis for the pump wells shall be carried out. The design of the pump wells, including the location of guides, shall be such that the natural frequency of the well is at least 20% away from the harmonic operating speed. The Contractor shall ensure that the design of the pump wells including vibration analysis is verified by the pump Supplier.

Pump well inside weld joints shall be flush. Welding backing rings on the inside are not permitted.

6.5.3 Liquid inlets

Liquid inlets shall be provided in accordance with information furnished in tank data sheet.

For propane tank(s) the top liquid inlets shall be provided with an inclined deflector plate to distribute the LPG on the liquid surface and shall be designed to withstand forces and vibration induced by the incoming LPG. This deflector plate shall be radially aligned such that flow is directly towards the tank centre to prevent splashing of liquid onto the inner tank shell.

For butane tank(s) two inlets shall be provided for;

- The top liquid inlets shall be provided with an inclined deflector plate to distribute the LPG on the liquid surface and shall be designed to withstand horizontal forces and vibration. The deflector plate shall be radially aligned such that flow is directly towards the tank centre to prevent splashing of liquid onto the inner tank shell.
- Spray ring used to condensate the butane boil-off with subcooled butane.

All inlets shall be designed against the loads (including vibration) induced by the incoming LPG.

6.5.4 Vapour outlets

Liquid entrainment shall be avoided in the vapour outlets and relief valves. The vapour outlets shall be positioned away from the deflector plate of the liquid inlet and far enough from any disturbances. The underside of the nozzles of the relief valves shall be minimum 500 mm (20 in) above Maximum Design Liquid Level (MDLL).

Additionally, for butane tank(s), the sub-cooling stream is also passing through the spray ring. Therefore, the Contractor shall clarify the turndown of the spray ring and nozzles such that there is an even spray distribution across the tank vapour space and the liquid droplet size is minimized. However, the design of the butane tank spray ring should avoid impingement of subcooled butane onto the inner tank wall.

6.5.5 Cool-down line

The cool-down line with spray nozzles shall be designed for cool-down rates, specified in this DEP and in accordance with the Contractor's cool-down procedure.

6.5.6 Purge/Venting system

A purge/venting system shall be installed, consisting of:

- For each layer of cellular glass blocks of the central part of the base slab insulation system, one centrally placed filter (perforated pipe end, surrounded with a 25 mm (1 in) thick glass-fibre, surrounded by coarse sand/gravel), connected to the roof with separate piping. This system shall allow purging and sampling of the bottom insulation system. The minimum horizontal distance between any two sand/gravel boxes shall be 1 m (40 in);
- A DN 100 mm (NPS 4) purge ring header, connected by two DN 100 (NPS 4) lines from the roof, shall be located in the annular space. At intervals of 300 mm (12 in), the purge ring header shall have three 8 mm (3/8 in) holes for venting, spaced at

equal intervals of 120 degrees around the local pipe circumference;

- A separate purge/vent nozzle shall be installed at the top of the tank roof, allowing complete purging of the dome space. Purge piping shall not be embedded in the concrete wall.

The design of the inner tank ring beam shall allow good gas flow for pressure equalisation between the bottom insulation space and annular space.

6.6 STRUCTURAL STEEL

Design of steel structural components shall be in accordance DEP 34.28.00.31-Gen.