

DEP SPECIFICATION

FULL CONTAINMENT REFRIGERATED LPG TANKS

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DESIGN AND ENGINEERING PRACTICE

DEM1



PREFACE

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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/ft^2) projected across the whole roof area and a point load (non concurrent) of 5kN (1100 lb) distributed on an area of 0.1 m^2 (1 ft^2).

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;

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

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.

7. MATERIAL REQUIREMENTS

7.1 CONCRETE TANK

7.1.1 Concrete

Concrete works shall be as per the requirements of DEP 34.19.20.31-Gen. and the requirements of this DEP. Reinforced and post tensioned components shall have minimum 28 day characteristic strengths (f_{ck}) of 40 MPa (5800 psi). Exposure class shall be XS1 as per EN 206-1. Blinding concrete used as "mud mat" shall be C20 as per EN 1992.

Maximum Water Cement Ratios (WCR) shall be as follows;

- C20 WCR 0.55
- C40 WCR 0.45

Minimum cover requirements shall be as follows:

- Concrete cast against soil 75 mm (3 in)
- Concrete cast on prepared ground (blinding concrete) 50 mm (2 in)
- Reinforced and prestressed concrete structures 50 mm (2 in)

7.1.2 Reinforcement

All reinforcement shall be uncoated and conform to the requirements DEP 34.19.20.31-Gen.

Normal reinforcement yield strength 500 MPa (60,000 lb/in²) shall be used for slab, roof and external reinforcement of the wall.

In case of inner tank leakage of the propane tank, the reinforcing bars of the concrete ring beam and, possibly, of the concrete base slab will be subjected to low temperatures. Selection of low temperature [$< -20^{\circ}\text{C}$ (-4°F)] reinforcing steel shall be based on ductile performance at low temperatures. The ductility shall be demonstrated by means of testing, under low and ambient temperature (notched and un-notched).

For bars under tension and subjected to temperatures less than -20°C (-4°F) TEMPCORE type bars may be installed [yield strength 500 MPa (72,000 lb/in²)]. Testing and acceptance criteria shall be in accordance with EN 14620-3.

7.1.3 Pre-stressing system

Post-tensioning materials shall include super low relaxation type strand and meet the requirements of DEP 34.19.20.31-Gen.

The prestressing steel shall consist of stress-relieved strands, assembled from cold-drawn wires. For the strand system, the Contractor shall submit data demonstrating that centre wire slippage does not occur at the minimum service temperature.

Low temperature toughness tests on pre-stressing strands is not required provided that the Contractor demonstrates the initial strain (at construction) in the system is never exceeded for all low temperature design cases (spill).

All post-tensioning tendons shall be stored and handled using methods that will assure that mechanical, chemical, electro-chemical, heat or other damage cannot occur. Flame cutting the ends of post-tensioning ducts is prohibited.

In addition, the assembly shall comply with FIP Recommendation "Recommendations for Acceptance of Post-Tensioning Systems" – 1993. The tendons and anchorage assemblies shall be cement grouted after post-tensioning.

7.2 INNER TANK

7.2.1 Inner tank

The inner tank shall be made of steel plate selected in accordance with section 4.3.2.1 of the EN 14620-2.

For type I and II steels, the following additional requirements apply:

- a) The steel shall be obtained from approved Suppliers with extensive experience in the production of specified materials;
- b) A reference list of proposed material Suppliers shall be provided giving details of their experience in the supply of specified steel materials
- c) The minimum specified ultimate tensile strength shall not be greater than 500 N/mm² (72,000 lb/in²) and the maximum specified shall not be more than 630 N/mm² (91 Ksi);
- d) Steels shall be weldable without preheat or minimum interpass temperature in the range of heat inputs from 1 to 4 kJ/mm. Type I steels shall have a carbon content (heat analysis) not exceeding 0.23% and a carbon equivalent, based on the heat analysis, not greater than 0.43%, whereby:

$$C_{eq} = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

C_{eq} is to be stated on the mill certificates;

- e) The Contractor shall specify plate flatness tolerances commensurate with the methods of plate preparation, welding techniques and attainment of high quality welds. Under no instance shall these be greater than EN14620-2 Section 4.3.1.2.4 requirements.
- f) Charpy impacts shall be according to (**Error! Reference source not found.**0).
- g) All weld edges and adjacent surfaces to be welded shall be thoroughly cleaned from oxide, scale, oil, paint or other foreign matter, and shall be dry. Any potential contamination of the weld edges and the adjacent surfaces by zinc shall be positively excluded. The Contractor shall prepare an adequate procedure for cleaning and inspection.
- h) All mechanical tests, non-destructive tests, chemical analyses and alloy verification shall be Type 3.1 as per EN-10204.
- i) Plate repairs by welding are not permitted on any Type I or Type II Steel plate. Repair by grinding is acceptable provided that the remaining thickness conforms to the minimum thickness requirements.
- j) All plates $\geq 10\text{mm}$ (3/8 in) shall be ultrasonically inspected at the mill for imperfections as follows:
 - Surface of each plate shall be scanned in grids of 100mm centres in both directions as per ASTM A578 5.6.1.
 - After cutting plates to the required size a 50 mm (2 in) wide band at the perimeter of the plates shall be 100% inspected.
 - Acceptance standard 'Level B' as per ASTM A578.
- k) All plate marking shall use paint as per ASTM A20 (§13.2.1) using materials which does not contain substances, which could harmfully affect the material (such as metallic pigments, sulphur, zinc, sulphides, chlorides or inorganic halogens).

7.2.2 Internal piping components (to first flange or first butt weld)

For the internals, reference is made to the piping requirements as specified in various piping DEP's.

7.3 WELDING CONSUMABLES

Contractor shall select filler metals and fluxes based on strength, ductility, soundness and previous successful application in LPG tank construction.

Selection of welding consumables shall be in accordance with the current list of welding consumables published by Lloyds Register of Shipping, ABS, Controls DNV or another internationally acknowledged inspection body.

Welding consumables shall be of the basic low-hydrogen type and shall be selected such as to meet the mechanical requirement of the base metal. Low-hydrogen consumables shall be handled and stored so as the weld metal diffusible hydrogen content $< 5 \text{ ml per } 100\text{g}$ of weld metal. The method of determination shall be as per ISO 3690.

The weld metal impact toughness shall meet the impact toughness requirements of the plate.

All welding consumables shall be stored in accordance with Manufacturer's recommendations

The Contractor shall submit a consumable Manufacturer's certificate verifying the consumables comply with these requirements.

7.4 IMPACT TESTING REQUIREMENTS

Impact tests shall be carried out both on base material, on deposited weld metal, and on the heat-affected zone (HAZ) as per EN 14620-2 Section 4.3.2 with following additional requirements:

The degradation of the welding shall be taken into account and the actual test temperature for Type I and Type II steels shall be lower than the specified test temperatures in EN14620-2 Table 2 by a value ΔT . Before placing an order for type I and II steels, the Contractor shall demonstrate, to the satisfaction of the Principal, that the proposed ΔT -value can be reliably achieved. This shall cover the full range of variability of the main fabrication parameters (thickness, chemical composition, rolling and heat treatment) within a single steel quality. However, Cv-impact testing of Heat Affected Zones (HAZs) inherently results in wide scatter. At least 10 impact tests shall be made at each set of conditions for testing the HAZ. The positions of the notches shall sample the full heat affected zone. ΔT shall be determined on the basis of minimum impact energy results. Specimens, which results are decisive for the determination of ΔT , shall have the position of the centre of the notch in the HAZ and be verified metallographically.

No single specimen shall have an impact energy value less than 75% of the specified value stated below.

Each plate shall be tested separately. In all cases, a single sample (3 impact tests) shall be taken at one end of the plate at a position midway between the edge and centre. Where plate length exceeds 6.1 m (20 ft), a second test sample (3 impact tests) shall be taken from the other end at the same position.

Material thinner than 5 mm (3/16 in) shall be exempt from impact testing.

7.5 VAPOUR BARRIERS, BOTTOM, WALL AND ROOF

The outer tank bottom, wall and roof vapour barrier and associated embedments to the concrete shall be as per the requirements of EN 14620-2 Section 4.4.1.

Structural framework under the roof plates used for roof plate erection and to provide support during concrete pouring shall be ASTM A36, ASTM A572, or equivalent.

The roof framework shall be welded to the roof plates.

7.6 SUSPENDED DECK

For propane service, the suspended deck including adjustable suspension rods, shall be made of weldable fine grained, fully killed C-Mn steel of low temperature grade with a specified Charpy-V impact toughness better than 27J at -20 °C.

For butane service the suspended deck including adjustable suspension rods, shall be made of weldable fine-grained, fully killed C-Mn steel.

For both above-mentioned types of steel, the following additional requirements apply:

- The minimum specified ultimate tensile strength of the steel shall not exceed 500N/mm² (72,000 psi)
- The carbon content (heat analysis) shall not exceed 0.23%.
- Carbon equivalent "Ceq" based on the heat analysis, shall not be greater than 0.43%, calculated according to the following formula:

$$\bullet \text{ Ceq} = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

Ceq shall be stated on the mill certificates.

The materials shall be properly marked identifying them as low temperature materials, Type 3.1. Certificates in accordance with ISO 10474 are required.

NOTE: Alternatively, stainless steel, aluminium alloy 5083-0, ASTM B-209 or approved equivalent may be used for the suspended deck (the suspension rods excepted) for propane or butane or both tanks subject to the Principal's approval.

8. MANUFACTURE AND CONSTRUCTION

8.1 STEEL COMPONENTS

8.1.1 Fabrication

During construction, temporary access through the inner tank shell using door sheets or man ways, is permitted. These openings shall be permanently closed by welding prior to the start of inner tank hydrostatic testing. The closing and testing procedure shall be submitted for review by the Principal.

Plate edge preparation of steel plates shall be by machining. Plasma cutting is permitted subject to approval of submitted procedures.

Where flame cutting is necessary for weld bevel preparation; 1.5 mm (1/16 in) of the flame cut edge shall be removed and the same ground to a bright metal finish.

- All edges of primary containment components shall be examined by Liquid Penetrant testing.
- Plate laminations or surface defects shall not be repaired by welding.
- The Contractor shall submit procedures for gas cutting and finishing of the gas cut edges, along with test data as appropriate, to demonstrate the suitability of welds.

Temporary attachment welding to the inner tank shall be kept to the absolute minimum and shall be removed as soon as practicable but prior the hydrostatic testing of the tank. Care shall be taken when applying and removing temporary erection attachments in order to prevent damage to the surface of the base material. (i.e., by grinding or arc air gouging). After removal of such items, any remaining weld metal or protrusion shall be ground flush with the surface of the part and crack detection (a dye penetrant test) shall be carried out to ensure that no cracks have resulted. The Contractor shall submit his proposed method for removal of cleats, including acceptance criteria, to the Principal for review prior to start of fabrication.

Weld toes of the fillet welds of the shell plate to annular plate shall be smoothly finished to avoid stress intensification.

No welding shall be permitted on the inner tank after completion of the hydrotest.

Arc strikes on primary components shall be avoided and temporary attachment welds kept to an absolute minimum. The Contractor shall take all precautions in adopting welding methodologies and best practices that protect the tank shell plates.

The surface of the primary component where arc strikes have occurred and where temporary attachment welds have been removed shall be properly conditioned to eliminate surface stress raisers. Pick-ups by weld repair are not permitted on any primary component. Any repair required shall be by blended grinding and any such repair shall not reduce the plate below the minimum acceptable plate thickness including tolerances. Such surfaces shall be examined by liquid penetrant to ensure any defects have been removed.

The welding and installation method of the primary and secondary bottoms shall be such that voids are minimised under the bottom liner. The Contractor shall submit for approval an installation procedure for the bottoms including welding sequence methodologies for control of heat induced plate distortion from welding processes; the cellular glass, and the concrete ringbeam.

A mouse-hole shall be made in the horizontal butt welds of the inner tank stiffeners.

For three-plate lap-joint of bottom plates (inclusive of those for the secondary bottom), the lower two plate lap shall be fully-welded to the ends of the lap prior to fitting and welding the third lap.

8.1.2 Production test plates

Production test plates shall be made for the vertical welds of the inner and outer tanks as per EN 14620-2 section 7.6. Test results shall be submitted for the Principal approval within 72 hrs of completing the production test plate welding.

Production test plates for vertical seams shall be welded as a continuation of the actual tank welded joint and with the same consumables and machine settings.

Production test plates for horizontal seams shall be welded in the field before the seams are welded. The plates shall be welded in the horizontal position and with the same consumables and machine settings. The Contractor shall provide appropriate test rig for this purpose.

At each third course, one production test plate shall be made. The impact toughness of the weld metal and HAZ shall be determined.

In addition to the production weld tests as per EN 14620-2 section 7.6, a production weld test plate shall be made for one vertical of each inner tank course

Testing shall be carried out according to the same requirements as those specified for the relevant welding procedure qualification test.

The list for production control test plates shall be submitted to the Principal for approval.

8.1.3 Welding general

Welding shall be in accordance with EN 14620.

All vertical and horizontal seams of the inner tank shell may be welded manually, semi-automatic or by machine. All welding procedure shall be qualified. The following welding processes are permitted:

- Shielded Metal Arc Welding (SMAW)
- Submerged Arc Welding (SAW Automatic)

Piping with Nominal Pipe Size (NPS) smaller than DN 80 (NPS 3) shall be welded with Gas Tungsten Arc Welding (GTAW). For diameters in excess of this limit the root run shall be made with GTAW.

All welding procedure specifications and procedure qualification records to be used for the construction of the tanks, including those for prefabrication, repair, tack and attachment welds shall be accepted by the Principal prior to the work being performed.

8.1.4 Welding procedures and qualification

Each welding procedure specification shall be qualified in accordance with EN14620. The following additional requirements shall apply:

- a) Welding procedures shall be qualified irrespective of previous qualifications.
- b) The Welding Procedure Qualification test shall be conducted in the same position and with the same joint details of the test plate as for the production weld.
- c) Separate qualifications are necessary for horizontal and vertical joints for V and X groove welds.
- d) A copy of the material certificate of the test plate and welding consumables shall be attached to the WPQR.

For the welding of inner tank steel, the following requirements apply:

- Weld test plates shall satisfy the same specifications as the tank plates.
- Qualification welds shall be subject to the same level inspection as per production welds including UT inspection as per (Appendix B).
- The strength and impact toughness of the test plates shall be within 1 standard deviation from the average of the tank plates to which the qualification applies.

For each WPQR, transverse bend tests shall be made in accordance with ASME IX, QW-451.1.

- For plate thickness less than or equal to 15 mm (5/8 in), 2 root and 2 face bend specimens shall be produced.
- For plate thickness, greater than 15 mm (5/8 in), 4 side bend tests shall be done. Acceptance criteria as per ASME IX QW-163 apply, however, open defects occurring on the corners of the specimen and longer than 3 mm (1/8 in) are not acceptable.
- For each WPQR, the Charpy V-notch impact values shall be as specified.

All welding shall be carried out by qualified welders, tested and certified to each process they will perform in accordance with the requirements of API 620 clause 6.8. For Type II steel welding, a minimum of 50% of the manual welders and one welder on each automatic welding machine shall be experienced in Type II steel welding. The Contractor shall maintain records verifying individual welder certifications at the job site and make them available to the Principal's inspection personnel when requested.

For each WPQR, hardness testing shall be carried out as required by EN 15614. The maximum permitted hardness HV10 shall be 350.

8.1.5 Welder qualification and identification

All welding shall be carried out by qualified welders, tested and certified to each process they will perform in accordance with the requirements of EN 14620-2 clause 5.1. For Type II steel welding, a minimum of 50% of the manual welders and one welder on each automatic welding machine shall be experienced in Type II steel welding. Contractor shall maintain records verifying individual welder certifications at the job site and make them available to the Principal inspection personnel when requested.

Welders and welding operators shall be qualified in accordance with the requirements EN 14620-2 clause 5.1. Individual welding qualification certificates shall be issued with a photograph to each qualified welder and welding operator. Welding shall only be done by welders and welding operators having individual certificates for the procedure being used.

All welders and welding operators shall be qualified specifically for the work irrespective of any previous qualifications with the exception of those qualified on carbon steel welding processes.

8.1.6 Inspection

8.1.6.1 Radiographic Inspection

The radiographic techniques acceptance criteria and extent for the inner tank shall be in accordance with EN 14620-2, section 9.3.2.1.

The Contractor may propose a Third Party Inspection (TPI) agency to undertake radiographic and ultrasonic inspection; the agency shall be subject to the Principal approval.

The Contractor shall engage an Independent Authority (IA) for film interpretation verification, ultrasonic monitoring and approval. The engaged Authority shall be subject to Principal approval. The IA is to be independent from any TPI agency engaged.

Lead screens are required. Radiographic inspection shall follow as soon as possible after welding, and the inspections shall be coordinated with the Principal's inspector.

Radiography shall be by X-ray with a maximum focal spot 2.5 mm x 2.5 mm (0.1 in x 0.1 in) for the X-ray method. All personnel performing code evaluations shall meet ASME Section V, SNT TC-1A Level II or equivalent qualifications. The film used shall be in accordance with EN 584-1 and as specified by EN 1435.

Radiograph film length shall be at least 250 mm (10 in), except if the weld is less than 250 mm (10 in) long. In such cases, film length shall be full length of the weld.

Spot-radiograph minimum film length shall be 250 mm (10 in).

8.1.6.2 Liquid penetrant examination

Liquid penetrant testing (solvent removeable or post emulsifying systems) shall be in accordance with EN 14620-2 (§9.3.2.1, 9.3.2.3)

In addition, the following welds shall be 100% inspected by the liquid penetrant method prior to hydrotesting of the tank;

- a) All vertical and horizontal shell welds (both sides) of the inner tank;
- b) All inner tank bottom welds (including bottom annular plate-to-bottom plate butt welds and both sides of bottom annular plate butt welds);
- c) All shell-to-bottom annular plate welds;
- d) All stiffener ring welds and stiffener ring-to-shell welds;
- e) All welds of the steel bottom liner (including bottom liner-to-anchor welds and all welds between anchor plates);
- f) All exposed welds of plates (suspended deck excepted) and pipes (including pump columns and internals) which will have contact with LPG or with gaseous propane or butane;
- g) All welds of roof nozzles and manholes;
- h) All permanent attachments to inner tank bottom including bottom annular plate;
- i) All ground areas after removal of temporary attachments.
- j) Annular plate butt-welds that are not 100% radiographed shall be examined from the topside after completion of the root pass and again after completion of the full weld.
- k) "T" welds between shell and annular plates shall be examined from the both sides after completion of the root pass and again after completion of the full weld.
- l) Each pass of weld joining the shell to the annular plate.

Recording shall be done by the Contractor. A Third Party Inspection agency shall review and approve the testing reports for the welds specified above. This Third Party Inspection agency is subject to acceptance by the Principal.

Magnetic particle examination (MP) may be substituted for liquid penetrant testing following approval from the Principal.

8.1.6.3 Ultrasonic Inspection and Time of Flight Diffraction (TOFD)

For wall thickness in excess of 12mm (1/2 in):

- 1) Instead of or in addition to radiographic Inspection (RT), all vertical butt welds of the inner tank (shell and annular bottom) Time of Flight Diffraction (ToFD) shall be applied.
- 2.a) In case UT is applied in addition to Radiographic Inspection (RT), all horizontal butt welds at the intersection with vertical welds over a length of 1 m (40 in) each side of the inner tank (shell) Time of Flight Diffraction (ToFD), shall be applied.
- 2.b) Instead of Radiographic Inspection (RT), all horizontal butt welds over full length of the inner tank (shell) Time of Flight Diffraction (ToFD) shall be applied.
- 3) The fillet weld between shell and annular shall be examined by Ultrasonic Testing (UT).

The examination shall be carried out in accordance with ASME Section V, Article 5. The reference sample and reference targets used to set the reference sensitivity shall be representative of the welds to be inspected (with respect to geometry and welding procedures).

The acceptance standards shall be in accordance with ASME VIII, Division 1, Appendix 12.

The examination shall be performed by ultrasonic operators qualified Level II/Level 2.

Procedures shall be approved by a UT level III/Level 3 qualified individual. All qualification of personnel shall be in accordance with ASNT ASNT-TC-1A or ISO 9712 or EN 473.

The Principal's inspector will monitor the examinations.

The Contractor shall submit details of the proposed procedure, provide name of company doing the examinations including operator qualifications and experience.

In case UT Phased Array inspections are carried out, procedures and personnel shall have the approval of the Principal.

Time of Flight Diffraction (ToFD) shall be carried out in accordance with (Appendix B) of this specification and subject to approval the Principal.

8.1.6.4 Vacuum box testing

Vacuum box testing shall be carried out in accordance with EN 14620-2 (§9.3.2.1, §9.3.2.3).

Inner tank bottom plates, including central and annular plates shall be tested before and after hydrotesting.

All inner tank welded joints shall be tested above the water test level down to 3 m (120 in) below the hydrostatic test level.

All welds of the roof liner plates shall be vacuum box tested before concrete placement on the roof.

100% vacuum-box testing of the bottom slab and sidewall vapour barrier welds shall be carried out on all vertical and horizontal welded joints and completed prior to commencing any operations that cover up the plates. Welds between liner components (e.g., wall liner to bottom liner) shall be vacuum box tested.

Vacuum box testing shall be applied to all roof nozzles against which internal vapour pressure will act under normal conditions and which could not be soap film tested during pneumatic testing of the tank.

The Contractor shall repeat vacuum box testing of all wall vapour barrier welds after post tensioning to demonstrate vapour barrier integrity and absence of cracking.

NOTE: The Contractor may propose alternate method such as ammonia testing of barrier in order to expedite the inspection process. Such alternates are subject to approval of the Principal.

8.1.6.5 Visual inspection

Visual inspection shall be in accordance with EN 14620-2 (§9.3.2.1, §9.3.2.3)

8.1.6.6 Pressure testing of shell plate-to-annular plate weld

The double fillet weld in the shell plate-to-annular plate joint shall be tested for leakage inside and outside in accordance with EN 14620-2.

8.1.7 Positive material identification

Positive Material Identification (PMI) shall be performed on all inner tank steel components. The Contractor shall be responsible for conducting the PMI test.

8.1.8 Tolerances

Construction tolerances for the inner tank shall comply with the requirements of EN 14620 and other applicable codes, except that the plumbness tolerance for each inner tank shell course is 1/250. Plumbness readings shall be taken after erection of each shell course at intervals not to exceed one-half the shell plate width, and reported immediately to the Principal.

Tolerances for steel structures shall be in accordance with DEP 34.28.00.31-Gen.

8.2 CONCRETE COMPONENTS

8.2.1 General

Tests shall be carried out to demonstrate the suitability of the selected concrete mix for use in the construction of external concrete LPG tanks. The actual heat evolution shall be determined taking account of the expected conditions during the early life of the member (e.g., curing, ambient conditions). The maximum temperature rise and the time of occurrence after casting should be established from the mix design, the nature of the formwork, the ambient conditions and the boundary conditions.

In addition the Contractor shall carry out full scale site trials as per the requirements of (Appendix D).

Maximum concrete temperature when poured shall be $\leq 30^{\circ}\text{C}$ (85°F).

Concrete production and construction shall ensure that mixes and methods produce smooth, clean, even-coloured, dense and impermeable finish. All noticeable textural defects resulting from inadequate vibration or construction, which may impact the visual appearance and also the specified soundness and durability, shall be thoroughly inspected for conformity and restored to reference surface finish. The Contractor shall submit a procedure for defect correction prior to commencement of the main works. For large scale repairs, specific procedures shall be developed and trials carried out prior to the execution proper.

Cracking in excess of that anticipated within the design shall be investigated and corrective action taken. Cracks which impair the performance of the containment structure under normal or abnormal loading conditions are not permitted. The Contractor shall submit a procedure for crack repair prior to commencement of the main works.

Surface finishes which are susceptible to damage during subsequent construction activities shall be provided with temporary protection.

All horizontal surfaces shall be laid to a grade of 1:40 to enable generation of free draining surfaces (including plinths).

During casting of the concrete, all inserts and embedments shall be located in position by the means of temporary connections to the shuttering. Temporary connection of 'inserts' to the reinforcement or tendon ducts shall not be permitted.

The construction sequence shall be developed to as to minimize restraint cracking. The casting sequence shall be such that the parts of the outer ring are cast first and are allowed to move freely. Where necessary, measures shall be taken to reduce the heat of hydration by using cements with low-slow heat development (CEM III 'LH' or 'VLH'), using inert fillers or fly ash or cooling.

All setting out shall be performed using methods and instrumentation appropriate to the work.

Wall finishes shall be Type A per BS 8110 Section 6.2.7.3, as produced by high quality metal or faced shutters.

8.2.2 Construction joints

When placing of concrete is temporarily discontinued, the concrete, after becoming firm enough to retain its form, shall be cleaned of laitance and other unsound material to a sufficient depth to expose sound concrete. Immediately following an approved discontinuance of placing concrete, all accumulations of mortar splashed upon the reinforcing bars and the surface of forms shall be removed.

The surfaces of all construction joints shall be prepared by roughening by mechanical means to expose but not damage or loosen the coarse aggregate after the concrete has been in position for more than 24 hours. The roughened surface shall then be washed with clean, fresh water.

The surfaces of the construction joints may also be prepared by water jetting or while the concrete is still green by light brushing to expose the coarse aggregates and to remove all laitance and loose material. No further roughening shall then be required.

At least 12 hours prior to a concrete pour, the surfaces of construction joints shall be covered with wet hessian. The hessian shall be kept thoroughly and permanently wet. At the time of concrete pouring, the old concrete should be saturated, but surface dry.

Curing compounds shall not be allowed to come in contact with the surfaces of construction joints.

8.2.3 Curing of top surfaces

Every part of the exposed surface shall be covered with a layer of polythene or similar impermeable sheeting immediately after finishing. The sheeting shall be in direct contact with the concrete, unless some initial separation is necessary to obtain a particular surface finish.

The sheets shall overlap adjacent sheets at the edges for at least 200 mm (2/3 ft) and they shall be fixed down at the ends and edges to prevent air circulation over the concrete.

As soon as the concrete has stiffened sufficiently and after not more than 24 hours, the layer of sheeting shall be completely replaced with a layer of wet hessian with a top layer of polythene or similar impermeable sheeting. The sheets shall overlap adjacent sheets at the edges for at least 200 mm (2/3 ft) and they shall be fixed down at the ends and edges.

Additional water shall frequently be introduced under the sheeting in order to keep the hessian thoroughly and permanently wet.

When it is impossible to cover the whole of a surface closely with wet hessian, e.g., where a lot of starter bars protrude from it, and if it is also impossible to pond it, as much of the surface as possible shall be cured as described above. A curing membrane shall be applied to the remainder (except bonding surfaces such as construction joints) immediately after finishing operations.

Full curing shall be maintained for at least 7 days.

On removal of the hessian and sheeting, the exposed concrete, when it is just surface dry, shall be sprayed with a film of a suitable aluminised or white-pigmented curing compound. The curing compound shall be in accordance with ASTM C309 and shall be accompanied by a certificate from an approved institute, stating:

- Exact range and method of application;
- Physical and chemical composition;
- Positive and negative side effects;
- Proportioning at application.

8.2.4 Curing of vertical surfaces

Directly upon removal of the formwork, the concrete shall be closely wrapped with wet hessian and enclosed with polythene sheeting. Battening shall be used to keep both hessian and polythene lightly in contact with walls. Additional mixing quality water shall continuously be introduced on the hessian by means of 'trickler' hoses in order to keep the hessian thoroughly and permanently wet. Full curing shall be maintained for at least 7 days. On removal of the hessian and sheeting, the exposed concrete, when it is just surface dry, shall be sprayed with a film of a suitable curing compound. This curing compound shall satisfy the requirements specified in above paragraph.

8.2.5 Tolerances

Construction tolerances for concrete elements shall be as per (Appendix E).

8.2.6 Durability

The outside surface of the concrete secondary containment, wall and slab, shall be made watertight by using low permeable concrete designed for chloride attack resistance based on the prevailing environmental conditions without the requirement for an external coating. Usually, an outer tank wall constructed with concrete made with Blast Furnace Slag Cement (BFSC) or Fly Ash or Silica Fume cement, combined with sufficient cover, provides sufficient durability and protection against chloride penetration. (Not painting tanks)

The Contractor shall clearly explain the measure taken to guarantee the concrete durability during the entire tank life. As a minimum, the following points shall be achieved;

- Appropriate cover.
- Permeability shall not exceed 2000 Coulombs at 28 days and values at 90 days and 1 year shall be measured, for information only.

NOTE: The purpose of values at 90 days and one year is to measure the evolution of the concrete permeability

- Open porosity shall not exceed 10%, per ASTM C 642.
- Total acid-soluble sulphate content in concrete shall not exceed 4% of the weight of cement.
- Precautions shall be taken to ensure that alkali-silica reaction does not occur.

8.2.7 Chloride resistance

The Contractor shall demonstrate that the selected type of cement, concrete mix and vibration of the concrete is such that over the lifetime of tank, there is no danger for chloride attack of the reinforcement. Core samples shall be drilled out of the wall or of a mock up piece of the wall. The samples shall be investigated on chloride attack by an independent laboratory, subject to agreement by the Principal.

If core sample test results conclude that there is risk of chloride attack, the Contractor at his own cost shall paint the external surface of the tank. The paint system shall be subject to Principal approval (shot blasting of the concrete surface, crack bridging capability, maintenance free lifetime of 5 years, etc., are conditions to be demonstrated). The purpose of the external coating in this application is to guarantee the concrete durability.

9. INSULATION SYSTEMS

9.1 GENERAL

The total heat-in leak shall be such that the boil off rate will not exceed the specified value on the datasheets. Boil-off calculations shall be based on the specified design ambient temperature under wind conditions at design relative humidity stated in (0).

External piping insulation shall conform to DEP 30.46.00.31-Gen. The Contractor shall use SS316 jacketing. Colour coding of piping shall conform to facility requirements.

9.2 BOTTOM INSULATION

9.2.1 General

The bottom insulation shall be comprised of cellular glass interleaved with block seating to reduce high points and the potential for service cracking. Dry sand bedding layers and levelling layers shall be provided to remove level alignment issues between blocks and enable level alignment of the secondary bottom and annular plates. Glass fibre blankets shall be provided to the inside face of the inner tank ring-beam allowing movement of the same.

9.2.2 Cellular Glass

The bottom insulation shall be assembled from cellular glass manufactured by an approved Supplier.

The minimum insulation requirements shall be in accordance with Table 5.

Table 5 Minimum Requirements for Bottom Insulation

Location	Minimum Requirements	
	Propane	Butane
Centre	300 mm (12 in)	200 mm (8 in)
Concrete Ring Beam	200 mm (12 in)	100 mm (4 in)

Factors of safety for cellular glass on minimum compressive strength shall be in accordance with the requirements of EN 14620 §6.3.2.2

- In normal operation, FOS =3.0
- Hydrotest conditions, FOS 2.25
- OBE Condition, FOS 2.0
- SSE Condition, FOS 1.5

Where higher strength cellular glass is unable to accommodate the line loadings concrete ring beams shall be provided. The impact of the variation in temperature profile arising from the selection of bottom insulation shall be explicitly considered within the design of the secondary container.

Cellular glass blocks shall be arranged such that they overlap by at least 100 mm (4 in) of length and width over proceeding layer blocks enabling staggering of all vertical joints.

Test certificates shall be furnished stating the compressive strength and thermal conductivity of the cellular blocks. Testing for each lot shall be performed at the Manufacturer's plant.

Cellular glass blocks shall be tightly butted against one another with gaps not exceeding 2 mm (1/16 in). Each successive course shall be level to the extent that the surface

irregularities shall not exceed ± 3 mm (1/8 in) in a distance of 2.0 m (6.5 ft) in any direction. Any out of tolerance shall be corrected prior to installing the next course.

Cellular glass that is cracked or damaged during transportation and storage shall not be incorporated in the main works other than for cutting and fitting purposes.

Cellular glass that has been contaminated with water or is wet shall not be incorporated within the main works.

9.2.3 Block seating (cellular glass system)

Block seating shall be provided above and below each layer of cellular glass to reduce the affects of hard spots and enable attainment of design compressive loads.

Block seating shall conform to Manufacturers recommendations and conform to the following:

- Either, Pluvex (or equivalent) No. 1, damp proof course manufactured in accordance with BS 6398, Class A with a hessian base.
- Or, asphalt roofing felt manufactured in accordance with ASTM D226 or ASTM D2626.

Each layer block seating shall be laid to form a complete level surface with closely butted edges. Overlapping of the felt shall not be permitted with the exception for the upper layer of felt in contact with bedding layers located at the tank centre. This layer shall overlap 75 mm (3 in) as a minimum to prevent sand penetrating between blocks.

9.2.4 Bedding Layers

Bedding layers between individual foam glass layers shall consist of clean dry sand in accordance with DEP 34.19.20.31-Gen.

Moisture content of placed sand shall have a moisture content of $\leq 2\%$ by weight.

Thickness tolerances of the levelling layers shall be controlled to ensure compliance with the level tolerances.

9.2.5 Levelling Layers

Sand levelling layers shall be provided as follows;

- Underneath the primary tank bottom and shall extend as a minimum to the inside face of the inner tank ring-beam
- Minimum thickness 50 mm (2 in); as-placed moisture content shall be $\leq 2\%$ by weight.
- Level control of sand shall be maintained in order to ensure compliance with tolerance criterion of cellular glass.

Concrete levelling layers shall be provided as follows;

- On top of the primary vapour barrier and extend across the complete tank bottom.

Concrete levelling layers shall be minimum thickness 50 mm (2 in) and strength 25 MPa (3500 lb/in²), reinforced for shrinkage and temperature cracking control to a minimum of 0.5% of the cross-section areas of concrete.

- Concrete shall have a moisture content of $< 2\%$, advise drying period necessary before construction of cellular glass. The Contractor is to advise the drying period necessary.

9.3 WALL INSULATION

9.3.1 General

The inner face of the outer tank wall and the top face of the outer tank base slab, up to the vertical plates welded onto the anchor plates of the bottom liner, shall be thermally

insulated with a PUF insulation system. This PUF Subcontractor and their PUF application system SHALL [PS] comply with all requirements of (Appendix C).

Where required to ensure proper application and performance of the PUF in the bottom corner, the wall-to-base connection shall be cast with an internal fillet as an integral part of the main structure.

To ensure adequate joints are provided between the PUF and 1) the bottom insulation system, and 2) suspended deck insulation system, solution details shall be developed and provided to the Principal for review. The developed arrangements shall take due consideration of applicable thermal heat-in-leak and consequent thermo-mechanical loads.

9.3.2 Suspended deck insulation

Insulation on the suspended deck shall consist of fibre glass blankets.

The Contractor shall calculate the minimum thickness such that condensation on the external face of the concrete roof is prevented under all ambient conditions. The minimum total thickness shall be 500 mm (20 in) for the propane tank and 200 mm (8 in) for the butane tank. Each blanket shall have a maximum thickness of 100 mm (4 in).

Blanket material shall have a minimum density of 11 kg/m³ (0.7 lb/ft³).

Installation of the insulation blankets shall be carried out only after all other activities requiring access through the roof deck have been completed. Any damage to the roof insulation prior to commissioning shall be remedied.

The Contractor shall allow in the design for any consolidation of the roof insulation both prior to and after installation, and shall install sufficient compensatory material to ensure that the specified total thickness of insulation is achieved after long-term consolidation. The thermal conductivity will assume the density of fibreglass after final expected settlement.

The glass-wool blankets shall be arranged with staggered joints, or be cross-lapped in the case of blanket material in roll form. The blankets shall be carefully cut and fitted and shall be individually sealed around all roof hangers, nozzles and protrusions. The blankets shall be stacked on the suspended deck so as to evenly distribute the weight from the same and avoid damage to the deck and hangers.

The top layer shall have a finishing with open weave glass fabric or aluminium foil.

Insulation around deck venting shall be tied down with stainless steel wire in diamond pattern between adjacent hangers.

Identification markers shall be provided to gauge the finished level of blanket insulation by means of easily identifiable coloured tape or an acceptable alternative, at all roof hangers, etc.

Roof hangers shall be marked to clearly identify the finished insulation level.

All materials in between the suspended deck and roof shall be non combustible.

9.3.3 Insulation of nozzles and internal piping

Penetrations through the suspended insulation support deck shall be wrapped with fibreglass blankets and/or glass fibre cloth to prevent insulation material ingress into the inner tank.

Nozzle connections and internal piping located in the dome space shall be provided with insulation in case operating temperature conditions are below the dome temperature.

Insulation shall be in the form of flexible glass wool blankets, wrapped around the pipe in one or more layers, and secured with stainless steel bands. The outside layer shall be protected with an open weave glass fabric having all horizontal overlaps secured with a suitable adhesive.

The nozzle insulation system shall be designed to prevent ice formation and condensation for 95% of the time, in particular

- Environmental parameters, i.e., combinations of temperature and relative humidity

shall be selected so as to adequately bound the solution and enable achievement of the target performance level.

- Dew point prediction shall be based on accepted published methods.
- Where heat transfer is non-axi-symmetric, such as due to the presence of stiffeners, specific checks should be carried out to ensure target performance levels are met
- Where forced convection is used for the determination, the wind speed shall be taken as the 5th percentile.

9.4 INSULATION MATERIAL HANDLING AND STORAGE

All insulation materials shall be transported and stored in an enclosed and ventilated dry environment and protection against water ingress from the instant, they are dispatched to site until they are required for installation.

Adequate provisions shall be made to ensure the complete absence of moisture in the insulation and in the zones where insulation is to be installed. The methods proposed for ensuring dryness shall be agreed with the Principal.

All wet or contaminated insulation shall be rejected and removed from site. It shall not be permitted to dry and subsequently, be incorporated in the main works.

The storage for resilient blanket shall be recommended by the Supplier to guarantee that the initial resilience will not be affected.

10. INSTRUMENTATION

10.1 GENERAL

The Contractor shall be responsible for the engineering, design, procurement, installation and integration of all tank related instrumentation that is necessary to monitor all tank fill operation, storage, inventory management and transfer of the LPG. The instrumentation shall provide monitoring to operate at optimum conditions, maximized safety, abnormal situation reliability and security for any potential adverse process consequence.

Moreover, special provisions shall be provided by the Contractor, to ensure an easy access, wherever feasible, for maintenance, inspection or replacement of the sensors pertaining to the Leak Detection and to the Cool Down system.

Instrument tagging shall be per the Project Numbering System.

Instruments are to be supplied per the Approved Manufacturers List.

Suitable nozzles for mounting instruments shall be provided in the tank roof and tank piping.

Valves, stilling wells and thermo wells shall be provided where required by instrument design and where indicated on PEFs (Process Engineering Flow Scheme).

Temperature sensors (RTDs) shall be supplied complete with temperature transmitters for connection to the Distributed Control System (DCS).

All temperature sensors for leak detection shall be 3-wire platinum resistance temperature detectors (RTD) with a resistance of 100 ohm at 0 °C (32 °F) and in compliance with IEC 751 Class A.

The serial interface to the DCS shall be redundant.

Instruments connected to the IPS (Instrumented Protective System) system shall be designed to meet the system SIL rating.

The tank Contractor shall wire all fire and gas detectors described below, starting and ending at a junction box supplied by the Contractor and located on top of tank. The outgoing and return path to the junction box shall be routed with sufficient separation to ensure that they will not be involved in a single incident.

All fire and gas junction boxes are designed for installation in a Class I, Div. 1 area. The tank Contractor's wiring between these devices shall meet the requirements for this classification.

10.2 COOLDOWN SENSORS

The Contractor shall provide temperature sensors to detect temperatures during tank cool down and operation and decommissioning. The minimum number of sensors and location shall be as indicated below. The Contractor shall be responsible for wiring these devices to a separate junction box on top of tank. The wiring shall be suitably supported and protected by conduit.

Temperature sensors shall be type "T" thermocouple in accordance with ISA MC96.1-82 suitable for the design temperatures.

The number and location of the temperature sensors shall be as follows:

- 6 temperature sensors shall be equally spaced along a vertical line on the inner tank shell.
- 16 on the inner bottom plate to monitor tank cool down/warm-up.

Thermocouple extension cable from the thermocouple lead to the tank junction box shall have 16 gauge conductors with appropriate insulation on individual wires with Mylar tape shielding, and Kapton® overall jacket. Extension wire must be suitable for type "T" thermocouples. All thermocouple wiring shall run through a single nozzle to the junction box

on top of tank. The Contractor shall use RTD cool down sensors based upon demonstrated past installation experience.

10.3 INNER TANK LEAK DETECTION SYSTEM

A leak detection system SHALL [PS] be installed in the outer tank bottom annulus to continuously monitor the temperature of the outer bottom liner plates. The system shall contain a sufficient quantity of sensor elements complete with cable pre-wired to a junction box located within tank Contractor's battery limit.

- A minimum of 4 sensor elements, evenly spaced, complete with cable pre-wired to a junction box shall be capable of producing a process alarm in the control room when low temperature due to a leakage, spillage, or condensation is detected. The system shall also include 4 spare sensors in the tank annulus pre-wired to a junction box at the tank bottom.

To provide an indication of the build-up of any liquid inside the annular space, at one location, two additional sensor elements shall be installed on a vertical line from the bottom corner, the tank Contractor shall provide relevant spares. The separation distance between the sensors shall be 1m (36 in), with the lowest sensor located 1m above the annular plate.

- Fibre Optic Leak Detection System with a temperature accuracy of 2 °C (4 °F) shall be installed at the bottom of annular space.

The monitoring system shall provide an alarm in the control room when liquid is detected.

The monitoring system shall also provide a system alarm if it malfunctions.

The leak detection system, including sensors, sensor lead wire, junction boxes at the tank .

10.4 THERMAL SENSORS FOR HEATING SYSTEM.

A continuous temperature monitoring system for the bottom slab is required. The system shall consist of heating controls and heating alarms. A minimum of 24 temperature sensors shall be distributed over the bottom slab. The following distribution shall be considered:

- A minimum of 4 of the sensors must be located under the inner tank concrete ring beam.
- A minimum of 1 active and a minimum of 1 spare sensor are to be located at the centre of the bottom slab.
- A minimum of 18 sensors (13 active and 5 spare) sensors is to be distributed over the bottom slab.

The Contractor shall provide and install a temperature-monitoring system including sensors, sensor lead wires and junction boxes.

Digital indicators and input controllers for use with the sensors shall be provided.

- The input controllers shall be capable of control with +1% repeatable accuracy.
- The input controllers shall provide alarms to detect open temperature sensor circuits and high/low temperatures.
- Control temperature is normally between 2 °C and 5 °C (35 °F and 41 °F)

The number of input controllers shall be selected to ensure monitoring the specified cold spots in each zone.

- The main zone requires a minimum of three controllers.
- Single-controller zones shall have a redundant controller installed as a backup.

The input controllers shall be connected to a low signal select device to control the heating cables in each zone. Operation of the control shall be failsafe. In the event of failure, a local and remote alarm shall be actuated and the heating system energised.

The output controllers shall provide control and monitoring functions for the heater cables. Solid state controller design shall use a zero-voltage on/off control coupled with time proportioning control feature to produce an evenly distributed power demand.

The output controllers shall digitally display the heater cable amperage for each circuit and provide high/low current alarm for each heater.

As an alternative on/off solid state output relays may be used subject to approval by the Principal.

Maximum current controlled by each relay shall not exceed 80% of its continuous ampere rating.

Ammeters shall provide visual indication of each circuit status.

Current sensing relays shall monitor each circuit for proper operation and provide high/low current alarms. Controllers and indicators shall be remotely mounted unless otherwise indicated.

Controllers, when located outdoors, shall be housed in an IP56 stainless steel enclosure, free standing or wall mounted. The enclosure shall be sized to allow easy access for maintenance of the controllers.

The enclosure shall be pressurised with either instrument air or nitrogen at a minimum of 62 Pa (1.29 lb/ft²).

Loss of pressurisation shall initiate a remote alarm in the central control room.

Controllers, when located outdoors, shall be housed in an IP65 stainless steel enclosure, free standing or wall mounted. The enclosure shall be sized to allow easy access for maintenance of the controllers.

10.5 LIQUID LEVEL INSTRUMENTS

The following tank instrumentation SHALL [PS] be provided by the Contractor.

Two independent level gauges equipped to provide remote readings and high level alarm signals in the Main Control Room. Each gauge shall be equipped with a transmitter and alarms for low level, normal maximum operating level, high level (LHA), and high-high level with emergency alarm and/or trip (LHHA (CO)). The primary and the secondary level gauge shall provide readings and alarms via two independent safety rated PLC (IPS).

A third level instrument shall be used as back-up for the secondary level gauge for level high alarm (LHA) and level high, high alarm with cut out (LHHA CO).

Both the secondary level gauge and the backup level gauge shall be wired independently from the primary level gauge to provide alarms and diagnostics. The backup gauge shall use different level sensing technology from the secondary level gauge to avoid the potential for common mode failure.

- The second and third level gauges are considered safety rated devices and shall be wired utilising separate junction boxes and separate cabling from the primary level gauge and all other non-safety devices. The safety gauges shall be wired directly to the terminal's safety rated PLC (IPS).

All level gauges shall be equipped with diagnostics to detect and alarm for device malfunctions.

A non-resettable HH level alarm (as existing tanks) connected to a beacon in the Main Control Room (MCR).

- The installed level measuring system shall meet the requirements of SIL 3 to ensure that the risk of overfilling may be considered ALARP.

Soft wired interface to DCS system is required. The Contractor shall provide address mapping data in format approved by the Principal.

The Contractor shall supply the gauges, stilling wells, supports, guides for gauges, and wiring including the electrical junction box on the tank platform for all components. The Contractor shall also provide receivers for installation and wiring in the MCR.

- All applicable field instruments shall be wired to junction boxes provided by the Contractor. The Contractor shall provide termination drawing or equivalent list for the TMS.
- The Contractor shall follow the Principal's tagging system instruments.

10.6 LIQUID STRATIFICATION MONITORS

The Level Temperature Density (LTD) instrument shall be located remotely from the liquid inlets and shall be used to monitor the potential stratification and thus preventing rollover.

The LTD instrument shall be servomotor operated and shall include a mobile multi-sensor probe assembly to sample liquid automatically at any depth chosen by the operator.

The instrument SHALL [PS] have facility to allow information to be sent to the plant control system and to indicate automatically the onset of unacceptable stratification.

10.7 FIRE AND GAS DETECTION SYSTEM

The Contractor shall install a fire and gas detection system for the LPG storage tanks. The fire and gas detection system will power detectors, monitor for alarms, perform logic and when applicable actuate water based fire protection systems and initiate alarms in the CCR and in the field. Alarm Annunciation and signalling shall follow the Principal standard.

The Principal will free issue all fire and gas detection devices to the Contractor with the exception of the heat detection loop. The tank Contractor is responsible for mounting the detectors and supply and installation of all JB's cabling on the top of the tank and from the cabling to the Principal's junction box at grade.

10.8 FLAMMABLE GAS DETECTION

Gas leaks will be detected by point IR and open path combustible gas detectors that will detect the evolved gas.

Infrared Point and Open Path combustible gas detectors SHALL [PS] be installed by the Contractor based upon a Fire and Gas detection mapping study using established modern modelling technology. The Contractor shall submit the mapping technology and methodology to the Principal for approval. The outcome of this study shall define locations and type of the required detectors.

10.9 FIRE DETECTORS

Heat detectors and flame detectors SHALL [PS] be installed on the tank roof to provide detection at the overlooking fire areas. IR flame detectors shall be located to provide coverage of the pump platform (main platform). Fire detectors shall be provided to cover the whole main platform.

- Flame detection shall cause an alarm and also start the fire water pump(s).
- Heat detection system consisting of a linear heat detection system, shall be installed along the roof platform railing, near the pressure relief valves and where a water based protection system is used for the protection of equipment.
- Upon alarm of heat detection at the pump platform, operators will assess the situation using CCTV cameras and as required actuate the water-based protection system from the control room.

10.10 MANUAL CALL POINTS

Manual call points shall be provided to allow manual actuation of fire alarms. Manual call points shall be located at the top and bottom of each of the LPG storage tank stairs to grade for a total of four (4) on each LPG storage tank.

These shall trigger both local and remote visual and audible alarms and automatically activate the firewater pump(s). Activation shall be via manual operation of water-based protection systems and shall be from the MCR.

10.11 CCTV CAMERAS

Colour CCTV system camera(s) shall be provided and installed by the tank Contractor in order to monitor all essential appurtenances on the main platform and on the tank roof. The cameras shall be connected to the existing plant supervision CCTV system.

10.12 PA/GA SYSTEMS

Telephone system and public address/general alarm systems shall be suitable for the area classification and comply with the requirements of DEP 32.71.00.10-Gen.

10.13 WATER MONITORS.

There is a general preference to use firewater monitors designed in accordance with DEP 80.47.10.30-Gen. and DEP 80.47.10.31-Gen. for exposure protection instead of nozzle spray systems.

Free standing water monitors for the LPG tank SHALL [PS] be provided on the roof platform for the protection against LPG tank relief valve discharge fire. The monitors shall be capable of covering the pump platform (main platform), PRV bodies and instrumentation platform (level/pressure platform). Protection of the PRV bodies requires normally a minimum of two firewater monitors and the pump platform plus a instrumentation platform and two-four firewater monitors (depending installed type).

The roof platform, equipment, instrumentation and safeguarding systems shall be protected against local fires at an application rate of 4 l/m²/min (0.10 gpm/ft²). The application rate can be reduced to 2 l/m²/min (0.05 gpm/ft²) if they are located > 25 m (80 ft) away from the nearest pressure relief valve.

The total firewater monitor configuration shall be based upon being capable of protecting against an own fire incident or a fire incident originated from a nearby tank.

Use of oscillating firewater monitors in combination with fixed firewater monitors might need to be considered to ensure adequate coverage for both design scenarios.

Fire water pressure at grade shall be as specified in the Tank Datasheet.

The piping and header system downstream of the remote operated water supply control valve shall be maintained in dry condition (i.e., self draining). Piping materials shall meet the minimum requirements as stated in DEP 80.47.10.31-Gen.

The Contractor will supply the firewater piping and local block valve.

In addition, portable powder extinguishers shall be provided for the following platforms, i.e., main, instruments, VRV and PRV platforms.

10.14 PRESSURE RELIEF PROTECTION

Pressure relief valve outlet pipes shall discharge vertically and at sufficient height so as not to require protection of the concrete structures by means of water-spray systems (deluge system). In the instance of a pressure relief valve fire, PSVs shall be provided with a tail pipe with length according to thermal radiation/gas dispersion analysis (0). The tank Contractor shall determine the final elevation of the discharge to meet the allowable thermal radiation on different parts of the dome roof. The outlet pipe shall discharge at 10 m (32 ft) above the concrete roof as a minimum (measured along a vertical line through the

discharge point) and SHALL [PS] allow unrestricted vertical flow in the event of a discharge. Hinged mechanical rain flaps shall not be fitted.

PSVs SHALL [PS] be provided with a nitrogen snuffing systems that can be operated (valves) from safe location (at grade).

10.15 INSTRUMENT CONNECTIONS

The tank shall be provided with nozzles for all instrument connections shown on the P&IDs. The Contractor shall provide a complete listing of all nozzles supplied with description of their function

10.16 INSTRUMENT WIRING AND ELECTRICAL WIRING.

All instruments shall be wired to junction boxes. Instrumentation shall be consistent with that of the process units. The equipment and field instrumentation and its installation, documentation, cable types/identification, signal segregation, instrument certification, TAG numbering, etc., shall conform to the balance of the plant check. Standards for general concerning radio frequency interference shall be adopted wherever possible.

11. ELECTRICAL

11.1 GENERAL

The tank Contractor shall be responsible for the engineering, design, procurement, installation and integration of all tank-related electrical installation that is necessary for tank fill operation, storage, and transfer of the LPG, including loading pump motors, base slab heating system, lighting system, earthing and lightning protection system, motor-operated valves, hoist and passenger lift electrical system, and all associated cabling, wiring and accessories.

The design of electrical systems and equipment shall ensure continuous operation and all operating and maintenance activities can be performed safely and conveniently. The electrical system shall be designed to be efficient, reliable and cost effective. Equipment shall be selected and specified with due consideration to the area classification, quality, efficiency, durability, availability, maintainability and cost. Standardisation of materials and equipment shall be consistent with existing design.

Electrical equipment shall be designed, fabricated, supplied, erected, inspected and tested in accordance with the relevant standards of the Principal, DEPs, IEC standards, and additional requirements as given in this DEP. Equipment of similar nature and incorporating similar or identical components and of similar or identical construction should be of the same manufacture (e.g., power and convenience outlets, luminaries, junction boxes, RCU's, switches, etc.).

The electrical installation and equipment for the LPG tank shall be in accordance to DEP 33.64.10.10-Gen.

Electrical safety rules shall be in accordance with DEP 80.64.10.10-Gen.

Electrical equipment tagging shall be per the Principal's standards.

Electrical equipment is to be supplied per the Approved Manufacturers List.

Electrical area classification shall be based on the IP Code of Safe Practices Part 15, supplemented by DEP 80.00.10.10-Gen.

All electrical equipment in the hazardous area within the tank battery limits shall be suitable for the area classification, gas group, temperature class and environmental conditions.

For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a certificate of conformity shall be obtained from the Manufacturer.

For non-hazardous area within the tank battery limits, material as specified for Zone 1 and Zone 2 areas shall be used.

11.2 PUMP ELECTRICAL INSTALLATION/HOOKUP

The submerged motor and pump shall comply with DEP 31.29.06.30-Gen. and DEP 33.66.05.31-Gen.

11.3 LIGHTING

The tank Contractor shall design and supply tank lighting attached directly to the LPG tanks. Lighting shall be installed to allow safe access and escape from the roof platform and to allow maintenance work in these areas. Lighting shall comply with the requirements of DEP 33.64.10.10-Gen. This scope includes supply and installation of lights, embedments, supports, conduit and cabling to junction box(es), located at grade level at the defined battery limit.

The Contractor shall design all permanent lighting and shall submit drawings to the Principal for approval. Lighting shall comply with the requirements of DEP 33.64.10.10-Gen., Section 4.10, Section 5.4 and Appendix 4.

11.4 EARTHING AND BONDING

Earthing shall be provided to ensure that an earth return path exists in case electrical equipment develops an electrical earth fault, e.g., the submerged pumps installed in the pump wells, light poles in contact with the metallic handrails, platforms or staircases, or the heating cables installed in the conduits.

Each tank shall have three earthing bosses. The inner tank, liners, etc., shall be bonded together and connected to earth at the bosses which shall be evenly distributed over the circumference of the tank.

LPG Tank earthing/grounding and bonding shall meet the requirements of DEP 33.64.10.10-Gen., Sec 5.5. All electrical equipment shall be earthed and bonded to the earthing grid. The earthing facilities to be provided in substation is detailed in Standard Drawing S 68.030. Typical earthing system for tanks is given in Standard Drawing S.68.001.

The inner tank and the roof and bottom liners shall be bonded together and connected to earth at least three locations, evenly distributed over the circumference of the tank. Earth electrodes shall be evenly distributed over the tank perimeter area and spacing of earth electrodes will be dependent upon earth resistivity. The 70 mm² (0.1 in²) conductor shall be buried at a depth of 500 mm (20 in) around the tanks.

11.5 LIGHTNING PROTECTION

Lightning protection shall be installed on the concrete roof in accordance with DEP 33.64.10.10-Gen. and IEC 62305. The Contractor shall supply a lightning protection system comprising air terminals, bonding conductors and down conductors of at least 70 mm² (0.1 in²) on each tank. The air terminals will be connected to 70 mm² (0.1 in²) copper cables which will be routed via the vertical pipe way to the LPG tank base, where the cables will be terminated at individual vertical earthing electrodes. A lightning protection system shall be connected to main plant earth grid as per DEP 33.64.10.10-Gen.

LPG tank circumferential handrail, lightning stanchions, platform, cable tray, vent sacks, piping and pipe way will be bonded to the individual down conductors lightning protection system to avoid side flashing.

11.6 AIRCRAFT WARNING LIGHTS

Aircraft warning lights shall be provided in accordance with DEP 33.64.10.10-Gen.

The tank Contractor shall design, supply and install aircraft warning lights at the highest point on the top of the tanks in accordance with International Civil Aviation Requirements (ICAO), "International Standards and Recommended Practices - Aerodromes", and per local government regulations.

The tank Contractor's scope of supply shall include warning lights, fixtures, electrical wiring, junction boxes, conduits, supports, control and alarm systems, transformers and other material as required for the installation, safe and reliable operation, and easy maintenance of the aircraft warning system.

Aircraft warning lights shall be controlled automatically by a photoelectric control system and shall be equipped with a lamp failure alarm system.

The lights shall be readily accessible to enable cleaning when necessary, and to facilitate lamp replacement.

11.7 BASE SLAB HEATING SYSTEM

11.7.1 General

A heating system shall be installed in the concrete bottom slab to prevent frost heave of the subsoil. The heating system shall be designed and positioned to provide a uniform and constant temperature in the protected areas and shall not result in uneconomic boil-off of refrigerated hydrocarbon as result of an unbalanced design.

Under normal operation conditions, the concrete base slab under the tank foundation shall be kept between 5 °C (41 °F) and 10 °C (50 °F).

The system shall be complete from the point of power supply and shall provide all necessary functions including under-tank heating, power distribution and control , protection, alarms, temperature sensing, temperature monitoring for each tank.

Electrical heating elements shall be placed in stainless steel conduits and tapes shall be installed in the bottom slab.

Both self-regulating and power limiting heater cables are technically acceptable for use of heater element material.

A conduit system shall be embedded in the concrete tank foundation to protect the heating cable inside the concrete and to allow easy installation and replacement.

The conduit shall be of 316-stainless steel and have an inside diameter of 25 mm (1 in).

The overall responsibility of the design, engineering, installation and testing of the heating system shall rest with the Contractor.

The Contractor shall fully describe his proposed foundation heating system, including design, layout, installation, temperature control, monitoring and maintenance in his proposal.

The bottom slab heating system shall comply with the requirement of DEP 33.68.30.31-Gen and project specifications.

Heater design, material, conduit system, circuit protection, etc. shall be per DEP 33.68.30.31-Gen.

The heating system temperature control shall comply with the requirements of DEP 32.31.00.32-Gen.

The heater power distribution panel shall be of the indoor, industrial type in accordance with DEP 33.67.01.31-Gen. and installed in the plant switch room.

The distribution board (sub distribution boards) shall be tested in accordance with the requirements of DEP 33.67.01.31-Gen.

The "Type" testing of the trace heaters shall be done in accordance with section 5.1 of IEC 62086-1.

The "Routine" testing of the trace heater shall be done in accordance with section 5.2 of IEC 62086-1.

11.8 CABLING, WIRING AND ACCESSORIES

In general, HV power cables (outside the LPG tank) shall be multi-core cross-linked polyethylene (XLPE) insulated, galvanised steel wire armoured and PVC oversheathed. The HV power cable from the outdoor HV terminal box to the ESP motors shall be suitable for its service (low temp, up to -50 deg C (-58F)).

In general, LV lighting and control cables shall be multi-core cross-linked polyethylene (XLPE) insulated, galvanised steel wire armoured and PVC oversheathed. The minimum cross-section shall be 2.5 mm² (0.004 in²), except for signalling and indication purposes, where a minimum cross-section of 1.5 mm² (0.0025 in²) may be used.

Flexible cables for voltages up to 450 V to earth shall be heavy duty neoprene rubber insulated, PVC sheathed. Flexible cables used in hazardous classified area shall meet requirements of IEC 60079-14.

Wiring shall be PVC insulated in accordance with DEP 33.64.10.10-Gen.

Junction boxes and cable glands for hazardous areas shall comply with DEP 33.64.10.10-Gen.

Glands shall be selected to suit the type of cable and termination box/enclosure, and shall be of the appropriate type of protection, e.g., Ex'd', Ex'e'. Effective earth continuity shall be ensured between the cable armour/braid and the gland plate or the internal earth terminal.

In general, power and control cable(s) shall be installed underground in direct buried trenches. Cables crossing roadways shall be routed in PVC conduit banks laid in concrete culverts.

All above ground cable shall be supported by cable racks, cable trays, or conduits all the way to their termination point and suitably protected from mechanical damage.

Cable ladder racks shall in general be heavy-duty, hot-dipped, galvanized-type, suitable for 6 m (20 ft) spacing without excessive deflection. Accessories shall be stainless steel or aluminium.

Cable trays shall be hot-dipped, galvanized-steel, suitable for 2m (6.5 ft) spacing without excessive deflection.

11.9 ELECTROMAGNETIC COMPATIBILITY (EMC)

EMC requirements shall be satisfied as per DEP 33.64.10.33-Gen., Section 3 and Section 4.

11.10 FLAMEPROOF EQUIPMENT

All electrical equipment installed in the hazardous area shall be suitable for the area classification, gas groups/temperature class, and environment conditions.

The Contractor shall provide a list of flameproof equipments and, as a minimum, the details below as per IEC 60079 – Part 17:

- a) Circuit safety documents, where appropriate;
- b) Manufacturer, equipment type and certificate numbers, level of protection and, in case of gases, equipment group and temperature class
- c) Where appropriate, electrical parameters such as capacitance and inductance, length, type and route of cables;
- d) Special requirements of the equipment certificate(s) and detailed methods by which such requirements are met in the particular installation;
- e) Physical location of each item in the plant.

11.11 INSTALLATION AND COMMISSIONING

The installation, testing and commissioning of electrical system shall be in accordance with DEP 63.10.08.11-Gen. The following shall be checked for the ESP motors before commissioning:

- a) ESP vertical supports
- b) Installation and positioning of the ESP
- c) Vertical leveling within acceptable range.
- d) ESP Suction/Discharge nozzle facings alignment.
- e) ESP package coupling alignments.
- f) ESP seal system checks

12. PRESSURE AND VACUUM RELIEF SYSTEMS

12.1 GENERAL

Provisions for pressure and vacuum relief nozzles and equipment, including spares SHALL [PS] comply with the P&ID's. Operating factors that shall be considered in sizing PRV's and VRV's are stated in NFPA-59A, 4.7. Design shall be in accordance with API 2000 – 1998.

Each tank shall be provided with pilot-operated pressure relief valves, with teflon diaphragm, seat and seals. Preferably the pressure relief valves shall be located opposite the main platform.

12.2 PRESSURE RELIEF VALVES

The valves shall relieve from the inner tank vapour space. This requires the inlet piping to penetrate the suspended deck. The penetration of the suspended deck shall be such that, in the event of an overfill, LPG cannot block the pressure relief inlet pipes.

The PSV's shall be set at the tank design pressure and shall be sized to accommodate the operating and emergency venting flow rates.

The Contractor utilizing flow rates and process conditions shall determine the number of valves. One spare, for maintenance operation (n+1), shall be provided, with a minimum of three (3).

The number of valves shall be adequate for safe relief of gas generated by inner tank design leakage (LPG rollover is not taken into account (EN 1473)). These valves shall be capable of preventing the internal tank positive pressure by exceeding the tank design pressure by more than 10% when at full flow and considering assumed overpressure.

Separate pressure and vacuum relief valves shall be provided each with a block valve and locking device on the tank side. Spare pressure and vacuum relief valve nozzles shall be provided in accordance with the recommendations contained in EN 14620.

Each tank shall be provided with a minimum number of pilot-operated pressure relief valves, including remote pilot pick-up. The valves shall be mounted on the concrete roof.

The outlet (tail pipes) shall be provided with a steel bird-screen and drain hole at the lowest point on the vertical riser to ensure that water does not pond or collect within the tailpipes.

Number of PRVs are indicated in the Tank Datasheets.

Access to the tail pipes shall be provided for routine maintenance and inspection.

12.3 RESERVE CAPACITY RELIEF VALVES

In accordance with the EN 1473, §6.6.3, the tank will be equipped with a rupture disk, (RCRV). The RCRVs shall relieve from the dome space and discharge to atmosphere.

The RCRVs shall be designed in the event of fire exposure, product rollover or other unusual event. These valves shall be capable of preventing the internal tank positive pressure from exceeding the tank design pressure by 20% for full force flow.

It shall be pointed out that the design of the RCRVs will take into account the failure to open of the hot gas which is a key consideration in the sizing of the RCRV capacity.

The RCRVs shall relieve from the dome space and discharge to the atmosphere. The valves shall be located far from the pressure relief valves (in view of possible fire).

Number of RCR's are indicated in the Tank Datasheets.

12.4 VACUUM RELIEF VALVES

Vacuum relief safety valves shall vent directly from atmosphere to the dome space of the tank. Vacuum relief safety valves shall not be mounted on the same nozzle in series with pressure relief safety valves.

The tank Contractor, utilizing flow rates and process conditions shall determine the number of valves. One spare, for maintenance operation (n+1), shall be provided, with a minimum of three (3).

Number of PRVs are indicated in the Tank Datasheets.

The tanks shall be provided with pallet type vacuum relief valves.

13. ACCESSORIES

13.1 ROOF PLATFORM

A concrete or steel frame roof platform, with a steel grating floor, stairways and other provisions for equipment support and personnel access shall be designed, furnished and constructed by the Contractor.

The roof platform and all isolated piping valves, etc. shall be supported from the concrete roof or sidewalls. The roof platform shall be designed to support all piping, valves pumps, hoists, etc., that are contained within the platform limits.

In addition, the platform shall be designed such that it can be used as a layout area for the pump cables. The Principal will advise the Contractor if flow meters are to be used for custody transfer of LPG.

13.2 ACCESS TO PLATFORM AND ROOF

13.2.1 Stairway

Ancillary structures shall comply with the requirements of DEP 34.28.00.33-Gen. A main stairway with intermediate landings at maximum vertical spacing of 6 m (20 ft) shall give access from the maintenance road to the roof platform. Stair treads shall be of the open grid type with visible edges and may be either welded rectangular pattern or of pressed steel. They shall be hot dip galvanised. The width of opening shall not exceed 25 mm (1 in) and rectangular pattern tread with main bearing bars having a minimum thickness of 5 mm (3/16 in) shall be used.

Two (2) additional staircases shall give access from the platform to the tank roof. An emergency cage ladder shall allow access from the tank roof to the maintenance road and shall be located opposite the roof platform. All components of these staircases shall be hot dipped galvanised in accordance with requirement of DEP 30.48.00.31-Gen.

Two (2) manholes shall be installed in the tank roof, one at either side of the platform. These shall have minimum dimensions of 900 mm (Ø 36 in) and 1300 mm (Ø 52 in), respectively. Two cage ladders, one per manhole, shall give access to the suspended deck. A staircase supported by one or more pumpwells shall give access to the inner tank bottom via a manhole in the suspended deck (minimum dimension 900 mm (Ø 36in)). A manhole in the suspended deck (minimum dimension 1300 mm (Ø 52 in)) shall be located directly underneath a roof manhole of corresponding dimensions. This is to allow transfer of materials and equipment between the tank roof and the inner tank.

Walkways shall be installed just above the insulation of the suspended deck to allow access from the cage ladders to all hatchways in the suspended deck.

Walkways shall be provided on the tank roof to facilitate maintenance of equipment.

13.2.2 Walkways and handrails

Walkways shall be installed just above the top of the insulation on the suspended deck. These walkways shall connect the cage ladders to the staircase of the inner tank.

A walkway shall be installed across the centre of the roof to the perimeter for accessibility of instruments, valves, etc. and for escape via the emergency access ladder. Walkways shall be provided on the tank roof to facilitate access and maintenance of instruments, equipment and valves installed above the roof on either side the roof platform. These platforms shall allow direct access to the roof platform.

Guard railing and toe plates shall enclose all product nozzles, pressure relief devices, and instrument attachments located on the top of the tank. Guard railing shall be provided on the open sides of all stairways and platforms, and around the roof perimeter.

Handrails, guardrails and platforms shall be hot dip galvanized in accordance with requirements of DEP 30.48.00.31-Gen.

13.3 CRANES/HOISTS

One or two electrically driven jib cranes, or, alternatively, a gantry crane, shall be installed on each roof platform to lift the submerged pumps into and from the pumpwells and to facilitate other maintenance work on the platform. The hoists shall be capable of lowering pumps to grade level. The lifting capacity of each hoist shall be at least 50 % greater than the maximum load to be lifted.

Each hoist shall comprise two independent lifting cables operated by a powered slow drive winch. A screw type, which cannot self unwind, is preferred. One cable is required for the lifting duty with the other acting (via a slipping clutch or similar device) as a reserve should the primary cable or lifting mechanism fail. Each hoist shall also be provided with a hand wind override and a high-speed break.

Movement of the hoist and lifted equipment along the jib or gantry structure shall be achieved by the use of an electrical winch. Provision shall also be made for the simultaneous withdrawal and storage of the pump electric cables. Lifting cables shall be of the cross wound, non-kink type.

Cable drums shall be provided to gather and prevent cables being laid on the deck areas.

All hoisting systems shall be load tested.

Cranes/Hoists shall be suitable for the hazardous area Zone = 2.

13.4 MONORAILS

For maintenance purposes, one monorail (trolley beam) for a gondola (2 persons) shall be installed inside the tank, above the annular space. The Contractor may install additional monorail(s) for tank erection purposes if needed.

The Contractor shall include the design and supply of reinforced pads, embedments, and plinths for attachment of pipe supports, electrical/instrument cable, platform, and handrail supports.

14. PAINTING AND COATING

14.1 INNER TANK STEEL PLATES

All surfaces of the inner tank, bottom/corner protection and liner plates, shall be grit blasted to SA 2.5 and shop primed with a suitable pre-construction primer (minimum dry film thickness 25 microns). A margin of approximately 50 mm (2 in), along weld edges, shall be left and coated using a weldable protection product such as deoxy-aluminite.

Any potential contamination of the weld edges and the adjacent surfaces by zinc shall be positively excluded. The tank Contractor shall prepare an adequate procedure for cleaning and inspection.

All precaution will be taken to avoid detrimental corrosion during delivery, transportation and storage. The tank Contractor shall explain clearly, during the proposal, measures to be taken to prevent any detrimental corrosion.

Mill or shop priming of steel plates is permitted. However, any prime coat applied to the LPG exposed inside surface shall be compatible with LPG service temperature and will remain intact during tank operation.

14.2 METALLIC VAPOUR BARRIER

The vapour barrier plates shall be shop primed on both sides to avoid detrimental corrosion during delivery, transportation and storage.

Steel plates shall be blast-cleaned on both sides up to the grade SSPC-SP 10/SA 2 ½ from ISO 8501-1 with a minimum thickness of 1.2-mil; (30 microns). All welding aspects will be taken into account in the choice of the final product.

14.3 STRUCTURAL STEEL

All exterior steel structures, stair, walkways, platforms and handrailing, guardrails, nozzle sections embedded in the concrete and fire protection piping shall be hot dip galvanised to the requirements of DEP 30.48.00.31-Gen.

All remaining exterior metallic surfaces including insulated surfaces, shall be fully painted in accordance with the requirements of DEP 30.48.00.31-Gen.

15. TESTING AND CALIBRATION

15.1 HYDROSTATIC TESTING OF INNER TANK

Hydrostatic testing of the inner tank shall be in accordance with EN 14620-5. In addition, the following shall apply.

- a) Prior to the hydrotest, the Contractor shall provide a full analysis of the test water.
- b) In the event that the chloride content of the test water exceeds 30 ppm, all austenitic stainless steel components which are exposed to the hydrotest water shall be flushed thoroughly with water of a chloride content of < 5 ppm.
- c) The water inlet shall be provided with a splash plate.
- d) A complete hydrostatic-pneumatic test procedure shall be provided by the Contractor including the drying and cleaning procedure after the test. The hydrostatic test shall be completed before installation of the suspended deck and wall insulation. The pneumatic portion of the test need not be simultaneous with the hydrostatic portion of the test.
- e) After testing, the tank shall be thoroughly cleaned with fresh water and dried.
- f) The tank shall be filled and emptied as quickly as possible. At the maximum level, the water shall be maintained for (minimum) 48 hours to facilitate inspection.

15.2 TESTING MEDIUMS

Acceptable testing mediums are as follows.

- Fresh water satisfying the water quality requirements specified in (0).
- Seawater satisfying the water quality requirements specified in (15.2.2). (There is a DR specific to seawater testing of LPG tanks. Equally, seawater testing of LNG is also permitted and covered by DRs.)

15.2.1 Fresh Water

The quality of water used for the hydrostatic test shall be potable and meet the requirements of EN 14620, and the following;

Contaminant		Concentration
Total Dissolved Solids	ppm	<500
Concentration of SiO ₂	ppm	<10
PH	-	>7 and <8.3
Ca and bicarbonate	-	Langelier index >=0
Chloride (NaCl)	ppm	<50
Sulphate (SO ₄)	ppm	<150
Free residual chlorine concentration	ppm	>0.3 and <1.0
H ₂ S	-	No presence
Filtering (50 microns)	-	As required

In addition, water shall be clear, with no objectionable odour. Tank bottom sediment is not allowed.

15.2.2 Sea Water

The quality of seawater shall meet the following requirements;

Contaminant		Concentration
Total dissolved solids	ppm	< 100
BOD5 (biochemical oxygen demand)	mg/l	< 5
Sulphate reducing Bacteria	-	none
pH	-	6 – 8.3
Free residual chlorine concentration	ppm	> 0.3 and < 1.0
H ₂ S	mg/l	< 0.1
Temperature	C	< 40
Dissolved O ₂ at 30°C	mg/l	< 5
Bacterial plate count	CFU/m	<1000

In addition, the feed water shall pass through a 200 micron filter.

15.3 HYDROSTATIC/PNEUMATIC TESTING OF PUMP WELLS

Pump wells shall be tested in accordance with ASME B31.3, Chapter VI, 345.6. The design pressure shall be the pump discharge pressure as indicated on Tank Data Sheet(s). Prior to the tank hydrotest, the pump wells shall be emptied and sealed.

15.4 PRESSURE AND VACUUM TESTING

The outer tank shall be pneumatically tested in accordance with EN 14620.

The outer tank and the pressure and vacuum relief valves shall be pneumatically tested in accordance with the requirements of EN 14620.

The hydrostatic testing and pressure/vacuum testing may be carried out independently but pneumatic pressure shall be completed prior to the installation of both deck and wall insulation.

15.5 CALIBRATION

The Contractor shall arrange, in consultation with the Principal, calibration of the inner tank by a specialist organisation in accordance with the API MPMS-2 or other internationally accepted code. The Contractor shall supply gauge tables, or equivalent calibration curves and equations, which relate the actual tank volume under operating conditions and at various product levels to the warm, measured, tank volume, as required by the Principal.

16. SETTLEMENT MONITORING

16.1 SURVEY MARKERS

A settlement monitoring system shall be provided to measure and record the inner and outer tank movement during construction, hydrotesting and operations.

Survey points at a maximum 10 m (32 ft) circumferential spacing shall be installed at the outer edge of the base slab. The total number of survey points shall be divisible by a multiple of 4 to ensure location at the cardinal locations.

Survey markers shall be permanent and easily accessible, from the base slab.

16.2 INCLINOMETERS

The Contractor shall install casings (non corrosive) along two perpendicular lines in the base slab of each tank and provide a horizontal, digital-type inclinometer sensor. The inclinometer shall be capable of measuring settlements to an accuracy of ± 2.5 mm (0.1 in) per 30 m (100 ft) of casing. The casings of suitable diameter for the proper functioning of the inclinometer shall be cast into the base slab and located at the upper most layer of the base slab. Casing shall be installed such that any water is free to drain to the tank edges and low spots should be avoided. Chairs or other devices shall be used to ensure the correct vertical position is maintained during pouring.

The inclinometer sensor shall be furnished with complete control and pull cables plus storage reels.

As a minimum, the readings for the settlement shall be taken as follows;

- On completion of base slab construction and prior to the first wall, lift shall be considered as the datum position.
- Remote control station shall be established which is free from settlement against which the benchmark shall be made.
- During construction, settlements of the base slab and inner tank shall be monitored on a monthly basis.
- During hydrotest, rotations and base slab tilting shall be monitored at each 2.5 m (8 ft) increment of water height for both filling and emptying operations.

The Contractor shall supply dial gauges to record vertical and horizontal movement of the annular plate during hydrotest. The dial gauges shall provide readings with an accuracy of ± 0.01 mm (0.0004 in). The tiltmeter for annular plate rotation shall be capable of measuring rotation with an accuracy of 8 seconds of arc or ± 0.02 degree rotation.

Dishing settlements and total settlements shall be verified with design allowables determined via the requirements of this DEP or the geotechnical Engineer.

The Contractor shall submit details of the system proposed to the Principal for approval.

17. PRE-COMMISSIONING

17.1 DRYING AND INERTING

A detailed drying, purging and cool-down procedure shall be provided by the Contractor for approval by the Principal.

Drying and purging shall be carried out with dry high purity nitrogen. The high purity nitrogen and the materials required for purging shall be supplied by the Contractor. Initial drying may be carried out with dry air if economically attractive.

- The complete space enveloped by the outer tank shall be purged to a maximum dew point of -27 °C (-16.6°F) and a maximum O₂ concentration of 5%.
- There is no specific oxygen level requirement for the under bottom insulation however the dew point and O₂ concentration shall be monitored during inerting.

Purging shall be conducted in accordance with the American Gas Association, Operating Section Report, Purging Principles and Practice, Section 4.35. The Contractor shall prepare procedures in accordance with AGA recommendations and submit for approval. The arrangement of purge piping and connections shall be fully illustrated and shall include the following provisions:

- a) All connections for the tank purging systems shall be through the roof.
- b) Purge ring in annular space.
- c) The tank base insulation between the inner tank and vapour barrier bottom shall be provided with means of purging residual vapour independently.
- d) Provision shall be made for each internal pump well to be purged prior to pump removal and after pump installation.
- e) Each pump foot valve shall be provided with a purge connection to the foot-valve seal if required by the pump Manufacturer.
- f) Each pump-well shall be provided with a high point vent connected to the vent system for venting purge gas from the pump-well.
- g) Provision shall be made to purge electrical terminal boxes for motor and instrument cables.
- h) Non-return check valves shall be provided on all purge lines. Removal spool pieces shall be provided on all lines connected to pump discharge and kickback lines.
- i) The inner tank and dome space shall be purged first. Dry air/nitrogen shall be introduced to inner tank through purge nozzle(s) and vented from a nozzle located at the top of the concrete roof. After completion, the annular space shall be dried and inerted by dry air/nitrogen displaced through the annular space and out of the tank through the ring header located on the bottom of the interspace. The bottom insulation shall be dried and inerted, as 'good as possible' with dry air/nitrogen from the annular space using the purge/venting system in the bottom insulation.
- j) The Contractor shall supply all required piping appurtenances for purging and cooldown.

17.2 COOLDOWN

It is the Contractor's responsibility to perform the tank cooldown operation. A cooldown ring line shall be provided under the suspended deck. The ring line shall be equipped with spray nozzles so that cooling down of the tank can be effectively controlled.

- The cooldown rate as measured at any one of the inner tank RTDs (or thermocouples) shall be controlled to not exceed 5 °C (9 °F) per hour.
- The maximum temperature difference between any two adjacent shell or bottom thermocouples shall be 10 °C (18 °F).

18. COMMISSIONING-GENERAL

The Contractor shall provide detailed commissioning procedure(s) for approval by the Principal and shall perform the commissioning in accordance with approved procedure(s).

19. REFERENCES

In this DEP, reference is made to the following publications:

- NOTES:
1. Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.
 2. The DEPs and most referenced external standards are available to Shell staff on the SWW (Shell Wide Web) at <http://sww.shell.com/standards/>.

SHELL STANDARDS

Thermal insulation	DEP 30.46.00.31-Gen.
Protective coatings for onshore facilities	DEP 30.48.00.31-Gen.
Centrifugal submerged motor pumps and electro submersible hydraulic turbines	DEP 31.29.06.30-Gen.
Piping - General requirements	DEP 31.38.01.11-Gen.
Instruments for measurement and control	DEP 32.31.00.32-Gen.
Plant telecommunication	DEP 32.71.00.10-Gen.
Electrical engineering guidelines	DEP 33.64.10.10-Gen.
Electromagnetic compatibility (EMC)	DEP 33.64.10.33-Gen.,
Electrical machines - Cage-induction types (amendments/supplements to IEC 60034-1 and IEC 60034-14)	DEP 33.66.05.31-Gen.
Low voltage switchgear and controlgear assemblies (amendments/supplements to IEC 61439)	DEP 33.67.01.31-Gen.
Electrical heating system for frost heave prevention of refrigerated hydrocarbon tanks	DEP 33.68.30.31-Gen.
Site preparation and earthworks including tank foundations and tank farms	DEP 34.11.00.11-Gen.
Geotechnical and foundation engineering - Onshore	DEP 34.11.00.12-Gen.
Reinforced concrete structures	DEP 34.19.20.31-Gen.
Onshore steel structures	DEP 34.28.00.31-Gen.
Onshore ancillary steel structures	DEP 34.28.00.33-Gen.
Field commissioning of electrical installations and equipment	DEP 63.10.08.11-Gen.
Area classification	DEP 80.00.10.10-Gen.
Assessment of the fire safety of onshore installations	DEP 80.47.10.30-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.

STANDARD DRAWINGS

Typical earthing systems for tanks	S.68.001
Typical earthing arrangements for substations, control buildings and field auxillary rooms and associated typical mounting details	S 68.030

AMERICAN STANDARDS

AGA Operating section report, Purging Principles and Practice <i>Issued by: American Gas Association</i>	AGA XK0101
Design and construction of large, welded, low-pressure storage tanks	API STD 620
Venting atmospheric and low-pressure storage tanks	API STD 2000

Manual of Petroleum Measurement Standard Chapter 2 - Tank Calibration Section 2A, B and C	API MPMS 2
2009 ASHRAE Handbook—Fundamentals. <i>Issued by: American Society of Heating, Refrigerating and Air-Conditioning Engineers</i>	ISBN: 978-1-933742-54-0
Large diameter steel flanges NPS 26 through NPS 60 metric/inch standard	ASME B16.47
Pipe flanges and flanged fittings NPS 1/2 through NPS 24 metric/inch standard	ASME B16.5
Use of ultrasonic examination in lieu of radiography - Section I; Section VIII, Divisions 1 and 2; and Section XII	ASME BPVC 2235-9
Process piping	ASME B31.3
Nondestructive Examination	ASME Section V
Rules for construction of pressure vessels, Division 1	ASME Section VIII
Qualification standard for welding and brazing procedures, welders, brazers, and welding and brazing operators	ASME Section IX
Recommended practice for personal qualification and certification in nondestructive testing - Item no. 2071, includes CP-105	ASNT ASNT-TC-1A
Qualification and certification of nondestructive testing personnel - Item no. 2508 , Includes CP-105	ASNT CP-189 Level I and II
Standard specification for general requirements for steel plates for pressure vessels	ASTM A20
Standard specification for carbon structural steel	ASTM A36
Standard specification for high-strength low-alloy columbium-vanadium structural steel	ASTM A572
Standard specification for straight-beam ultrasonic examination of rolled steel plates for special applications	ASTM A578
Standard specification for aluminum and aluminum-alloy sheet and plate	ASTM B209
Standard test method for steady-state heat flux measurements and thermal transmission properties by means of the guarded-hot-plate apparatus	ASTM C177
Standard specification for liquid membrane-forming compounds for curing concrete	ASTM C309
Standard test method for density, absorption, and voids in hardened concrete	ASTM C642
Standard specification for asphalt-saturated organic felt used in roofing and waterproofing	ASTM D226
Standard test method for compressive properties of rigid cellular plastics	ASTM D1621
Standard test method for tensile and tensile adhesion properties of rigid cellular plastics	ASTM D1623
Method of test for rate of burning or extent and time of burning of cellular plastics using a specimen horizontal	ASTM D1692-68
Standard specification for asphalt-saturated and coated organic felt base sheet used in roofing	ASTM D2626

Temperature Measurement Thermocouples ISA MC96.1

Issued by: International Society of Automation

IP SAFE- Model codes of Volume 3.00 Model Code of Safe Practice
Part 15: Area classification code for installations handling flammable
fluids IP

Issued by: Institute of Petroleum

Standard for the production, storage, and handling of liquefied natural
gas (LNG) NFPA 59A

BRITISH STANDARDS

Bitumen damp proof courses for masonry BS 6398

Structural use of concrete BS 8110

Recommendations for the design and construction of prestressed and
reinforced concrete tanks and tank foundations, and for the design
and installation of tank insulation, tank liners and tank coatings BS 7777-3

Welding use of time-of-flight diffraction technique (TOFD) for
examination of welds DD CEN/TS 14751-2004.

Non-destructive testing — Ultrasonic examination Part 6 — Time-of-
flight diffraction technique as a method for detection and sizing of
discontinuities DD ENV 583-6:2000

Double concrete tanks for liquefied gas – guide to design, construction
and operation EEMUA PUB NO 207

Issued by: The Engineering Equipment and Materials Users Association

EUROPEAN STANDARDS

Concrete — Part 1: Specification, performance, production and
conformity EN 206-1

Non-destructive testing - Qualification and certification of NDT
personnel - General principles EN 473

Non Destructive Testing - Industrial radiographic film - Part 1:
classification of film systems for industrial radiography EN 584-1

Thermal insulating products for building applications - Determination of
compression behaviour EN 826

Non-destructive testing of welds - Radiographic testing of welded
joints - Includes amendments A1:2002 and A2:2003 EN 1435

Installation and equipment for liquefied natural gas - Design of
onshore installations EN 1473

Eurocode - Basis of structural design - Incorporates Amendment A1:
2005; Incorporating corrigenda December 2008 and April 2010 EN 1990

Eurocode 1: Actions on structures - Part 1-4: General actions - Wind
actions - Incorporating corrigendum January 2010; Incorporates
Amendment A1: 2010 EN 1991-1-4

Eurocode 2 : Design of concrete structures - Part 1 : General rules
and rules for buildings EN 1992-1

Eurocode 8: Design of structures for earthquake resistance - Part 4:
Silos, tanks and pipelines EN 1998-4

Metallic products - Types of inspection documents	EN 10204
Design and manufacture of site built, vertical, cylindrical, flat-bottomed steel tanks for the storage of refrigerated, liquefied gases with operating temperatures between 0°C and -165°C	EN 14620
Part 2: Metallic components	EN 14620-2
Part 3: Concrete components	EN 14620-3
Part 4: Insulation components	EN 14620-4
Part 5: Testing, drying, purging and cool-down	EN 14620-5
Protective clothing for firefighters - Laboratory test methods and performance requirements for wildland clothing	EN 15614
Non-destructive testing of welds - Time-of-flight diffraction technique (TOFD) - Acceptance levels	EN 15617

INTERNATIONAL STANDARDS

International standards and recommended practices – Aerodromes <i>Issued by: International Civil Aviation Organization</i>	ICAO
Industrial Platinum Resistance Thermometer Sensors	IEC 751
Explosive atmospheres – Part 14: Electrical installations design, selection and erection	IEC 60079-14
Explosive atmospheres — Part 17: Electrical installations inspection and maintenance	IEC 60079–17
Electrical Apparatus for Explosive Gas Atmospheres - Electrical Resistance Trace Heating - Part 1: General and Testing Requirements	IEC 62086-1
Protection against lightning	IEC 62305
Recommendations for acceptance and application of post-tensioning systems, ISBN 978-0-7210-1231-5 <i>Issued by: International Federation for Structural Concrete</i>	IFSC
Welding and allied processes - Determination of hydrogen content in ferritic steel arc weld metal	ISO 3690
Paints and varnishes - Pull-off test for adhesion	ISO 4624
Welding — Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) — Quality levels for imperfections	ISO 5817
Preparation of steel substrates before application of paints and related products - Visual assessment of surface cleanliness - Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings	ISO 8501-1
Non-destructive testing — Qualification and certification of personnel	ISO 9712
Steel and steel products - Inspection documents	ISO 10474
Non-destructive testing of welds - Ultrasonic testing - Use of time-of-flight diffraction technique (TOFD)	ISO 10863
Non-destructive testing — Industrial radiographic film Part 1: Classification of film systems for industrial radiography	ISO 11699-1

OTHER DOCUMENTS

Impact and Explosion

M.Y.H Bangash, Blackwell,
CRC Press 1993

Recommendations for Acceptance of Post-Tensioning Systems –
1993

FIP Recommendation

APPENDIX A FIRE SCENARIOS

The concrete tank roof and side wall of each tank shall be designed for the thermally-induced loads resulting from adjacent tank fires and pressure relief valve fires documented herein.

A.1 ADJACENT TANK FIRES

For full containment tanks with concrete roofs, a roof collapse is considered non-credible in accordance with EN 14620. Adjacent tank fires of a full containment tank with a concrete roof need, therefore, not be considered within the design of the LPG tank.

A.2 PRESSURE RELIEF VALVE FIRES

These cases shall include the heat flux associated with each case, which is to be calculated by the tank Contractor and is subject to review by the Principal or the Principal's Contractor. Calculations shall include requirements of EN 1473, § 4.3.1, and Table 1.

The structures and concrete elements of the tank shall be designed for the following situation.

For the relief valve discharge fire, the following shall apply:

- a) Incident heat flux on the tank shell and structures shall be calculated for the maximum relieving rate associated. The cooling effect of the wind may be taken into account for the calculation, but the cooling effect of firewater spray shall not be taken into account.
- b) The most unfavourable condition shall be assumed in the calculation in conjunction with the 5th percentile wind speed.
- c) The calculation method may be Shell Jet Flame Model, which is available in DNV with Shell's FRED. Also, the Contractor shall ensure that their design satisfies the full containment integrity of the tank system and includes allowance for any thermal gradients across and through exposed tank parts.
- d) The tank Contractor shall advise the times required, at the specified or calculated heat flux levels, for the tank to suffer structural damage. In performing his calculations for the relief valve discharge fire case, the tank Contractor shall advise the heat flux incident on the LPG pump platform and on the tank roof walkways.
- e) The PRVs are assumed to release at full capacity.

The structures impacted by the incident heat flux shall be designed to withstand the same without escalation or collapse.

No credit for deluge shall be taken under the tail pipe fires.

APPENDIX B ULTRASONIC INSPECTION

B.1 INTRODUCTION

Ultrasonic inspection may be used in lieu of the radiographic examination.

The following options in terms of access are possible;

- Examination from both inner surface and outer surface.
- Examination from one surface.

Inspection shall be carried out by Time of Flight Diffraction (ToFD) method that will replace radiography and shall be carried out in accordance with the following.

B.2 FIRST OPTION - ASME BPVC CODE CASE 2235-9

ASME BPVC code Case 2235-8 "Use of Ultrasonic examination in lieu of Radiography, Section I and section VIII, division 1 and 2 (Dated October 27, 2005)

Acceptance/rejection criteria shall be in accordance to Tables 1 / 2 or 3 of Code Case 2235-9. Flaw interaction is defined in Figure 1 through Figure 5.

The ToFD operators performing the examination, data analysis/interpretation and evaluation shall be qualified and certified in accordance to the requirements of ASNT-SNT-TC1A and ASNT CP189 Level I and II. The employer's written practice for qualification and certification of ToFD personnel shall have the approval of the Principal. ToFD procedures shall have the approval of an ASNT-SNT-TC1A Level III individual and of the Principal.

References:

- ASME BPVC Code Case 2235-8
- Section I and Section VIII, Divisions 1 and 2" (dated October 27, 2005).
 - 2004 Section V
 - Article 4
 - o Article 4
 - o Appendix III – Time of Flight Diffraction (ToFD) technique (A06)
 - Article 4 – Non Mandatory Appendices
 - o Appendix L – ToFD sizing – Demonstration/Dual probe computer imaging Technique.
 - o Appendix N – Time of Flight Diffraction interpretation.
- ASNT-SNT-TC1A -2001 "Recommended Practice No: SNT-TC-1A
- ASNT CP189 "Qualification and certification of Non-Destructive testing Personnel"

B.3 SECOND OPTION – EURONORM.

The ToFD method shall be applied in accordance with DD ENV 583–6:2000 and DD CEN/TS 14751-2004.

Acceptance/rejection criteria shall be in accordance to NEN 1822-2005 (Equivalent to EN 15617 Level 1 (Stringent Acceptance Level)).

The ToFD operators performing the examination, data analysis/interpretation and evaluation shall be qualified and certified in accordance to the requirements of EN 473 Level I and II, ToFD procedures shall have the approval of Level III individual and of the COMPANY.

The qualification and certification of ToFD personnel shall have the approval of COMPANY.

References:

- a) EN 473-2000 “Non-Destructive testing – Qualification and Certification of NDT personnel – General principles”
- b) DD ENV 583 – 6:2000 “Non-Destructive testing – Ultrasonic Examination – Part 6: “Time of Flight Diffraction Technique as a matter of detection and sizing of discontinuities” (Former BS7706)
- c) DD CEN/TS 14751-2004 (Former BS7706) “Welding – Use of Time of Flight Diffraction Technique (ToFD) for examination of welds”
- d) NEN 1822-2005 “Acceptance criteria for the Time of Flight Diffraction inspection technique” a Dutch standard to be followed up by CEN standard pr EN (WI00121471):2006
- e) Note: The prEN acceptance levels related to the quality classes as mentioned in EN ISO 5817.
- f) EN 15617:2006 “Non-Destructive testing of welds - Time of Flight Diffraction Technique (ToFD) – Acceptance Levels”

B.4 EXAMINATION FROM ONE SURFACE

In case ToFD examination is carried out from one surface only, the following shall apply:

- The near probe surface of the weld shall be examined by creep wave probes.
- The creep wave probes shall be calibrated on a 2.5 mm (0.1 in) diameter Side Drilled Hole located on the weld centreline and a depth of 3.0 mm (0.12 in) below outer surface. The probe front face to SDH distance equals 10 mm when weld cap is ground flush, else half width of weld cap.
- Acceptance/rejection criteria shall be in accordance to ASME VIII Division 1 - Appendix 12.
- Procedures shall have the approval of a UT Level III individual and of the Principal.

APPENDIX C SPECIFICATION FOR PUF INSULATION SYSTEM

C.1 SCOPE OF THE TECHNICAL SPECIFICATION

This specification covers the requirements for selection, design, supply, application and inspection of the PUF insulation, which is to be applied to the inner face of the outer tank wall and to the bottom of the annular space of the LPG tanks to be built. Furthermore, this specification sets the guidance for the detailed application specifications, quality control specifications and HSE requirements of the PUF works.

C.2 ROLE OF THE PUF INSULATION

The PUF insulation shall fulfil the requirements under normal and emergency conditions as stated within this specification.

C.3 NORMAL OPERATING CONDITIONS

In normal service conditions, the product is retained by the inner tank and the annular space is permanently filled with product vapour at a temperature equal to the atmospheric boiling point of the product. Under these conditions, the PUF insulation shall provide an effective thermal insulation for the tank wall and of the bottom of the annular space.

The PUF shall limit the heat in-leak through these parts of the outer tank to the amounts corresponding with the allowed boil-off.

The Contractor shall determine the maximum heat in-leak for each surface of the tank, based upon the maximum boil-off rate specified.

Based upon the maximum heat in-leak allowed for tank wall and bottom of annular space, the Contractor proposes:

C.4 EMERGENCY CONDITION OF INNER TANK LEAKAGE

Under Emergency conditions (inner tank leakage), the maximum inner tank inventory is contained by the outer tank and where the liquid product fills almost the full height of the annular space.

Under these emergency conditions, which could last for a designed period of up to 6 months, the PUF shall still provide an effective thermal insulation.

Moreover, it shall provide an impermeable, liquid-tight insulation that prevents any direct contact between the liquid LPG and the outer tank.

This liquid-tight insulation is necessary to prevent unacceptable damage to the outer tank and at the same time to prevent excessive boil-off under such conditions.

C.5 PUF SUBSTRATE: VAPOUR BARRIER

The properties, design and application method of the PUF shall take into account the type of vapour barrier used.

C.6 PERFORMANCE REQUIREMENTS

C.6.1 Thermal insulation during normal tank service

The design thermal conductivity adopted for the determination of the Boil Off Gas requirements shall be guaranteed under the operating temperature ranges and in the operating environment of product vapours.

Additionally, the Poly-Urethane Foam (PUF) shall be able to withstand the stresses and strains induced by thermal and mechanical loadings, including but not limited to the low temperature effects of the contained product in conjunction with seasonal temperature variations and solar gain; the deformation based loadings arising from the effects of pre-stressing of the outer tank along with the creep and shrinkage effects from the concrete.

Under all conditions and throughout the service life of the tanks, there shall be no degradation or impairment of the PUF system including:

- a) The formation of cracks
- b) Loss of adhesion to the vapour barrier
- c) Loss of cohesion within the foam
- d) In order to prevent penetration and accumulation of LPG vapours inside the insulation system and entrapment within layers, the following performance level shall be achieved:
 - The PUF system shall be completely free of voids, air pockets and porosity.
 - The insulation itself shall have a low permeability and low absorption rate for LPG vapours under the normal tank operating pressures.
 - The insulation shall remain free of joints/cracks.
 - The PUF shall have adequate bond to the vapour barrier.

C.6.2 Liquid-tight insulation in case of LPG leakage into the annular space

In the event of a spillage from the inner tank, the PUF shall be able to contain the LPG for at period of least 6 months to allow the LPG to be pumped out of the tank or to evaporate.

During this event, the PUF shall provide an effective thermal insulation between the refrigerated LPG liquid and the warm concrete wall, with a thermal stiffness that is not significantly different from that during normal operating conditions.

In order to fulfil the above requirements, the PUF shall, when in direct contact with liquid propane, achieve the following:

- a) Retain its bond to the vapour barrier with an adequate factor of safety
- b) Remain free of cracks
- c) Not absorb LPG liquids;
- d) Resist the hydrostatic pressure of the liquid product without unacceptable compression levels or degradation
- e) Not degrade or require replacement after the spillage event

During this emergency condition, the hydrostatic pressure in the tank shall be assumed to be approximately 2 barg (29 lb/in²).

After emptying the tank, the de-gassing (gas-freeing) of the PUF shall be relatively fast in that there should be no protracted durations necessary to allow for migration of LPG vapours from the system.

In order to achieve the above, the PUF shall:

- Contain no void spaces inside or behind the insulation material;
- Consist of a closed cell material, having a cellular structure able to remain intact under the specified conditions.
- During such conditions of LPG leakage and long term presence inside the annular space, minor defects and damages to the PUF can be accepted, provided that these do not impair the functional performance of the system as described above.

C.6.3 Performance characteristics

The principal requirement of this DEP is that the PUF shall meet all the performance requirements as outlined above.

The Contractor shall provide demonstrable evidence that the proposed PUF system meets these technical and performance requirements of this specification including but not limited to:

- a) Material properties under ambient and product conditions
- b) Testing Data
- c) Reference lists where the product has been used
- d) Method statements in respect of application
- e) Field test and Inspection Test Plans

Typically the PUF system should conform to the requirements of Table C.1 and Table C.2.

Table C-1 Material data for PUF at ambient temperature

Property	Units	Suggested Test Method	Typical Values
Closed cell content	%v	ASTM D2856	90-95
Thermal conductivity	kcal/m/°C	ASTM C177	
- fresh foam			< 0.020
- after ageing			< 0.022
- for calculations			< 0.025
Compressive strength parallel to rise	kPa	DIN 53421; ASTM D1621	
- at 10% deflection or at maximum force	kPa		500-600 (72-87 lb/ft ²)
- at proportional limit	kPa		400-500 (58-72 lb/ft ²)
Tensile strength across rise	kPa	SRL-method, ASTM D1623	500-600 (72-87 lb/ft ²)
Tensile strength parallel to rise	kPa	SRL-method, ASTM D1623	500-600 (72-87 lb/ft ²)
Adhesion to vapour barrier	kPa	Pull-off test, BS EN ISO 4624	> 500 (72 lb/ft ²)
Resistance to contact with butane and propane vapours	-	Gas box test at 100 kPa (14.5 lb/in ²) for minimum of 3 months	no change in physical properties
Absorption of LPG vapours	%v	Gas box test at 100 kPa (14.5 lb/in ²) for minimum of 3 months	no measurable absorption
Crack-bridging capacity	-	Crack-bridging test; Tensile elongation test	> 5% elongation at break, no loss of adhesion during crack-bridging action of vapour barrier

Table C-2 Material data for PUF at -50 °C (-58 F) Temperature

Property	Units	Suggested Test Method	Typical Values
Compressive strength parallel to rise	kPa	DIN 53421 [DIN has been withdrawn in 1984 and not superseded; there was a reference to BS EN 826]; ASTM D1621	
- At 10% deflection or at maximum force	kPa		600-700 (87-101 lb/ft ²)
- At proportional limit	kPa		500-600 (72-87 lb/ft ²)
Tensile strength across rise	kPa	SRL-method, ASTM D1623	600-750 (87-109 lb/ft ²)
Tensile modulus across rise	kPa	SRL-method, ASTM D1623	20,000-25,000 (2900-3626 lb/ft ²)-
Elongation at break across rise	%	SRL-method, ASTM D1623	> 3%
Safety coefficient for use at -50 °C (-58 °F)	-	-	> 3
Absorption of liquid LPG	%	2 weeks at - 48°C (118F) and 2 bara (29 lb/in ²)	< 1%v
Desorption rate of LPG after immersion	-	-	> 99% in 24 hrs
Physical and chemical resistance to immersion in LPG	-	2 weeks at - 48°C (118F) and 2 bara (29 lb/in ²).	No change in physical properties
Liquid-tightness to LPG	-	2 weeks at - 48°C (118F) and 2 bara (29 lb/in ²).	No penetration of LPG through PUF

NOTE: ¹ Tensile strength across rise divided by in plane thermal stress.

C.6.4 Additional requirement

In addition to attaining the performance requirements above, the PUF shall comply with locally applicable environmental requirements. The foam shall be based on a blowing agent locally acceptable and internationally accepted by the United Nations Environment Programme. CFC-11 shall not be used.

C.6.5 Safety

The foam to be applied shall have fire-retarding properties to limit the risks of fire during the construction period. Suggested test method is ASTM D1692-68.

C.6.6 Application

To achieve uniform layer thickness and overall quality, the PUF shall be applied using an automatic process. Local details at top and bottom may be applied manually by experienced and qualified foam technicians subject to approval site trials and acceptance by the Principal.

Application of the PUF shall be carried out in a layer-by-layer process, enabling inspection of all layers.

C.7 GENERAL DESCRIPTION OF THE PUF INSULATION AND PUF WORKS

C.7.1 PUF insulation

The PUF insulation system shall consist of a monolithic, joint less, high density, rigid polyurethane foam, suitable for low-temperature use which shall be spray-applied in a layer-by-layer process onto the vapour barrier of the outer tank wall and of annular space bottom.

C.7.2 PUF insulation works

The PUF works comprise all works, activities and materials to produce the required PUF, to achieve the required adhesion to the vapour barrier and to give it all the properties and finishing as required.

C.7.3 Surface preparation of the vapour barrier

The required surface preparation is dependent on the vapour barrier and type of PUF adopted. The Contractor shall demonstrate the surface preparation results in attainment of adhesion characteristics.

C.7.4 Spray application of polyurethane foam

The polyurethane foam is sprayed in a layer-by-layer process, with intermittent inspections, until the required total thickness as determined in the design is achieved.

This work includes all the auxiliary activities, such as manufacturing/blending of the materials, climatic control of the tank, masking, clean up, etc.

C.7.5 Post-treatment/finishing of the sprayed PUF

In order to achieve a completed PUF complying with the performance requirements, it may be necessary to post-treat or finish the sprayed PUF.

This post treatment/finish can vary according to the following factors:

- Reinforcement inside or on the PUF surface. The need for this depends on the type of PUF proposed and may also vary according to the location in the tank (vertical surface, bottom, corner, etc.)
- Finishing work to complete the insulation in accordance with the dimensions, shape, tolerances, and acceptable defect sizes specified for the PUF system in the Method Statement.

C.7.6 Reinforcement - facings

Reinforcement applied onto the PUF surface or inside the PUF can be accepted if these are required for the proposed PUF system to prevent it from forming cracks under the designed operating conditions. In this case, it shall be demonstrated that the reinforcement itself and its installation method improve the PUF and do not introduce weaknesses (voids, weak interlayer bonding or other).

The liquid-tightness of the PUF shall result from the impermeability of the cellular structure of the PUF itself. Liquid-tight facings or membranes, applied onto the PUF surface to provide liquid-tightness to the PUF, shall not be allowed.

C.7.7 Design of the PUF insulation

The Contractor shall carry out the detailed design of the PUF system including but not limited to the following,

C.7.8 Detailed design

The selected PUF system shall be designed to meet the specific requirements, dimensions, and expected loadings.

The detailed design shall include, amongst others, following items:

- a) Drawing showing exact location and extent of PUF insulation system on wall and base slab;

- b) Exact PUF thickness and tolerances to meet the boil-off requirements;
- c) Exact density of the PUF to meet the required physical characteristics;
- d) Design of possible foam reinforcements, laminates, anchoring details;
- e) Shape of PUF at top, bottom, anchoring points, protrusions, etc.;
- f) Effects on PUF of expected movements and dimensional changes of outer tank wall.

C.7.9 Specifications for application and quality control

The Contractor shall prepare and submit detailed specifications and procedures for application and quality control of the PUF system. These shall cover all the requirements as specified within this DEP.

C.7.10 HSE specification

The Contractor shall prepare a specification covering all HSE related aspects of the PUF, supply and installation.

C.8 APPLICATION SPECIFICATIONS FOR THE PUF INSULATION

C.8.1 Introduction: Submission and approval of application manual

The Contractor shall prepare and submit detailed specifications and procedures for application of the PUF system. The Contractor shall demonstrate with sufficient details how the materials, equipment, tools, personnel and application methods used will lead to an application of the PUF in compliance with the performance and schedule requirements. The Contractor shall also cover, in detail, all-important subjects of the works, including, but not limited to, the items listed below.

C.8.2 Subjects to be covered in the application manual

C.8.3.1 Installation of equipment and temporary facilities

- a) Site establishment;
- b) Sufficient (temporary) means for access into the tank and into the annular space;
- c) Lighting of the annular space, inner tank, tank entrances, and outside of tank (good semi-permanent working lighting in all parts of the tank throughout the work period);
- d) Ventilation system, including ventilation holes of sufficient capacity in the tank roof (continuous ventilation for whole working space, minimum 3 air changes per hour);
- e) Climate control system (continuous conditioning of the complete annular space);
- f) Facilities to lift materials and equipment into and out of the tank;
- g) Scaffolding/cradles;
- h) Safety equipment.

C.8.3.2 Surface preparation of the vapour barrier

The surface preparation will vary depending on:

- a) The type of vapour barrier;
- b) The condition of the vapour barrier.
- c) As a minimum, the following aspects shall be covered in the application manual:
 - a. Degree and method of cleaning;
 - b. Inspection/repair of possible damages;
 - c. Surface preparation method;
 - d. Primer:
 - e. Type of primer;

- f. Coverage;
- g. Application method.

C.8.4 Application of PUF

Application procedures shall cover all aspects for the application, including, but not limited to, following elements.

- a) Transport to site and storage on site of PUF chemicals (temperature controlled storage);
- b) Method and equipment for blending of PUF chemicals;
- c) PUF equipment:
 - a. Type and description;
 - b. Number;
 - c. Capacity;
 - d. Positioning of machines:
 - e. Location;
 - f. Length of spray hoses;
 - g. Delivery of products, filling of machines;
- d) Ventilation and climatic control during works (continuous climatisation and following conditions required:
 - Humidity < 75 %;
 - Temperature > 15 °C (59 °F), < 35 °C (95 °F);
 - Vapour barrier temperature > 20 °C (68 °F), minimum 3°C (37.4 °F) above dew point;
- e) Personnel:
 - Manpower chart;
 - Description of how the Contractor will staff the job with the necessary specialists and experienced people.
- f) Application Method
 - a. Suitable, well-proven automatic application method for wall;
 - b. Manual application for lower part, insulation details, repairs;
 - c. Application in a layer-by-layer process enabling intermittent inspections;
 - d. Masking system to catch overspray;
 - e. Adequate procedure for repairs;
 - f. Application in such a manner that time, place and facilities are available for regular inspection activities.

C.8.5 Finishing of PUF insulation

Description to be how the PUF will be finished:

- Surface finish and tolerances;
- Insulation details at top, bottom, corner, etc.;
- Surface laminates, reinforcements in PUF.
- To be described are:
 - o Methods of work;

- o Materials used;
- o Equipment's, facilities and tools;
- o Climatisation and ventilation during these works.

C.8.6 Quality control specifications for the PUF insulation

C.8.6.1 Introduction: submission and approval of QC manual

The Contractor shall prepare a detailed quality control manual for the PUF works.

This manual shall demonstrate that the type and frequency of inspections, tests and the documentation are such that they provide sufficient evidence that the complete installed PUF in the tank is in compliance with the required properties.

C.8.6.2 Contents of the Quality Control manual

In the manual, the Contractor shall cover in detail all inspections and quality control necessary to be carried out on the PUF, including but not limited to the items listed hereafter.

C.8.6.3 Inspection/QC on vapour barrier surface preparation

- a) Type, frequency, methods, criteria and documentation of inspection/QC to be described for:
 - Initial surface condition;
 - Cleaning works - grade of cleanliness;
 - Touch-up/repair works;
 - Primer application:
- b) Type;
- c) Coverage;
- d) Adhesion;
- e) Climatic conditions.

C.8.6.4 Quality control for PUF application

- f) Type, frequency, method, criteria and documentation system to be described for inspections and tests in order to cover all aspects of the work, such as:
 - Primed vapour barrier surface;
 - PUF materials;
 - Climatic conditions in the tank;
 - Operation of PUF machines;
 - Blending of chemicals and QC on blends;
 - Application process:
- g) Thickness of individual layers;
- h) Adhesion of PUF on vapour barrier (minimum 50 tests per tank);
- i) Adhesion between PUF layers;
- j) Surface condition and defects of PUF layers;
- k) Total PUF thickness, with electronic gauge (minimum 1 reading/5 m2);
 - Samples of PUF produced during application process:
- l) Density (daily for each machine);

- m) Adhesion (minimum 10 samples per tank);
- n) Compressive strength (minimum 10 samples per tank);
- o) Tensile strength (minimum 10 samples per tank);
- p) Closed cell content (minimum 10 samples per tank);
- q) Thermal conductivity (minimum 10 samples per tank);

C.8.6.5 Quality control on finishing works of PUF

- a) Type, frequency, method, criteria and documentation system to be described for inspections and tests on all aspects of finishing/ reinforcements of PUF such as:
 - Surface defects/finish;
 - Shape/tolerance of insulation details;
 - In case of laminates/reinforcements:
- b) Control on materials;
- c) Control on mixing;
- d) Control on application parameters;
- e) Control on: adhesion, overlaps, defects;
- f) Control of the completed laminate/reinforcement: curing, adhesion, overlaps, defects and mechanical strength.

C.8.6.6 Health, Safety and Environmental Requirements

The Contractor shall submit a HSSE procedure that will address the specific hazards associated with the PUF works.

It shall describe/analyse each of the existing problems/hazards and put forward effective measures to reduce and mitigate these.

As a minimum, the following aspects shall be covered,

- a) Reference to internationally recognised regulations for working with these products and processes;
- b) Reference to the relevant national laws and regulations;
- c) List of specific Health and Safety instructions to workers;
- d) Visibility during works in the tank;
- e) Risk related to working at heights;
- f) Dust problems associated with blasting;
- g) Health and Safety problems associated with paint application;
- h) Health and Safety problems associated with PUF works;
- i) Health and Safety protection during PUF sanding;
- j) Health and Safety protection during laminating;
- k) Fire risks: fire prevention and fire-fighting;
- l) Emergency evacuation and escape out of the tank;
- m) First aid;
- n) Transport of materials;
- o) Waste disposal;
- p) Safety supervision and control.

C.8.7 Organisation and scheduling of PUF works as part of the tank works

The Contractor shall fully realise the difficult and critical nature of the application of the PUF system. Therefore, as a minimum, he shall incorporate the following measures to enable this:

- a) Sufficient and safe access and facilities shall be provided as necessary for:
 - Access of personnel;
 - Emergency escape of personnel;
 - Access for materials and equipment;
 - Openings for ventilation and climatisation;
- b) In the Schedule an adequate and realistic period shall be included for the PUF works;
- c) During this period, no other construction works shall take place inside the annular space or in the suspended deck area to avoid reduced quality due to contamination of the works and health and safety risks for the people;
- d) PUF works shall be scheduled near the end of the tank works for following reasons:
 - Outer tank wall and roof shall provide a weatherproof and safe working area;
 - Welding work inside the tank shall be completed before the start of PUF works in order to prevent fire risks (exceptional welding works later on only with a 'hot work permit' and sufficient fire preventive measures);
 - Construction activities inside the tank shall be practically completed before start of PUF works to avoid mechanical damages to the PUF.

APPENDIX D FULL SCALE TRIALS AND MOCK UPS

D.1 SCOPE AND PURPOSE

The Contractor shall prepare a procedure for a full-scale site trial under the expected ambient exposure conditions. The procedure shall detail the proposed methods of construction for the permanent works including all inspection (sampling, testing and monitoring) requirements. The purpose of this trial mock-up is to assess:

- The strength, durability, early age thermal cracking performance and off-form finish for the proposed concrete mix designs (base, wall and roof) as a finished product considering all aspects of mixing, placement, formwork design and curing methodology.
- Ability to adequately place and achieve compaction of the roof corner junction.
- And demonstrate that the overall standard of workmanship that will be representative of finished product.
- Demonstrate that under the climatic temperatures design mix and the method of manufacturing the tank are suitable to achieve the specified quality and avoid excessive cracking.

D.2 TRIAL PANEL SIZES

Trial panel sizes shall be:

- Full-scale mock-up representing the thickened base ring and lowest section of the concrete wall. Approximate size - slab length 4 m (13 ft) width 2.5 m (8.2 ft) x design depth – wall height 3.0 m (12 ft) x design thickness.
- Full scale mock up of the roof/corner junction area. Approximate size – 4 m (13 ft) perimeter length of ringbeam x 3 m (12 ft) width of roof x 1 m (3.3 ft) of wall height.

Formwork shall be constructed from similar materials to those used for the construction proper, i.e., the roof steel forms shall be used to capture thermal affects from solar gain. Forms shall be orientated so as to pick up the full strength of the sun at midday.

Construction joints in the horizontal and vertical planes shall be included within the base and wall mock up.

Reinforcement distribution shall be as close to that used in the final design.

Post tensioning ducts shall be included within the mock ups.

D.3 REQUIREMENTS OF TEST PANELS

As a minimum the Contractor's procedure shall address the following:

- a) Placement and curing methods are correct and that the finished product meets the specified requirements such as strength, homogeneity, allowable surface defects and off form finish (with photograph record).
- b) Workability of the mix design and confirmation of required pumpability rate.
- c) Discharge temperature of the concrete shall be recorded.
- d) Demonstration and agreement on acceptable construction joint preparation (in the horizontal and vertical planes. (Document with photographic record)
- e) Stripping time for forms.
- f) Heat of hydration monitoring by placement of thermocouples and compliance confirmation. Location of thermocouples to be agreed with the Principal. Redundant thermocouples shall be included in the trial panels.
- g) Core removal (slab, wall and roof) for strength and durability testing.

- h) Core removal (slab) to demonstrate sound embedment of reinforcement after initial curing i.e., no sagging of concrete directly underneath of reinforcement.
- i) Confirm which laboratory will be used for carrying out the testing/reporting.
- j) Concrete curing shall be agreed with the Principal.
- k) Test is to be carried out on or as near to the site as possible.
- l) The demolition and removal of the trials at an agreed time is to be included within the Contractor's scope.

APPENDIX E CONSTRUCTION TOLERANCES CONCRETE STRUCTURES

1	Variation from verticality For each lift $\pm 6\text{mm}$ (1/4 in) Maximum from any point measured from the bottom $\pm 25\text{ mm}$ (1 in).
2	Variation from roundness (on radius) The maximum permissible deviation from the base slab radius measured to the outside face of the base slab shall be the lesser of $\pm 0.1\%$ R or $\pm 40\text{ mm}$ (1.5 in). The maximum permissible deviation from the specified tank wall radius measured to the inside face of the tank wall at the bottom of the wall shall be the lesser of $\pm 0.06\%$ R or $\pm 25\text{ mm}$ (1 in). The maximum permissible deviation from the specified tank wall radius measured to the inside face of the tank wall at the top of the wall shall be the lesser of $\pm 0.1\%$ R or $\pm 40\text{ mm}$ (1.5 in). Intermediate tolerances between the bottom and top of the wall may be interpolated.
3	Localized Tank Radius The maximum deviation of any tank wall measured along any 10% circumference shall be less than 5% of the core wall thickness.
4	Level Alignment The variation in level from specified elevations for any completed surface excluding the support underneath the inner tank wall shall be limited to $\pm 13\text{ mm}$ (1/2 in). In the instance of flat slabs along any 3 m (12 ft) straight line, the difference in elevation of any two points shall not exceed $\pm 5\text{ mm}$ (1/5 in), In the instance of the edge of the base slab, and walls along any 3 m (10 ft) circumference, the difference in elevation of any two points shall not exceed $\pm 5\text{ mm}$ (0.02 in). The variation in level from specified elevations for any completed concrete surface supporting the inner tank and annular plates shall not exceed $\pm 13\text{ mm}$ (1/2 in). The top of the concrete layer supporting the inner tank shall be level within $\pm 3\text{mm}$ (1/8 in) in any 10m (33 ft) circumference and within $\pm 13\text{ mm}$ (1/2 in) in the total circumference.
5	Variation in cross sectional dimensions Variation in cross sectional dimensions of slabs shall be as follows; $\pm 9\text{ mm}$ (3/8 in) where the section thickness is less than or equal to 200 mm (6.5 ft). $\pm 13\text{ mm}$ (1/2 in) where the section thickness exceeds 200 mm (6.5 ft). Variation in cross sectional dimensions of walls shall not vary by more than $\pm 6\text{ mm}$ (1/4 in) from the specified thickness. Variation in cross sectional dimensions of dome roof shall not vary by more than 13 mm (1/2 in) from the specified thickness.
6	Inserts and Openings Location of the centerline of access openings and cross sectional dimensions of access openings shall be within $\pm 12\text{ mm}$ (1/2 in). Variation in the position of cast in insert plates measured in the plane of concrete surfaces $\pm 12\text{ mm}$ (1/2 in). Variation in the position of cast in insert plates measured normal to the plane of concrete surfaces -0 mm +5 mm (1/5 in). The Variation in the position of openings and sleeves shall not exceed $\pm 6\text{mm}$ (1/4 in).
7	Embedded items, Inclinometers and Base Heating Conduit

	The vertical alignment, lateral alignment and level alignments for embedded items such as inclinometer tubes and conduit shall be within ± 25 mm (1in). Inclinometers and base heating conduit shall be laid to fall of 1/1500 from the centre of the tank to enable free draining
8	Reinforcement The centre to centre bar spacing shall not deviate by more than ± 15 mm (0.6 in) to that indicated on the construction drawings. The tolerance for minimum concrete cover in flexural members, walls and compression members shall be as ± 5 mm (1/5 in).
9	Prestressing Tendons Where embedded pre-stressing tendons are used, the diameter of the prestressing duct should not exceed 1/5th of the wall thickness For horizontal members located within the wall ± 6 mm (1/4 in) of the intended radius. The vertical elevation of the horizontal ducts shall be within ± 20 mm (4/5 in) of the theoretical position. Tolerances for vertical alignment are not cumulative and measured for each duct. Radial position of the vertical ducts shall be within ± 12 mm (1/2 in) of the intended radius. The position of the vertical tendons shall be within ± 12 mm (1/2 in) of the theoretical position when measured along a circumference of the tank shell.