

DEP SPECIFICATION

FULL CONTAINMENT REFRIGERATED LNG TANKS

DEP 34.51.01.32-Gen.

February 2011

(DEP Circular 41/11 has been incorporated)

(DEP Circular 58/12 has been incorporated)

DESIGN AND ENGINEERING PRACTICE

DEM1



PREFACE

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

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

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

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

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

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

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

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

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

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

TABLE OF CONTENTS

1.	INTRODUCTION	6
1.1	SCOPE.....	6
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS	6
1.3	DEFINITIONS	6
1.4	CROSS-REFERENCES	7
1.5	COMMENTS ON THIS DEP	8
1.6	DUAL UNITS.....	8
2.	GENERAL.....	9
2.1	DESCRIPTION OF THE TANKS	9
2.2	CONTRACTORS SCOPE OF WORK	9
2.3	CODES AND INDUSTRY STANDARDS.....	10
3.	TANK DESIGN	11
3.1	GENERAL	11
3.2	SERVICE CONDITIONS.....	11
3.3	CONSTRUCTION LOADING.....	11
3.4	WIND LOADS AND SNOW LOADS	11
3.5	EARTHQUAKE	11
3.6	HEAT LEAK	12
3.7	HAZARD DESIGN CONDITIONS.....	12
3.8	HAZARD PROTECTION REQUIREMENTS	13
4.	CONCRETE TANK DESIGN	14
4.1	GENERAL DESIGN REQUIREMENTS.....	14
4.2	CONCRETE TANK DESIGN CODE	15
4.3	DESIGN/ANALYSIS.....	15
5.	COMPONENT DESIGN OF THE METAL TANK	19
5.1	GENERAL	19
5.2	INNER TANK	19
5.3	LINERS (VAPOUR BARRIER)	19
5.4	SUSPENDED DECK.....	20
5.5	SECONDARY BOTTOM AND THERMAL CORNER PROTECTION (TCP).....	20
5.6	PIPING AND ROOF NOZZLES	21
5.7	STRUCTURAL STEEL	22
6.	MATERIALS REQUIREMENTS	23
6.1	CONCRETE TANK	23
6.2	INNER TANK, SECONDARY BOTTOM, AND TCP MATERIALS	23
6.3	WELDING PROCEDURES (QUALIFICATION & IDENTIFICATION)	24
6.4	IMPACT TESTING REQUIREMENTS.....	25
6.5	VAPOUR BARRIERS, BOTTOM, WALL AND ROOF.....	26
6.6	SUSPENDED DECK.....	26
7.	MANUFACTURE & CONSTRUCTION - STEEL COMPONENTS	27
7.1	FABRICATION.....	27
7.2	WELDING PROCEDURES.....	28
7.3	WELDING QUALIFICATION AND IDENTIFICATION	28
8.	INSULATION SYSTEMS.....	31
8.1	GENERAL	31
8.2	BOTTOM INSULATION	31
8.3	WALL INSULATION.....	33
8.4	MATERIAL HANDLING AND STORAGE	37
9.	FIRE SCENARIOS	38
9.1	PRESSURE RELIEF VALVES.....	38
9.2	HEAT DETECTION.....	38
9.3	FIRE PROTECTION SYSTEM	38
10.	INSTRUMENTATION	39

10.1	INSTRUMENT CONNECTIONS.....	39
10.2	LEAK DETECTION	39
10.3	COOLDOWN SENSORS.....	39
10.4	TEMPERATURE SENSORS	39
11.	TANK GAUGING AND OVERFILL PROTECTION REQUIREMENTS	41
11.1	TANK INSTRUMENTATION.....	41
11.2	INSTRUMENT NOZZLE CONNECTIONS	41
12.	ELECTRICAL	42
12.1	GENERAL	42
12.2	LNG TANK EARTHING	42
12.3	LIGHTNING PROTECTION.....	42
13.	PRESSURE AND VACUUM RELIEF SYSTEMS	43
13.1	GENERAL	43
13.2	PRESSURE RELIEF VALVES.....	43
13.3	RESERVE CAPACITY RELIEF VALVES	43
13.4	VACUUM RELIEF VALVES.....	44
14.	ACCESSORIES	45
14.1	ROOF PLATFORM	45
14.2	ACCESS TO PLATFORM AND ROOF	45
14.3	JIB CRANE	45
15.	MONORAILS	46
15.1	GENERAL	46
15.2	LIGHTING	46
15.3	SUPPORTS	46
16.	PAINTING	47
17.	HYDROSTATIC/PNEUMATIC TESTING.....	47
17.1	HYDROTESTING OF INNER TANK (FRESH WATER).....	47
17.2	PRESSURE AND VACUUM TESTING	48
18.	SETTLEMENT MONITORING.....	49
18.1	SURVEY MARKERS	49
18.2	INCLINOMETERS	49
19.	CALIBRATION	50
19.1	GENERAL	50
20.	DRYING AND INERTING	50
21.	COOLDOWN AND COMMISSIONING	51
21.1	COOLDOWN GENERAL	51
21.2	COMMISSIONING-GENERAL.....	51
22.	CONSTRUCTION REQUIREMENTS AND TOLERANCES	51
22.1	METALLIC STRUCTURES.....	51
22.2	CONCRETE STRUCTURES, CONSTRUCTION REQUIREMENTS:.....	51
22.3	CONCRETE STRUCTURES, TOLERANCES.....	51
23.	ADDITIONAL REQUIREMENTS ON REINFORCING STEEL	52
24.	BASE SLAB HEATING SYSTEM	52
24.1	GENERAL	52
24.2	HEATER DESIGN AND MATERIALS	52
24.3	PROTECTIVE DEVICES	53
24.4	SENSORS, INDICATORS, AND CONTROLLERS	53
24.5	HEATER CONDUITS.....	54
24.6	OTHER EQUIPMENT	55
24.7	INSTALLATION	55
24.8	INSPECTION AND TESTING.....	55
24.9	VENDOR DATA	55

25.	REFERENCES	57
-----	------------------	----

APPENDICES

APPENDIX A	FIRE SCENARIOS AND RELATED DESIGN TEMPERATURES	61
------------	--	----

APPENDIX B	ULTRASONIC INSPECTION	62
------------	-----------------------------	----

1. INTRODUCTION

1.1 SCOPE

This new DEP specifies requirements and gives recommendations for the technical requirements pertaining to the design, supply, fabrication, erection, inspection, testing and commissioning of field erected Full Containment Refrigerated Liquefied Natural Gas (LNG) tank(s).

This DEP supplements and amends the applicable design standards referenced herein.

Unless noted otherwise all requirements stated herein shall be applicable to tanks located at export and import facilities.

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 authorization 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 and gas handling. This DEP may also be applied in other similar facilities.

When DEPs are applied, a Management of Change (MOC) process should 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 abbreviations

Term	Definition
AGA	American Gas Association

Term	Definition
ALARP	As Low As Reasonably Practicable
CCR	Central Control Room
DCS	Distributed Control System
EPC	Engineering Procurement and Construction
HAZ	heat-affected zone
LNG	Liquefied Natural 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
TCP	Thermal Corner Protection
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 (25).

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

**Amended per
Circular 58/12**

Dual units have been incorporated throughout this DEP.

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 TANKS

The tanks SHALL [PS] be "Full Containment"¹ double wall type as described in EN 1473 and designed and constructed as per the requirements specified herein.

The Full Containment Tank(s) SHALL [PS] comprise a liquid tight 9% nickel inner tank and a liquid and vapor tight concrete secondary container. Both SHALL [PS] be capable of independently containing the stored product.

The inner tank shall [PS] be as per API 620 Appendix Q and the requirements of this specification and associated datasheets.

The outer tank SHALL [PS] be constructed from concrete respectively in accordance with the requirements of EEMUA 207 and the requirements of this specification and associated tank data sheets. The roof and base of the secondary container SHALL [PS] be reinforced concrete whilst the walls SHALL [PS] be post tensioned in accordance with the requirements of EEMUA 207.

In accordance with API 620 the inner tank shall be designed for all specified loading conditions/combinations that may occur during construction, testing, commissioning, operation, emergency, de-commissioning and maintenance.

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

- i. In normal service:
 - Accumulation of product within the interspace is not permitted.
 - Vapour tightness of the secondary container is achieved through the introduction of a metallic vapour barrier to the walls, roof and base.
- ii. In upset or emergency conditions where product accumulates in the interspace:
 - the secondary container contains the liquid product and prevent leakage.
 - Product losses due to 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 CONTRACTORS SCOPE OF WORK

The site location for the tanks will be graded to a rough finish grade.

Design and construction of the foundation, including soil improvement, deep foundations (or other wise) is by the Contractor.

A reinforced concrete base slab with under tank heating system designed to prevent frost heave and support inner tank, outer tank and appurtenances.

A 9% nickel steel open topped inner tank designed and constructed in accordance with API620 Appendix Q.

A concrete outer tank consisting of a post tensioned concrete wall rigidly connected to the outer tank concrete bottom slab, with a roof constructed of reinforced concrete. The inside of the concrete outer tank shall be lined with a carbon steel vapour barrier.

A 9% Nickel steel Secondary Bottom and 9% Nickel steel Insulated "Thermal Corner Protection". These shall be linked together and the top of the Thermal Corner Protection anchored into the pre-stressed concrete wall, approximately 5 m above the base slab. The

¹ Membrane tanks are considered as equivalent to Full Containment tanks and maybe substituted as an alternate to Full Containment Tanks.

Secondary Bottom shall be placed above the lower system of Cellular Glass bottom insulation.

A carbon steel roof liner which forms an integral structure with the reinforced concrete roof.

A flat plate suspended inner deck, supported by hangers from the concrete roof and roof liner constructed of aluminium., stainless steel, or 9% nickel steel.

A tank insulation system including insulation under the inner tank bottom (below the secondary bottom, and if required, between the secondary bottom and the inner tank bottom), insulation between the steel inner tank shell and the concrete outer tank, and insulation on top of the suspended inner deck.

Submerged pump risers including pumps lifting mechanisms, cables from the top of the tube to the pump, and junction Boxes, internal piping, etc, as indicated on the referenced drawings or data Sheets, and other accessories as stated in this specification, referenced drawings and data Sheets

Platform, staircase, stairs, walkways, caged ladders, monorails, cranes, handrails, etc as indicated on the Referenced Drawings.

Instrumentation for level, pressure and temperature recording, leak/gas detection, and cool-down control, and any other instrumentation specified for supply by the Contractor.

Valves for pressure and vacuum protection.

A fire detection and control system for the relief valves.

Design, installation, NDE and testing of all pipework and pipework insulation associated with the tank. to the Battery Limit near the base of the tank.

Contractor shall model and design the piping systems within his scope of the tank and determine pipe loads that the anchors must accommodate.

Contractor's Battery Limit is as generally defined in the Project Area Drawings and P&ID's. Contractor shall also comply with the following:

- a) Piping: All piping in the tank or on the tank roof or wall is within the Contractor's Battery Limit. Wall piping termination point will be near the base of the wall at the top of the elbows where piping turns horizontally on the adjacent rack.
- b) Electrical: For the pump power cables, the Contractor will supply and install the cables from grade to a Junction Box (JB or JB's) at the top of the Pumpwells. For other electrical items, Contractor will 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.
- c) Instrumentation: Contractor will 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.
- d) 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 will design, furnish, and install external pipework and Insulation materials for external pipework within the Contractor's Battery Limit and any special support components and any non-standard insulation materials required at any pipe support or guide.

2.3 CODES AND INDUSTRY STANDARDS

Detailed list of applicable codes and standards is included in Appendix A of this document. All codes and standards unless noted other wise shall be the latest edition, including revision addenda, supplements or others at the time of Invitation to Tender.

3. TANK DESIGN

3.1 GENERAL

Each tank shall consist of two liquid containers. Each container shall be capable of holding the gross liquid volume of cryogenic liquid without liquid leakage.

The Contractor shall be responsible for specifying purging, cool-down, and commissioning procedures.

3.2 SERVICE CONDITIONS

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:

- a) Hydrotest of the inner tank to the water level specified herein
- b) Normal operation of the tank containing LNG at maximum design product level.
- c) OBE and SSE Earthquake as per Tank Datasheets.
- d) Predicted maximum differential centre to edge settlements of the concrete bottom slab based on interpretation of the geo-technical data at each tank site. The design must allow for total differential settlement through construction, hydro-testing and operational lifetime.

The external pressure on the inner tank shell, exerted by the perlite insulation in the annular space, in particular for the situation of an empty tank.

3.3 CONSTRUCTION LOADING

The roof liner may be used as form work for the construction of the concrete roof and, consequently, shall be designed to support loads from the fresh concrete. Roof structural in combination with internal air pressure may be utilised to support the liner and fresh concrete weight during construction of a concrete roof.

3.4 WIND LOADS AND SNOW LOADS

Wind loads and Snow loads shall be in accordance with the Tank Data Sheet.

3.5 EARTHQUAKE

Seismic design of the inner and outer tank shall be in accordance with EN 1473. Implementation of EN 1473 requirements shall be as described in the Seismic Hazard Assessment Report.

The LNG container and its impounding system shall be designed for two levels of seismic ground motion, the Operating Basis Earthquake (OBE) and the Safe Shutdown Earthquake (SSE) as defined in EN 1473 section 4.2.4.

Inner Tank: Earthquake loading shall be per the Seismic Assessment Report. The inner tank shall be designed using the methods in API 620 Appendix L and the additional requirements of this specification. In addition, the Operating Base Earthquake (OBE) and Safe Shutdown Earthquake (SSE) criteria specified in EN 1473 shall be used. It shall be assumed that the inner tank is filled with LNG to its maximum operating level. When designing for the SSE condition, allowable stresses shall be determined in accordance with NFPA-59A, 4.1.3.6.

Outer Tank: The outer tank shall be designed using a dynamic lateral force procedure, utilising a finite element model. The overall model shall include the inner tank, inner tank contents, outer concrete tank and foundation all modelled as a single multi-degree of freedom complex system. Specific combinations of components may be modelled and analysed separately.

Load Conditions and Combinations

- a) 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.
- b) Modal damping ratios and limitations on maximum damping for OBE and SSE shall be in accordance with EN14620.
- c) Modal combination shall be by "Square Root Sum of the Squares" (SRSS) method, spatial combination shall be the maximum of
 - i. 100% horizontal + 30% vertical
 - ii. 30% horizontal + 100% vertical
- d) Allowable stresses for the SSE condition shall be determined in accordance with NFPA-59A, 4.1.3.6.

The corresponding earthquake loads experienced by the bottom insulation shall be incorporated in the design, taking into account the safety factors as stated in API 620.

3.6 HEAT LEAK

The total heat in-leak shall be such that the boil-off rate will not exceed the percentage of the gross tank contents per day based on pure methane as specified in the Data Sheet(s). Boil-off calculations shall be based on the maximum ambient temperature, wind speed, relative humidity, and the average daily global solar radiation listed in the Data Sheet(s).

Contractor shall provide calculations during the contract detailed engineering phase demonstrating that the insulation fulfils the heat in-leak requirements.

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

3.7 HAZARD DESIGN CONDITIONS

Heat Radiation/Fire Exposure: The outer tank roof and side walls shall be capable of withstanding fire exposure and heat radiation from a relief valve discharge fire with the relief valves discharging at the maximum relieving rate.

LNG Spill Conditions: In addition to the specified service loading, the post-tensioned concrete tank wall and its connection to the base slab shall be designed to withstand the thermal shock of LNG in the annular space. The outer tank shall be capable of containing the full inner tank contents. Intermediate liquid levels shall be considered as required to represent the controlling worst condition and combined with maximum internal pressure. The temperature gradient shall be analysed for critical steady state spill levels. Since the annular space is assumed to fill gradually, there is no specified leakage rate.

Combination of Loading Conditions:

The inner 9% nickel steel container and outer post-tensioned concrete tank shall be designed for all specified service and hazard loading conditions. Combinations of loading conditions that produce the most severe design case(s) shall be considered. Hazard loading conditions may be considered as separate events; combinations of hazard conditions in addition to service loading cases are not required (except as noted above).

Impact Loads due to projectiles from external explosions shall be as specified in the Tank Data Sheet(s). Resistance and acceptance criterion shall be as per EEMUA 207.

Blast loads from external Vapour Cloud Explosions (VCE's) shall be as specified in the Tank Data Sheet(s).

The impounding system (the outer concrete tank wall and bottom) shall, as a minimum, be designed to withstand an SSE while empty and an OBE while holding the volume, which is

equal to the full inner tank contents with vapour pressure at design pressure. After an OBE or an SSE, there shall be no loss of containment capability.

3.8 HAZARD PROTECTION REQUIREMENTS

3.8.1 LNG Spill Protection

Contractor shall design and install splash plates under flanges to protect the surrounding steelwork and enable vaporisation of product.

3.8.2 Flammable Gas Detection:

Two flammable gas detectors (infrared flame detectors) shall be installed under the roof platform near flanged piping connections that have spill protection systems. An audible alarm, which is clearly marked as a fire and gas alarm system, shall be installed at the outside periphery of the platform. The warning system shall also activate in the Central Control Room (CCR).

3.8.3 Heat Detection

Heat detection shall be provided wherever water spray is used on the tank roof for protection of equipment or accessories. The detection system shall be configured with two sensors such that both sensors must register and send an alarm to the CCR. The sensors shall consist of double loop air pressurized black PVC tubes.

3.8.4 Manual Call Points

Manual call points are required on the stairway providing access to the tank roof platform, and on the roof platform. These manual call points shall be configured so that they may be used to activate local and remote audible and visual alarms and also activate fire water pumps or a spray system on the roof platform.

3.8.5 Water Protection of Equipment and Accessories on Roof Platform

A fire water system including firewater piping to the top of the LNG Tank Roof Platform shall be designed and provided by Contractor capable of producing spray coverage for the entire platform. Design parameters shall be as specified in the Tank Data Sheet. In the PRV area, spray nozzles shall be positioned to protect the PRV's in the event of a relief stack fire.

3.8.6 Relief Valve Discharge Lines

Tailpipes of relief valves discharging to atmosphere shall be provided with a nitrogen connection for a hand operated valve from grade snuffing system. Contractor shall supply the snuffing system.

4. CONCRETE TANK DESIGN

4.1 GENERAL DESIGN REQUIREMENTS

4.1.1 General

Contractor shall carry out detailed design of the concrete outer tank based on the requirements of this DEP and the principal dimensions of the tank. Thickness of the bottom slab, wall, and roof are to be selected by Contractor. Inner Tank Diameter and height dimensions shall be selected to suit Project constraints.

4.1.2 Tank Bottom

Tank concrete base slab/foundation design shall incorporate the recommendations of the Geotechnical report. Concrete compressive strength requirements shall be as per this specification.

During construction of the wall, a temporary construction joint in the slab located just inside the concrete wall, may be made to allow differential settlements /movements between the wall area and the inner slab area. The joint shall be closed after partial post-tensioning of the wall.

Kickerless construction shall be permitted provided the Contractor can demonstrate the ability to restrain and control the forms.

4.1.3 Tank Wall

The wall shall be designed to be LNG tight with a monolithic connection to the base slab. A monolithic connection shall be made between the wall and concrete roof.

The tank wall shall be made of post-tensioned concrete with a characteristic strength per this Specification. Pre-stressing shall be accomplished with an impermeable duct and tendon system.

Contractor shall design the pre-stressed concrete wall for Service, Abnormal Loadings, and Temperatures to assure that the load carrying ability is maintained for all applicable design conditions. Design shall be in accordance with this specification. Determination of a need for cryogenic rebar at the inside of the wall shall be made by Contractor and subject to approval by Company.

Temporary openings in the wall for construction purposes may be considered in the design. This opening(s) shall be located so that they pass through the wall below the anchorage area of the TCP system, and should be limited to approximately 3.5 metres in height. Contractor shall determine post-tensioning arrangements for the location of temporary openings and for the method used to permanently seal the openings before pressure test of the outer tank.

Thermal Corner Protection anchorage shall be centred a minimum of one metre above the top of the Temporary Opening described above.

Above the top level of the 9%Ni thermal corner protection (TCP) Company require the concrete of the outer tank wall be cast by complete 360° pours. Vertical construction joints in the wall will be allowed only below this level, including those required to form the temporary construction opening(s).

4.1.4 Tank Roof

The roof shall be spherical in shape, and made of reinforced concrete with an interior carbon steel vapour barrier (liner).

The characteristic strength of concrete shall be as given in this specification. It may be poured in layers to restrict loading on the liner. 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. Contractor shall demonstrate by analysis that the roof plates and framing are adequately designed for non-symmetrical loading due to the concrete pouring sequence.

4.1.5 Ringbeam under Inner Tank Shell

A concrete ringbeam shall be installed under the inner tank shell. The ringbeam shall be designed such that the shell loads are properly distributed onto the bottom insulation under the ringbeam. Horizontal forces caused by possible movements of the annular plate, shall be taken into account.

The concrete ringbeam shall be reinforced with cryogenic rebar, or carbon steel rebar if designed in accordance with EEMUA 207.

4.2 CONCRETE TANK DESIGN CODE

The design of the prestressed concrete outer tank shall be in accordance EN 1992 part 1 and 3 (also known as EC2). All applicable sections of the latest edition of the design code, including supplements and chapters describing precast and prestressed concrete, shall be followed except when supplemented or modified by provisions of this specification.

Loads on outer tank shall be in accordance with EEMUA 207 where not specified in Tank Data Sheet(s).

4.3 DESIGN/ANALYSIS

4.3.1 Tank Wall Design Method

The concrete slab and pre-stressed concrete wall shall be designed for the following two Limit States:

- a) Serviceability Limit State (SLS) – Includes construction, normal operating, OBE and spill load conditions. This design state shall be utilised to determine concrete crack widths for construction and normal operating loads, and liquid tightness of the wall for the spill condition. All partial safety factors shall be taken as 1.0.
- b) Ultimate Limit State (ULS) – Includes all load conditions. This design state shall be utilised to determine concrete section adequacy per the strength requirements, material partial safety factors in Table 1 and the load partial safety factors in EEMUA 207 except that for the OBE event, a load factor of 1.5 shall be used.

All appropriate load cases and combinations shall be incorporated in the design of the concrete outer tank. A detailed loading summary table, as contained in EEMUA 207 shall be prepared to cover all phases of the tank life.

Seismic load combinations shall consider all possible combinations of the sum of 100% of the effect in one direction (horizontal or vertical) and 30% of the effect in the other direction.

Adverse and beneficial effects of the prestress and shrinkage loads shall be considered for construction, maintenance, and normal operating load conditions. A reduced ULS load factor of 1.0 shall be used for prestress and shrinkage loads when they are determined to be beneficial in strength evaluation of concrete design sections.

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

The design shall meet the acceptance criteria of this specification.

4.3.2 Tank Modelling & Analysis

The concrete tank shall be analysed for service and abnormal loads using a combination of 2D and 3D finite element modelling and analysis techniques. The model shall also include both heat transfer and non-linear thermal effects. The overall model shall include the foundation stiffness effects (soil-structure interaction), the concrete base slab, the concrete wall, the outer tank roof, the inner tank, the suspended deck, the insulation system and allowance for piping and tank top structures

Summer and winter design temperatures shall be commensurate with 95th and 5th percentile temperatures as per EEMUA 207.

Solar gain shall be considered as additional to the (Summer) Design Maximum temperature.

- a) Solar gain shall be determined using the Solar Radiation data contained in tank datasheet.
- b) Correlations shall be made using ASHRAE (2009 ASHRAE Handbook—Fundamentals) or other recognised standards to determine the total gain on horizontal and vertical surfaces.
- c) 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 subjected to a wind speed of 4ms⁻¹.

Spring elements shall be used as a minimum to model the sub-soil. Contractor shall determine the spring stiffness's from the soil investigation commensurate with short term and long term behaviour.

Alternatively, more advanced models of the sub-soil may be used in order to adequately represent the foundation behaviour.

Where appropriate to the loadcase under consideration the model shall take into account reduced stiffness of the structure as a result of crack formation in the concrete using established industry standard constitutive models. (e.g. for liquid spill, cold spot and fire conditions).

Loads due to prestressing may be simulated by axi-symmetrical loads, acting perpendicular to the tank wall. Stress distributions arising from discontinuities shall be examined.

Creep and shrinkage of the concrete, as well as relaxation of the prestressing steel, shall be taken into account;

Steady-state thermo-mechanical analyses shall be carried out in order to design the tank for conditions involving thermal loads. In addition, transient thermo-mechanical analyses shall be carried out where appropriate (e.g. for liquid spill);

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 verification and validation documentation shall be supplied to the Company for review and approval.

4.3.3 Foundation Stiffness

Long term and short Foundation flexibility shall be explicitly included in the finite element model to determine upper bound and lower bound demands.

Where piles are provided specific considerations shall be given to the representation of foundation flexibility and 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 the orthogonal pile layout in an axis symmetric space.

4.3.4 Thermal Analysis

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

The upper and lower bound surface temperatures shall be determined from heat transfer analyses with film coefficients commensurate with a cylinder is cross flow subjected to the following:

- a) Windspeed for the determination of film coefficients shall be the 5th percentile mean hourly wind speed.
- b) Maximum and minimum solar gain along with maximum and minimum (5th and 95th percentile) temperatures. Where appropriate Solar distribution shall be scaled from ASHRAE (2009 ASHRAE Handbook—Fundamentals).
- c) Base heating demands shall be commensurate with the condition under consideration.
- d) Short term and long term foundation stiffnesses shall be considered in the mechanical model.

4.3.5 2D and 3D Global linear Elastic Analyses

2D and 3D Elastic analysis shall be used to determine global symmetric and non symmetric demands in the outer tank. Local models shall be used to determine the impact of structural discontinuities such as buttresses and where relevant non-axisymmetric piling layouts.

- a) Where necessary the stress analysis shall take into account the non-linear behaviour of the concrete; i.e. reduced stiffness due to cracking.
- b) Long term and short soil affects along with upper and lower bound determination of soil parameters.
- c) The pre-load effects due to post-tensioning (including relaxation), creep and shrinkage of the concrete shall also be considered.
- d) Predicted edge to centre differential settlements shall be included inherently in all load cases through the use of appropriate foundation analogues.

4.3.6 2D and 3D Cracked analyses

Nonlinear (cracking) analyses is 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. Determination of crack widths shall be in accordance with EN 1992 and no credit shall be taken for tension stiffening when this is included in the constitutive model.

4.3.7 Acceptance Criteria

The following acceptance criteria are required for load conditions as applicable:

- a) Strength Criteria, Concrete strength criteria per EN 1992 shall be satisfied for all load conditions using the material and load factors as applicable.
- b) Shear links in the wall shall not be permitted for normal operation loadcases

Crack Control, for normal operating conditions, concrete crack widths in the wall shall be limited to 0.2 mm (0.007 in) for prestressed zones and crack widths in the slab and roof shall be limited to 0.3 mm (0.012 in). Additional requirements for crack widths shall be as per EEMUA 207.

4.3.8 Wall Liquid Tightness (Applies to Inner Tank Spill Condition Only)

Spillage conditions shall examine critical combinations of maximum and minimum external temperatures/pressures, long term and short term affects including prestressing, creep and shrinkage so as to determine the critical positions at the TCP position.

The product shall be prevented from migrating behind the TCP embedment through the control of compressive zones and crack widths within a zone extending $\pm$ twice the wall thickness measured above and below the top of the embedment. Within this zone;

- a) The compression shall not be less than 80mm (3.15 in)
- b) Crack widths shall be less than $<0.1\text{mm}$ (0.004 in) be determined in accordance with EN 1992 using the strains from the nonlinear analysis. Where tension stiffening

is included within the constitutive model then this shall be removed from the subsequent determination of crack widths whereby avoiding 'double dipping'.

Where explicit nonlinear methods are used constitutive models for concrete and steel shall comply with EN 1992. Other methods of analysis maybe permitted subject to Company approval.

Where proprietary software is proposed by the contractor full validation and verification shall be provided for company review and approval.

Both transient and steady state effects shall be whereby maximising the structural demands on both the concrete and embedment. The effects of a 'cold' embed and warm wall should be explicitly considered.

In the absence of a predefined spillage the contractor shall examine the secondary container full to the maximum level along with intermediate level top capture the structural demands. Particular attention shall be paid to spills in the immediate vicinity of the embedment

5. COMPONENT DESIGN OF THE METAL TANK

5.1 GENERAL

The following components 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 specification. The inner tank, secondary bottom plus the thermal corner protection (TCP), suspended deck, bottom liner, wall liner, and the roof liner.

5.2 INNER TANK

Maximum allowable stresses for the inner tank design for normal and testing conditions shall be in accordance with API 620 Appendix Q.

Maximum allowable stresses for the inner tank design for OBE conditions shall be in accordance with API 620 Appendix L.4.2.5.

- a) Response at the OBE level shall be essentially elastic and the force reduction factor shall be taken as 1.0.
- b) Earthquake definition for the OBE shall be as per Tank datasheet.

Maximum allowable stresses for the inner tank design for SSE conditions shall be in accordance with NFPA 59A with the force reduction factor taken as 1.0.

- a) Force reduction factors greater than 1.0 shall be demonstrated explicitly via a pushover analysis or similar approved analysis.
- b) Earthquake definition for the SSE shall be as per the Tank Datasheet.

Shell and bottom annular plates shall be butt welded. Welding of the inner tank bottom annular plates shall comply with API 620 Q 7.1.1. Shell to annular plate welds shall conform to API 620 sections 5.9.5 and Q 7.1.1 requirements.

Temporary access through the inner tank shell, using 'door sheets' or manways, is permitted.

All permanent structural attachments welded directly to the 9% nickel steel shall be of the same material as that to which they are welded.

Minimum plate thickness: per API 620.

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 (except for circumferential stiffening rings at vertical shell joints as shown in API 620, Appendices Q and R).

5.3 LINERS (VAPOUR BARRIER)

5.3.1 Bottom Liner

A vapour tight bottom liner, connected to the wall liner, shall be provided. The design shall account for stresses, strains, and thermal considerations. The bottom liner minimum thickness shall be 5 mm (0.2 in), and it may be lap welded. The design temperature shall be -20°C (-4°F). Acceptable materials shall be selected from API 620, Table R-4 or equivalent.

5.3.2 Wall Liner

A vapour tight wall liner which is connected to the bottom liner, the TCP embed plate and the roof liner shall be provided. The wall liner above and below the TCP embed may fail in the case of the abnormal inner tank spill. The wall liner shall be attached to embedded anchors which are flush with the inside of the outer tank wall. The wall liner minimum thickness shall be 3 mm (0.12 in). The wall liner and embedment material shall have a design temperature of -20°C (-4°F). Acceptable materials shall be selected from API 620, Table R-4 or equivalent.

The wall liner and embedded anchors shall be designed for the stresses and strains resulting from prestress loads and geometrical tolerances of construction of the liner and embedded anchors.

The tolerance of the strips to which the liner plates are welded, shall be specified by Contractor and the liner shall be designed accordingly.

The anchors of the strips shall be designed for shear resulting from prestressing loads.

5.3.3 Roof Liner

A carbon 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 (0.2 in) thick. The design temperature shall be -20°C (-4°F). A structural framing design temperature shall be selected by Contractor appropriate to the use and design considerations of the framing. Acceptable materials shall be selected from API 620, Table R-4 or equivalent.

5.4 SUSPENDED DECK

The suspended deck shall be a flat plate deck, trough decks shall not be permitted.

The suspended deck shall be provided with open vents to ensure equilibrium of gas pressure on both sides of the suspended deck.

The minimum plate thickness of the deck shall be 5 mm (0.2 in).

The minimum design temperature of the deck shall be -170°C (-274°F).

The suspended deck shall be designed for:

- a) a minimum live load of 0.5 kN/m², or
- b) a concentrated live load of 1.5 kN at any place of the suspended deck, or
- c) walkways where supported from the suspended deck

5.5 SECONDARY BOTTOM AND THERMAL CORNER PROTECTION (TCP)

The secondary bottom shall consist of minimum 5 mm (0.2 in) thick 9% nickel steel lap welded inner bottom plates and annular plates at the perimeter. The secondary bottom shall be placed on top of the bottom insulation system or between groups of insulation when insulation is also utilised above the secondary bottom. The secondary bottom shall extend into the annular space and shall connect to the TCP. (The TCP consists of vertical shield plates with a top horizontal stub connecting to a vapour tight flush anchor plate. The anchor plate is embedded in the concrete wall with anchors located on the back side of the flush anchor plate). The annular plates shall be butt welded (backing strips may be used). The connection of the annular plates to the vertical shield plates of TCP shall be made with a partial penetration corner weld with fillet.

Contraction/ expansion of the secondary bottom and vertical shield plates due to operating conditions or thermal shock caused by leakage shall be taken into account and included in the design of these plates. Consideration may be given to the increased material strength that occurs at cryogenic temperatures when calculating stresses and strains for this emergency condition.

5.6 PIPING AND ROOF NOZZLES

5.6.1 General

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

External flanges up to and including 600 mm (NPS 24") shall conform to ASME B16.5. Flanges larger than DN 600 mm (NPS 24") shall conform to ASME B16.47, and the design shall satisfy the requirements of API 620, 5.20.2.

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 or inner tank shell are not permitted.

All roof nozzles shall have vertical axes, with the flange boltholes straddling the north-south centreline of the nozzle.

The sum of local bending and simple tension Nozzles and piping, which are primary components, shall be designed in accordance with ASME B31.3.

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

5.6.2 Pump Wells

The tank shall be equipped with pump wells with foot valve and filter box. Refer to Tank Data Sheet(s) for number of pump wells. The pump, pump wells, and foot valves shall be supplied and installed by Contractor.

The pump wells shall be supported from the concrete tank roof. Pump wells may be guided from the inner tank shell if the tank top layout permits, or alternatively from the tank bottom. Either 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 clearance between the underside of the foot-valve (in the open position) and tank bottom plate shall be as recommended by the pump vendor (typically at least 51 mm (2 in)).

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.

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

5.6.3 Liquid Inlets

All tanks shall comprise a top liquid inlet. The top fill line shall be furnished with an inclined deflector plate at the underside and be designed against horizontal forces and vibrations.

- a) In addition Import tanks shall be furnished with a bottom fill line such that the liquid flows directly over a cone and into a standpipe such that the LNG runs down the inside wall of the standpipe. The cone shall be equipped with a vapour release pipe to permit vapour entrained in liquid in the standpipe to pass into the tank vapour space.
- b) A distributor shall be provided in the bottom of the standpipe with 10 slots 200 apart, directed radially outward and located on the side of the standpipe nearest the centre of the tank. The standpipe shall be self venting at design flow rate, and be located such that it is not possible for entrained liquid in the flash vapour to pass to the tank vapour outlet.

5.6.4 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.

5.6.5 Cool-down Line

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

5.6.6 Purge/Venting System

The purge/venting system shall comply with the requirements of this specification.

5.7 STRUCTURAL STEEL

Design of steel structural components shall be in accordance DEP 34.28.00.31 Steel Structures.

6. MATERIALS REQUIREMENTS

6.1 CONCRETE TANK

6.1.1 Concrete

Concrete shall be as per DEP 34.19.20.31-Gen. and shall have a 28 day characteristic strength of 30 MPa (4350 psi) for reinforced concrete components and 40 MPa (5800 psi) for post-tensioned components, or higher if advantageous for design purposes. Blinding concrete used as "mud mat" shall be C20 as per EN 1992.

Concrete mix design and production shall comply with 'DEP 34.19.20.31-Gen

6.1.2 Steel

All reinforcement, excluding cryogenic reinforcing steel, shall be un-coated deformed bars conforming to the requirements DEP 34.19.20.31-Gen . Cryogenic reinforcing steel shall also be uncoated.

6.1.2.1 Pre-stressing System

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

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 Recommendations "Acceptance and Application of Post-Tensioning Systems" – 1981. The tendons and anchorage assemblies shall be cement grouted after post-tensioning.

6.1.2.2 Cryogenic Reinforcing Steel

Selection of cryogenic steel, where required, shall be based on EEMUA 207. Testing of Cryogenic Reinforcing Steel to ASTM A370 is acceptable if so chosen by Contractor. Details of rebar materials, tests to be performed and acceptance criteria shall be subject to Company review.

6.2 INNER TANK, SECONDARY BOTTOM, AND TCP MATERIALS

6.2.1 Inner tank

All inner tank primary component plate materials shall comply with ASTM A553 Type 1. with maximum sulphur and maximum phosphorus contents of 0.005% and 0.010% respectively.

Charpy impacts shall be according to (6.4.1).

The following additional requirements shall apply:

- a) A reference list of proposed material suppliers shall be provided giving details of their experience in the supply of 9% nickel steel materials.
- b) Prior to leaving the mill all four corners of all 9% nickel steel plates shall be checked using a gauss meter. Plates exceeding 50 gauss shall be de-magnetised and re-inspected.
- c) Heat treatment in accordance with steel manufacturer's recommendation is required for ASTM A553 Type 1 material cold deformed between 3% and 5%. Under no circumstances shall cold deformation exceed 5%.
- d) 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 ASTM A20 requirements.

All plate surfaces shall be descaled after heat treatment via shot blasting as per ASTM A553 (8.1) additionally:

- a) Surface preparation shall be SA 2.5 as per ISO 8501-1.
- b) A suitable coating shall be applied to all plate surfaces selected by Contractor to be compatible with methods of transportation, storage, welding and hydrotesting.
- c) Adhesion tests shall be carried out to demonstrate the suitability of the coating should the Contractor elect to leave the coating in place.

All mechanical tests, non-destructive tests, chemical analyses and alloy verification shall be Type 3.1 as per EN-10204.

Plate repairs by welding is not permitted on any 9% Nickel plate. Repair by grinding is acceptable provided that the remaining thickness conforms to the minimum thickness requirements.

All plates $\geq 10\text{mm}$ (0.4 in) shall be ultrasonically inspected at the mill for imperfections as follows:

- a) Surface of each plate shall be scanned in grids of 100mm (4 in) centres in both directions as per ASTM A578 5.6.1.
- b) After cutting plates to the required size a 50mm (2 in) wide band at the perimeter of the plates shall be 100% inspected.
- c) Acceptance standard 'Level B' as per ASTM A578.

All plate marking shall use paint as per ASTM A20 (13.2.1).

6.2.2 Internal Piping Components (to first flange or first butt weld)

Materials for piping, tubing, forging and bolting shall be as per API 620 Appendix Q (Table Q-1).

6.2.3 Secondary Bottom and Thermal Corner Components

All secondary bottom and Thermal Corner Protection (TCP) components shall comply with the requirements of (6.2.1).

The embedment plate cast into the concrete wall to which the TCP is attached shall comply with the requirements of (6.2.1).

Anchors (studs) and associated welds connecting the embedment plate to the concrete shall be selected by the Contractor and qualified for service at -196°C .

6.3 WELDING PROCEDURES (QUALIFICATION & IDENTIFICATION)

6.3.1 General

Each Welding Procedure Specification (WPS) shall be qualified in accordance with API 620 6.7 and Appendix Q, Q6. All vertical and horizontal seams of the inner tank shell may be welded manually, semi-automatic, or by machine.

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 Company prior to the work being performed.

The welding procedures used for all welds and the radiographic inspection procedure shall be clearly indicated in construction documents.

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

6.3.2 Welding Consumables

High nickel, austenitic weld metal shall be used for all welded joints with 9% Ni-steel and shall conform to AWS A5.11 (ENiCrMo-6) and/or AWS A5.14 (E(R)NiCrMo-3, E(R)NiCrMo-4).

Filler metals and fluxes shall be selected by Contractor based on providing strength, ductility, soundness and successful LNG tank experience.

For 9%Ni materials the electrode manufacturer shall furnish mill certificates showing compliance with required yield and tensile strengths. Testing shall be on each heat for bare electrodes and on each lot for coated electrodes.

Each lot or heat of the austenitic stainless steel welding (filler) materials shall meet the requirements of ASME Section VIII, Division 1, UHA-51 (e) & (f).

All welding procedures shall be qualified in accordance with API620 and the requirements of this specification.

All welding consumables shall be stored in accordance with manufacturers recommendations.

Low-hydrogen consumables shall be handled and stored so as the weld metal diffusible hydrogen content < 5ml per 100g of weld metal. The method of determination shall be as per ISO 3690.

Contractor shall submit a consumable manufacturers certificate verifying the consumables comply with these requirements.

6.4 IMPACT TESTING REQUIREMENTS

6.4.1 General

Required impact test values shall be carried out both on base material, on deposited weld metal, and on the heat-affected zone (HAZ). Required test values are per (6.4.2) for base metal and (6.4.3) for weld metal and HAZ.

Where thickness permits specimen sizes shall be standard full size Charpy V Notch specimens as per ASTM A370 otherwise the largest feasible subsize specimen shall be prepared as per ASTM A370 (22.2.2.3).

Notch preparation of subsize specimens shall be as per ASTM A370 (22.2.2.5).

The required impact values for standard subsize specimens shall as a minimum be proportional to the absolute value of standard size specimens as API 620, Table Q-2.

6.4.2 Plate Materials

All 9% nickel steel materials shall be tested in accordance with the requirements of API 620, Q.2.2.2, Q.2.2.3 and Q.2.2.4. Testing methods and controls shall be as per ASTM A370 with the following additional requirements:

- a) 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 plates exceed 6.1m (20 ft) a second test sample (3 impact tests) shall be taken from the other end at the same position.
- b) No single specimen shall have an impact energy value less than 75% of the specified value stated in below.
- c) Where required tests for impact energy shall be in accordance with ASTM A370 (26.1.1.2)
- d) Where required retests for lateral expansion shall be in accordance with ASME Section VIII, Division 1, UHA-51.

Primary component plate materials shall have minimum average Charpy V-notch impact test values of 80 J, when tested at -196°C (-320°F) in the transverse direction for full size specimens.

Material thinner than 5mm (0.2 in) shall be exempt from impact testing.

6.4.3 Welded Joints

Impact testing procedure requirements shall be in accordance with API 620, Q.6.2. Testing methods and controls shall be as per ASTM A370 with the following additional requirements:

- a) No single specimen shall have an impact energy value less than 75% of the specified value states in below.
- b) Where required tests for impact energy shall be in accordance with ASTM A370 (26.1.1.2)
- c) Where required retests for lateral expansion shall be in accordance with ASME Section VIII, Division 1, UHT-6(a)(4).

For weld material and the heat affected zone of 9% Nickel joints the minimum average Charpy V-notch impact values shall be 55J when tested -196°C (-320°F) for full size specimens.

6.5 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 API 620 Appendix R, R1.5 and Table R-4.

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

The roof framework shall be welded to the roof plates.

Welding procedures shall comply with API 620, Appendix R.6.

6.6 SUSPENDED DECK

The suspended deck shall be a 'flat plate' deck of Aluminium Alloy 5083-O as per ASTM B209 (or approved equivalent).

Suspension rods/hangers shall be stainless steel and conform to the following;

- a. Type 304 as per ASTM A276 (UNS S30400) or agreed alternate material.
- b. Field welded material shall be Type 304L as per ASTM A276 (UNS S30403) or agreed alternate material.

7. MANUFACTURE & CONSTRUCTION - STEEL COMPONENTS

7.1 FABRICATION

Use of magnets for handling 9% Nickel steel is prohibited.

During construction temporary access through the inner tank shell using door sheets or manways, is permitted. These openings shall be permanently closed by welding. The closing and testing procedure shall be submitted for review.

Plate edge preparation of 9% nickel 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; 1.5mm (0.06 in) of the flame cut edge shall be removed and the same ground to a bright metal finish.

- a. All edges of primary containment components shall be examined by Liquid Penetrate testing.
- b. Plate laminations or surface defects shall not be repaired by welding.
- c. 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.

Production tests for 9% nickel steel plate fabrication for the inner tank are required per API 620 Q. Test results shall be submitted for Company 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 vertical seams shall be welded as a continuation of the actual tank welded joint 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.

Temporary attachment welding to the inner tank shall be fabricated from 9% Nickel, kept to an absolute minimum and qualified in accordance with API 620. The welds shall be removed as soon as practicable, but prior the hydrostatic testing of the tank.

Care shall be taken when removing temporary attachments in order to prevent damage to the surface of the base material. Following removal weld protrusions shall be ground flush and subjected to non-destructive examination to ensure no cracks have occurred. Contractor shall submit his proposed method for removal of cleats, including acceptance criterion for review prior to commencement 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 should be avoided and temporary attachment welds kept to an absolute minimum. Contractor shall take all precautions in adopting welding methodologies 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 risers. 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. Contractor shall submit for approval an installation procedure for the bottoms, the Cellular glass, and the concrete ringbeam, based on this requirement.

A mouse-hole shall be made in the horizontal butt welds of the inner tank stiffeners in accordance with Figure Q-1 of API 620.

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.

7.2 WELDING PROCEDURES

Welding shall be in accordance with API 620.

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 as required by API 620. The following welding processes are permitted:

- a. Shielded Metal Arc Welding (SMAW)
- b. Submerged Arc Welding (SAW Automatic)

Piping with Nominal Pipe Size (NPS) smaller than 75mm (3 in) 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 principal prior to the work being performed.

In addition to the production weld tests as per API 620 Q 6.6 a production weld test plate shall be made for one vertical of each inner tank course.

The latter plates shall be evaluated in the same way as in the welder qualification specified.

7.3 WELDING QUALIFICATION AND IDENTIFICATION

7.3.1 Welding procedure

Each welding procedure specification shall be qualified in accordance with API 620, Q.6, R6 as appropriate. The following additional requirements shall apply;

Welding procedures shall be qualified irrespective of previous qualifications.

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.

Separate qualifications are necessary for horizontal and vertical joints for V and X groove welds.

A copy of the material certificate of the test plate and welding consumables shall be attached to the WPQR.

For the welding of 9% nickel steel the following requirements apply:

- a. Weld test plates shall satisfy the same specifications as the tank plates.
- b. Qualification welds shall be subject to the same level inspection as per production welds including UT inspection as per Appendix C
- c. 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.

- a. For plate thickness less than or equal to 15 mm (0.6 in), 2 root and 2 face bend specimens shall be produced.
- b. For plate thickness greater than 15 mm (0.6 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 1/8 inch are not acceptable.

- c. 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. For 9%Ni steel welding, a minimum of 50% of the manual welders and one welder on each automatic welding machine shall be experienced in nickel steel welding. Contractor shall maintain records verifying individual welder certifications at the job site and make them available to the Company 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.

Welders and welding operators shall be qualified in accordance with the requirements of API 620 clause 6.8. 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.

7.3.2 Inspection

7.3.2.1 Radiographic Inspection

The radiographic, techniques, acceptance criteria and extent for the inner tank shall be in accordance with API 620.

Radiographic inspection of butt welds in plates shall be in accordance with the requirements of API 620, Q.7.6

Contractor shall propose Third Party Inspection (TPI) agency to Company for approval.

Lead screens are required. Radiographic inspection shall follow as soon as possible after welding, and the inspections shall be co-ordinated with the Company's inspector.

Radiography for 9% nickel steel welds shall be by X-ray or gamma methods with a maximum focal spot 2.5 x 2.5 mm (0.1 x 0.1 in) for the X-ray method. Focal spot size for gamma methods is subject to Company approval. All personnel performing Code evaluations shall meet ASME Section V, SNT TC-1A Level II or equivalent qualifications. The film to be used for radiography shall be ultra fine, high contrast type e.g. Kodak AA, M, or Agfa D7.

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.

7.3.2.2 Ultrasonic Inspection

All vertical welds of the tank wall and circumferential welds at the connection with the vertical welds shall be ultrasonically inspected as per Appendix C.

7.3.2.3 Liquid Penetrant Examination

Liquid penetrant examination for the inner tank shall be carried out as per API 620 and additionally:

- a. Each pass of weld joining the shell to the annular plate will be PT examined.
- b. The Secondary Bottom Annular Plates shall have the same Liquid Penetrant Examination Requirements as the Inner Bottom Annular Plates.
- c. TCP welds shall have the root pass and the final weld examined by Liquid Penetrant.
- d. The weld between the Secondary Bottom and the TCP shall have the root pass and the final weld examined by Liquid Penetrant.

7.3.2.4 Vacuum Box Testing

Vacuum box testing shall be carried out in accordance with API 620, Q.8.2.

100% vacuum-box testing shall be carried out on all vertical and horizontal welded joints in the upper part of the primary tank shell down to 3 m (9.8 ft) below the hydrostatic test level at a vacuum of 350 to 500 hPa (5 to 7 psi).

All welds of the roof liner plates shall be vacuum box tested before concrete placement on the roof. Vacuum box testing of the bottom slab and sidewall vapour barrier welds shall be completed before commencing any operations that cover up the plates. Welds between liner components (e.g. wall liner to bottom liner) shall be vacuum box tested.

All secondary bottom and outer bottom vapour barrier plate welds shall be vacuum box tested.

Inner tank bottom plate welds shall be vacuum box tested before and after hydrostatic testing.

The inner tank shell-to-bottom Tee joint annular space shall be pressure tested for leakage using a solution film in accordance with API 620, Q.8.2.2.

7.3.2.5 Positive Material Identification

Positive Material Identification (PMI) shall be performed on all 9% Nickel and Austenitic stainless steel components. Contractor shall be responsible for conducting the PMI test.

8. INSULATION SYSTEMS

8.1 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.

For exposed surfaces during a period of 12 h the daily 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. Contractor shall provide calculations demonstrating that the insulation fulfils the heat in-leak requirements.

8.2 BOTTOM INSULATION

8.2.1 General

The bottom insulation shall be comprised 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 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.

All insulation materials located between the inner bottom and primary vapour barrier shall meet the

8.2.2 Cellular Glass

The bottom insulation shall be assembled from cellular glass and comprise;

- a. Cellular glass manufactured by an approved supplier.
- b. An 'upper zone' of cellular glass located between the inner tank bottom and secondary bottom.
- c. An inner tank 'ring-beam' of cellular glass located immediately underneath the shell in the upper zone.
- d. A 'lower zone' of cellular glass part located between the secondary bottom and the primary vapour barrier.

The minimum insulation requirements for upper and lower zones shall be in accordance with Table 1.

Table 1 – Minimum Requirements for Bottom Insulation

Location	Minimum Requirements	
	Thickness mm (in)	Number of Layers
Upper Zone	200 (8)	2
Lower Zone	300 (12)	2

Factors of safety for cellular glass shall be in accordance with EN 14620.

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 100mm 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 manufacturers plant.

Cellular glass blocks shall be tightly butted against one another with gaps not exceeding 2mm (0.08 in). Each successive course shall be level to the extent that the surface irregularities shall not exceed ± 3 mm (0.12 in) in a distance of 2.0m (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.

8.2.3 Block Seating (Cellular Glass System)

Block seating shall be provided above and below each layer of cellular glass to reduce the effects 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 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 75mm (3 in) as a minimum to prevent sand penetrating between blocks.

8.2.4 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.

8.2.5 Levelling Layers

Sand levelling layers shall be provided as follows;

- a. Underneath the primary tank and secondary bottoms and shall extend as a minimum to the inside face of the inner tank ring-beam
- b. Minimum thickness 25mm (1 in), as placed moisture content shall be $\leq 2\%$ by weight.
- c. 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;

- d. On top of the primary vapour barrier and extend across the complete tank bottom.
- e. On top of the secondary bottom and extend as a minimum, to the inside face of the inner tank ring beam.
- f. Concrete levelling layers shall be minimum thickness 50mm (2 in) and strength 25Nmm⁻², reinforced for shrinkage and temperature cracking control to a minimum of 0.5% of the cross section areas of concrete.

- g. Contractor shall have a moisture content of <2% advise drying period necessary before construction of cellular glass.

8.2.6 Inner Tank Ringbeam(s)

Where higher strength cellular glass is unable to accommodate the design stresses from the inner tank shell primary and secondary inner tank ring beams shall be provided as follows:

- a. A concrete primary inner tank ring-beam shall be provided in the upper zone directly underneath the primary tank shell and distribute the demands to the lower zone.
- b. A secondary inner tank ring-beam shall be provided in the lower zone directly under the primary ring-beam as necessary to distribute the loading into the underlying cellular glass.
- c. Where provided primary and secondary ring-beams shall have a minimum thickness of 300mm (12 in).
- d. Reinforcement for all ring-beams shall be either cryogenic grade qualified for service temperatures, or, the allowable reinforcement stresses shall be in accordance with the requirements of NFPA 59A.
- e. A minimum depth of 200mm (8 in) of cellular glass shall be provided under the secondary ringbeam otherwise the minimum thicknesses stated in Table shall apply.

8.2.7 Glass Fibre Blankets

Glass fibre blankets minimum thickness 50mm shall be provided as follows:

- a. To the inside face of secondary container in the lower zone of the base insulation.
- b. To the inside face of the primary inner tank ring-beams.
- c. Where provided to the inside face of the secondary inner tank ringbeam.

8.3 WALL INSULATION

8.3.1 General

The wall insulation shall comprise upper and lower sections as follows;

- a. A lower section commonly referred to as "Thermal Corner Protection" (TCP) offering thermal isolation to the secondary container comprising foam glass, expanded perlite and resilient blanket.
- b. An upper section comprising expanded perlite and resilient blanket located above the TCP emdement.

The minimum thickness of wall insulation shall be 1000mm when measured in the upper section of the wall.

8.3.2 Resilient Blanket

Resilient Glass fibre blankets shall be installed on the outside of the primary container to reduce the compressive loadings on the inner tank arising from perlite powder and enable cooldown/warmup and cooldown of the tank without buckling the primary tank.

The minimum thickness of the uncompressed blanket shall be 300mm (12 in) and extend over the full height of the inner tank.

The methodology used to predict the perlite pressures against the inner tank shall have been demonstrated and verified through load testing.

8.3.3 TCP Zone Lower Wall

Cellular glass blocks shall be provided to the

The lower part of the outer tank wall shall be thermally insulated with cellular glass or PVC material. The insulation material shall be subject to the same material and design requirements as those for the bottom insulation.

8.3.4 Perlite

The remainder of the annular space at the upper and lower parts between the secondary wall and the steel inner tank shall be filled with expanded perlite powder.

A 'retaining wall' or 'dam' consisting of corrugated sheeting and steel stiffeners, shall be installed in the dome space to form a 'hopper' to retain the perlite powder.

Top up nozzles perlite nozzles shall be spaced shall be positioned at 4.5m (15 ft)

To provide sufficient to compensate for the effects of inner tank contraction and compaction/settlement of Perlite during service and will provide additional reserve capacity to avoid Perlite refilling during the intended tank lifetime of the tank.

The hopper shall be sized to provide a minimum reserve capacity of 10% of the Perlite volume within the tank annular space itself. Contractor shall verify and establish by calculation the minimum hopper volume required and state the target settlement of Perlite to be achieved on completion of installation.

CONTRACOR shall provide calculations including all assumptions and predictions to show the extent of Perlite settlement predicted to occur during placement, vibration, cooldown and operation for the duration of the tank's design life.

8.3.5 Perlite Ore

The perlite shall be manufactured on site under controlled furnace conditions from a "glass like" volcanic ore of variable chemical composition. – typically an aluminium/potassium/sodium silicate mixture.

Perlite ore shall be supplied from sources with a track record of supplying perlite to the cryogenic industry and shall enable attainment of the requirements for cryogenic grade perlite documented herein

Prior to shipment to site the Perlite ore shall be prepared in accordance with Perlite Institute Specifications PI-111 or PI-112 and then subject to the following acceptance tests.

All precautions shall be taken to keep the ore dry during transit and storage.

Grading of the ore shall be determined on the basis of expandability tests in order to satisfy the requirements of this specification. Perlite contractor shall nominate his basis of grading the ore in respect of the sieve size (Perlite Institute Specification 115).

Samples shall be taken to check on "expandability" of the perlite ore in accordance with the Perlite Institute Specification 307. Alternatively if the Insulation Contractor can provide previous records from the same ore supply that confirms expanded perlite results the this requirement may be waived.

Samples shall be taken for sieve analysis at a rate of 100-200g for every 150 tonnes (min) of ore.

Moisture content of the ore shall be between 2.0 and 4.0%. Samples shall be taken for water content at a rate of 25g for every 150 tonnes of ore, reference Perlite Institute Specification 118.

Samples shall be taken for spectrographic analysis by X-Ray fluorescence methods in accordance with BS 1902-9.1 techniques at a rate of 50g for every 300 tonnes of ore. The analysis shall demonstrate the consistency of the ore and the absence of matter which could prove detrimental to the production of perlite for cryogenic use.

All ore shall be delivered with a certificate confirming the properties as required by the above.

8.3.6 Perlite production testing requirements

Installed perlite shall have an insitu compacted density between 48-65kgm-3 tested in accordance with Perlite Institute Specification PI-201-Part A.

Loose density shall be calculated in order to enable the determination of compacted density no acceptance criterion are specified herein.

Sieve analysis tested in accordance with ASTM C136 shall conform to the following Table 2.

Table 2 - Grading requirements expanded perlite

Sieve Aperture Size mm(in)		% Retained	
Passing	Retained	Minimum	Maximum
		0	10
1.18 (0.047)	0.850 (0.033)	0	25
0.850 (0.033)	0.600 (0.023)	5	35
0.600 (0.023)	0.300 (0.012)	15	50
0.300 (0.012)	0.150 (0.006)	10	40
0.150 (0.006)		0	30

Thermal conductivity shall not exceed $0.044\text{W.m}^{-1}.\text{C}^{-1}$ tested at a mean temperature of 0°C (32°F) in accordance with ASTM C177 using dry air as the interstitial gas.

Free moisture content less than 0.5% tested in accordance with Perlite Institute Specification PI-118-Part A

Organic content maximum 0.1% by weight using the Trichloroethane Method.

8.3.7 Frequency of Testing

Certificates shall be produced to record all "production" test results stated above at the frequencies stated below.

Table 3

Clause	Compliance For	Frequency
7.4.6	Loose Density	4 Hours
7.4.6	Compacted Density	4 Hours
7.4.6	Sieve Analysis	8 Hours

7.4.6	Thermal Conductivity	At top and bottom of tank
7.4.6	Moisture Content	Daily
7.4.6	Organic Content	At top and bottom of tank

8.3.8 Filling Requirements installation

All erection activities inside the tank shall be completed prior to the commencement of perlite installation. All openings into the inner tank shall be properly sealed to prevent perlite movement into the inner tank. All thermocouple wires and optic cables shall be installed and tested for continuity.

Perliting shall not occur prior to hydro-testing, drying and cleaning of the primary tank

Perlite expansion Contractor shall:

- a. Have a proven track record of plant and equipment on similar projects.
- b. Provide a reference list of similar projects where the equipment has been deployed.
- c. Fully describe the equipment and control systems necessary expand perlite.
- d. Provide a means to control and monitor relevant production parameters, including fuel supply, air supply, perlite supply and temperatures.
- e. The expansion plant shall have a dust suppression system and proven performance in similar projects

The air supplied to the perlite delivery shall be dry and have a maximum dew point of - 30°C (86°F)

Filling heights shall be inspected at every nozzle to ensure correct attainment of fill height.

Initial filling of the tank may be conducted from the suspended deck. Perlite shall not be discharged directly against the resilient blanket nor outer tank. The hose shall be checked and moved frequently to guard against accident abrasion damage to the blanket or tank components.

Final filling of the tank shall be carried out via perlite fill located above the tank annular space.

The Perlite shall be installed by internal vibration to establish initially the main settlement during the installation phase.

During filling perlite levels shall be maintained as uniform as possible. Differential heights between maximum and

Perlite shall be vibrated to assure that all voids are filled. Methodology for filling control and vibration shall be supplied with his proposal.

Vibrators shall be positioned around the complete circumference of the tank and the perlite vibrated.

The Perlite shall be installed in uniform layers, or lifts, around the circumference of the tank. The loads against the inner tank shell, shall be balanced by periodic repositioning of the fill hoses.

8.3.9 Insulation layer

The minimum insulation layer thickness shall for cellular glass shall be 150mm (6 in) for the wall/Corner protection applied in 2 layers.

8.4 MATERIAL HANDLING AND STORAGE

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

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

8.4.1 **Suspended Deck Insulation**

Insulation on the suspended deck shall consist of fibre glass blankets minimum thickness shall be 0.7m (27.5 in) with due allowances for long term settlement, consolidation, creep and elastic compression. Adequate material shall be installed to comply with these requirements. Perlite shall not be permitted.

Each blanket layer shall have a minimum installed thickness of 150mm (6 mm)

Minimum density of blanket shall be 11kgm-3 (0.7 lb ft-3)

Blankets shall be cut, fitted and sealed around all roof hangers, nozzles and protrusions

All deck plate shall be fully welded and inspected prior to commencement of blanket installation.

Installation of blanket shall only commence once all other activities in the roof space are completed.

Blanket 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.

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

For suspended deck blanket the following shall apply.

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

9. FIRE SCENARIOS

9.1 PRESSURE RELIEF VALVES

Where Pressure Relief Valves (PRV) discharge to atmosphere then a PRV tailpipe fire shall be considered within the design subjected to the following;

The heat radiation shall be determined based on the total design flow rate of a single PRV discharging through the tail pipe.

Calculations shall be based on a duration of 1 hour in conjunction with wind speed having a 90% occurrence probability.

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 fire.

9.2 HEAT DETECTION

A heat detection system, consisting of pressurised tubing made of black polyethylene, shall be installed along the roof platform railing, near the pressure relief valves and where water-spray is used for the protection of equipment. It shall give an alarm in the Control Room in case of fire so that operators can activate the fire protection system.

Manual call points shall be installed along the main road near the tank, near the stairway to the roof platform and on top of the roof platform. These shall trigger the fire alarm (audible).

9.3 FIRE PROTECTION SYSTEM

The steel roof appurtenances (level and pressure instruments, relief valves, manholes and nozzles of 4" and greater) shall be protected against thermal radiation by means of special operator-free fire protection system (exposure protection by water spray).

In addition, the piping and equipment on the roof platform shall be protected. The water spray rates shall be as follows:

- 2 l/sq. m/min for the roof platform;
- 4 l/sq. m/min for the roof appurtenances.

In view of maintenance and reliability the use of fire monitors is preferred. Alternatively, spray systems with nozzles may be used.

10. INSTRUMENTATION

10.1 INSTRUMENT CONNECTIONS

The tank shall be provided with nozzles for all instrument connections shown on the P&ID's, and shall include the following instrumentation:

10.2 LEAK DETECTION

A leak detection system shall be installed in the annular space between inner and outer tank wall to continuously monitor the space for accumulations of LNG. The system shall contain a minimum of 4 sensor elements, equally spaced around the tank annulus with cable and 4 spare sensors wired up to a junction box in the tank annulus, and then to a junction box external to the tank. At one location two additional sensors and one spare sensor on a vertical line along the wall corner protection liner shall be installed to measure liquid build-up levels.

The system must produce a process alarm in the Central Control Room (CCR) when LNG spillage is detected, and also provide a system alarm if there is a malfunction in the monitoring system.

The leak detection system, including sensors, sensor lead wire, junction boxes at the tank interface shall be provided and installed by Contractor.

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 BS 1904 (1984) Class A.

In addition a fibre optic monitoring system with a temperature measuring accuracy of 2°C (35.6°F) and a temperature range of +150°C (302°F) to -165°C (-265°F) may shall be installed at the bottom of the annular space.

10.3 COOLDOWN SENSORS

Contractor shall provide temperature sensors to detect temperatures during cooldown and operation of the inner shell plate, inner bottom plate, and annular space bottom plate. The number and location of these sensors shall be selected for optimum performance. The minimum number of sensors shall be as indicated below. Contractor shall be responsible for wiring these devices to a separate junction box outside the 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 shown on the attached drawings.

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

- 3 on the outside of the inner shell plate to detect bulk material temperature.
- 8 on the inner bottom plate to monitor tank cool down.

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 outside of the tank.

Contractor will used RTD cool down sensors based upon demonstrated past installation experience.

10.4 TEMPERATURE SENSORS

A continuous temperature monitoring system for the bottom slab is required. The system shall consist of heating controls and heating alarms. A quantity of 6 temperature sensors shall be distributed over the bottom slab, per Contractor Design. Temperature monitoring system including sensors, sensor lead wires, and junction boxes shall be provided.

Contractor may recommend an alternate quantity of temperature sensors based upon demonstrated past installation experience.

11. TANK GAUGING AND OVERFILL PROTECTION REQUIREMENTS

11.1 TANK INSTRUMENTATION

The following tank instrumentation shall be provided by Contractor.

The requirements specified in paragraph a), b), c), d), and h) need to be confirmed at EPC stage.

- a. Two independent level gauges equipped to provide remote readings and high level alarm signals in the Central 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 level gauge shall provide readings and alarms via the Tank Monitoring System (TMS), and the secondary level gauge shall provide alarms generated by an independent safety rated PLC.
- b. 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).
- c. 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.
- d. 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.
- e. All level gauges shall be equipped with diagnostics to detect and alarm for device malfunctions.
- f. The installed level measuring system shall meet the requirements of SIL 3 to ensure that the risk of overfilling may be considered ALARP.
- g. When noted on the P&ID, Contractor shall provide an independent LTD (Level Temperature, Density) System Monitor with density difference alarm.
- h. Softwired interface to DCS system is required. Contractor shall provide address mapping data in format approved by Company.
- i. 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. Contractor shall also provide receivers for installation and wiring in the CCR.
- j. Contractor shall provide an integrated tank-monitoring system (TMS) capable of receiving tank-gauging data for up to at least eight tanks. Contractor shall be responsible for interfacing the TMS to the Process Automation System (PAS), which includes interfaces to both DCS and Safety Instrumented System (SIS) per specification provided by Company. The TMS shall have a minimum of one computer display for display of tank-gauging data. Standard software for the TMS shall be included. All applicable field instruments shall be wired to junction boxes provided by the Contractor.
- k. Contractor shall provide termination drawing or equivalent list for the TMS.
- l. Contractor shall follow the Company tagging system instruments.

11.2 INSTRUMENT NOZZLE CONNECTIONS

A listing of all instrument nozzles to be furnished by Contractor shall be as included in the Tank Data Sheets and drawings referenced in the Scope of Work, and/or the P&ID drawings. Contractor shall provide a complete listing of all nozzles supplied with description of their function.

12. ELECTRICAL

12.1 GENERAL

The following electrical provisions shall be made internal with the tank.

Contractor shall supply and connect the power cable between the submerged pump motors and the junction boxes located at head plate. The pump motor power cable (from substation to JB) and junction boxes will also be supplied and installed by Contractor.

12.2 LNG TANK EARTHING

Tank earthing/grounding shall meet the requirements of IEEE 142 "Recommended Practice for Grounding", and API RP2003-1998, "Protection Against Ignitions Arising Out of Static Lightning and Stray Currents".

Contractor shall supply an earthing ring for the tanks consisting of a 1/C-70 mm² stranded copper conductor, with green XLPE insulation and yellow stripes. The 70 mm² (0.108 in²) conductor shall be buried at a depth of 500 mm (20 in), around the tanks.

Each tank shall have three earthing bosses; three (3) connections shall be made between each tank and the earthing ring.

The earthing electrodes shall be installed and connected to the earth ring at each point of connection to the tank earth bosses. Intermediate earth electrodes shall be installed as necessary to obtain the required overall earth resistance. The distance between any two electrodes shall not be more than 65 m (213 ft). The grounding electrodes shall be stainless steel, and be at least 3 m (10 ft) long and a minimum diameter of 15 mm (0.6 in). The overall earthing resistance, to be verified by field tests, shall not exceed 1 ohm.

Provisions shall be made to connect the main plant earthing system in two locations at the piperacks leading into the Tanks. Firm tie-in locations shall be furnished by Contractor.

12.3 LIGHTNING PROTECTION

Contractor shall supply a lightning protection system comprising air terminals, bonding conductors and down conductors of at least 70 mm² (0.108 in²) on each tank. The down conductors shall terminate at the earth bosses, which shall be connected directly to the earthing ring described in 9.3.2 with 70 mm² (0.108 in²) insulated grounding cable. The lightning protection system shall be designed in accordance with the requirements of NFPA 780.

13. PRESSURE AND VACUUM RELIEF SYSTEMS

13.1 GENERAL

Provisions for pressure and vacuum relief nozzles and equipment, including spares shall comply with the P&ID's.

Each tank shall be provided with pilot-operated pressure relief valves, with teflon diaphragm, seat and seals. The valves shall be located 90 degrees from the platform.

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, LNG cannot block the pressure relief inlet pipes.

Pressure relief valve outlet pipes shall discharge vertically, at sufficient height so that no water protection is required on the roof for the event of a pressure relief valve fire. This requires that the outlet pipe is at least 10.0 m (33 ft) above the concrete roof (measured along a vertical line through the discharge point). The outlet shall be provided with a rain flapper and drain.

Each pressure relief valve shall have a nitrogen connection for extinguishing small fires and for possible purging against ice formation. The valve for operation shall be located remote from the tank at grade level so that an operator can supply nitrogen in case of a 'small' relief valve fire.

One spare pressure relief valve shall be provided in addition to the calculated number.

13.2 PRESSURE RELIEF VALVES

Sizing of PRV's and VRV's shall take account of boiloff rate due to rollover calculated according to EN 1473: 1977, Para. B.11: $VB=100 \times VT$.

Operating factors that shall be considered in sizing PRV's & VRV's are stated in NFPA-59A, 4.7. Design shall be in accordance with API 2000 – 1998.

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 EN14620.

Each tank shall be provided with a minimum of 3 pilot operated pressure relief valves, including remote pilot pick-up. The valves shall be mounted on the concrete roof.

One level of pressure relief valves discharging to atmosphere shall be provided. Relief valves shall discharge to atmosphere through a vent stack.

Pressure relief valves shall relieve from the inner tank vapour space. This requires the inlet piping to penetrate the suspended deck.

The Relief Valves shall accommodate the design requirements of the datasheets.

One spare valve above the calculated number shall be provided.

Relief valves shall be fitted with a cap to prevent entry of water into the tail pipes. The cap shall 'blow off' during a relief event enabling unrestricted flow and pressure relief.

Hinged mechanical flappers are not permitted.

Drain holes shall be provided in the tail pipes to ensure that water does not pond or collect within the tailpipes.

Height of the tail pipes shall in in accordance with the Tank Datasheets.

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

13.3 RESERVE CAPACITY RELIEF VALVES

Reserve Capacity Relief Valves (RCRV's) shall be required depending on the pressure relief design flow specified and relief scenario considered.

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

13.4 VACUUM RELIEF VALVES

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

One spare valve above the calculated number shall be provided, with a minimum total number of 4.

These vacuum relief valves shall allow air to enter the dome space only.

Amended per
Circular 41/11

14. ACCESSORIES

14.1 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 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. Company will advise Contractor if flow meters are to be used for custody transfer of LNG.

14.2 ACCESS TO PLATFORM AND ROOF

14.2.1 Stairway

A main stairway with intermediate landings at maximum vertical spacing of 6 m (19.5 ft) (preliminary value to be confirmed at EPC stage) shall be provided as shown on design concept drawings. 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 (0.2 in) shall be used.

Two (2) additional staircases shall give access from the platform to the tank roof. Two (2) manholes shall be installed in the tank roof, one at either side of the platform. Two (2) cage ladders, one per manhole, shall give access to the suspended deck.

14.2.2 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 escape.

Handrails, guardrails and platforms shall be hot dip galvanized in accordance 'DEP 34.28.00.31-Gen Steel Structures'

Guard railing and toe plates shall enclose all product nozzle, pressure relief device, 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.

14.3 JIB CRANE

One Jib crane shall be installed to access in-tank pumps. The crane shall comprise two independent lifting cables operated by a powered slow drive winch (a screw drive is preferred which cannot self unwind). One cable only 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.

The hoist shall also be provided with a handwind override and a high speed brake. Rated Capacity shall exceed the weight of the maximum load to be lifted plus an allowance for rigging .

Provision shall also be made for the simultaneous withdrawal and storage of the pump electric cables.

Lifting cables shall be of the crosswound, non-kink type.

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

15. MONORAILS

15.1 GENERAL

For maintenance purposes, one monorail (trolley beam) for a gondola (2 persons) shall be installed inside the tank, above the annular space. A second monorail (for same gondola) shall be installed outside the tank along the perimeter of the roof. Contractor may install additional monorail(s) for tank erection purposes if needed.

15.2 LIGHTING

Contractor shall provide all temporary lighting for his construction purposes. Contractor shall design all permanent lighting and shall submit drawings to the Company for approval. Contractor shall furnish all wiring, fixtures and posts. Contractor shall furnish and install all supports attached to the tank and install permanent lighting.

15.3 SUPPORTS

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.

16. PAINTING

All exterior steel structures, stair, walkways, platforms and handrails shall be hot dip galvanized in accordance with ISO 1461 or equivalent ASTM specification.

All external metal surfaces including insulated or fire proofed surfaces, equipment, and piping (excluding stainless steel) shall be suitably coated or painted.

17. HYDROSTATIC/PNEUMATIC TESTING

17.1 HYDROTESTING OF INNER TANK (FRESH WATER)

Hydrostatic testing of the inner tank shall be in accordance with API 620 Section Q.8 except that the water level shall be as specified in this specification.

A complete hydrostatic-pneumatic test procedure, including the drying and cleaning procedure after the test, shall be provided. 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.

After testing, the tank shall be thoroughly cleaned and dried.

The quality of water used for the hydrostatic test shall be potable and meet the requirements of API 620, and the following;

Contaminant	Concentration
Total Dissolved Solids	<500ppm
Concentration of SiO ₂	<10ppm
PH	>7 and <8.3
Ca and bicarbonate	Langelier index >=0
Chloride (NaCl)	<100ppm
Sulphate (SO ₄)	<150ppm
Free residual chlorine concentration	>0.3 and <1.0ppm
H ₂ S	No presence
Filtering (50 microns)	As required

Prior to the hydrotest the Contractor shall provide a full analysis of the test water.

A complete hydrotesting and pneumatic testing procedure, including the drying and cleaning shall submitted

In the event that the chloride content of the test water exceeds 30ppm all austenitic stainless steel components which are exposed to the hydrotest water shall be flushed thoroughly with water of a chloride content of <5ppm.

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.

After testing the tank shall be thoroughly cleaned and dried.

Pumpwells shall be tested in accordance with ASME B31.3 Chapter VI, 345.6 –Hydrostatic-Pneumatic Leak Test. Prior to the hydrotesting the pumpwells shall be emptied and sealed.

17.2 PRESSURE AND VACUUM TESTING

The outer tank shall be pneumatically tested in accordance with API 620, Q.8 procedures.

Pumpwells shall be tested in accordance with ASME B31.3, Chapter VI, 345.6 – Hydrostatic-Pneumatic Leak Test. 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.

18. SETTLEMENT MONITORING

18.1 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 10m (33 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. Whereby facilitating level surveys.

18.2 INCLINOMETERS

Contractor shall install casings in the base slab of each tank and a horizontal Digitilt-type inclinometer along two perpendicular lines. The inclinometer shall be capable of measuring settlements to an accuracy of $\pm 2.5\text{mm}$ (0.1 in) per 30m (98.5 ft) of casing. The casings 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 2.5m (8 ft) increment of water height for both filling and emptying operations.
- 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 $\pm 0.01\text{mm}$ (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.
- Following hydrotest settlements shall be taken on purging.
- Filling with LNG then finish
- Dishing settlements and total settlements shall be verified with design allowables determined via the requirements of this specification of the geotechnical Engineer.

During normal operations settlements shall be recorded. Frequency/interval durations shall be in accordance with the requirements of ACI 376 (unless stated otherwise).

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

19. CALIBRATION

19.1 GENERAL

Contractor shall arrange, in consultation with Company, calibration of the inner tank by a specialist organisation in accordance with the API MPMS (Manual of Petroleum Management Standard, Chapter 2, Tank Calibration), or other internationally accepted code. 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 Company.

20. DRYING AND INERTING

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

Drying and purging shall be carried out with dry high purity nitrogen produced by cryogenic air separation or membrane technology. The high purity Nitrogen and the materials required for purging shall be supplied by Contractor.

The inner tank dome space shall be purged to a maximum dew point of -20°C (-4°F) and a maximum O₂ concentration of 5%.

The annular space (perlite powder) shall be purged to a maximum dew point of -10°C (14°F) and a maximum O₂ concentration of 5%.

There is no specific oxygen level requirement for the under bottom insulation.

The inner tank shall be purged first. Nitrogen shall be introduced to inner tank through purge nozzle(s) noted on the LNG tank drawings.

Purging shall be conducted in accordance with the American Gas Association, Operating Section Report, Purging Principles and Practice, Section 4.35. Contractor shall prepare procedures in accordance with AGA recommendations and submitted 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. Each section of tank base insulation between bottoms or vapour barrier 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. Bypass valves shall be provided on at least one relief valve to atmosphere and one relief valve connected to the vent system for venting purge gas.
- i. 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.

Contractor shall supply all required piping appurtenances for purging and cooldown.

21. COOLDOWN AND COMMISSIONING

21.1 COOLDOWN GENERAL

It is the Contractor responsibility to perform the tank cooldown operation. The 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.

Requirements for cooldown sensors are described in this specification.

The cooldown rate as measured at any one of the inner tank RTD's (or thermocouples) shall be controlled to not exceed 5°C (41°F) per hour.

The maximum temperature difference between any two adjacent shekel or bottom thermocouples shall be 10°C (14°F).

21.2 COMMISSIONING-GENERAL

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

22. CONSTRUCTION REQUIREMENTS AND TOLERANCES

22.1 METALLIC STRUCTURES

Construction tolerances for metallic structures shall comply with the requirements of API 620 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 Company.

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

22.2 CONCRETE STRUCTURES, CONSTRUCTION REQUIREMENTS:

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

Wall finishes shall be DEP 34.19.20.31-Gen.

Concrete production and construction shall ensure that mixes and methods produce a dense impermeable finish.

During casting of concrete, all insert plates (embedments) shall be located in position by means of temporary connections to the shuttering. Temporary connection of 'inserts' to rebar cage or tendon ducts shall not be permitted.

22.3 CONCRETE STRUCTURES, TOLERANCES

Construction tolerances for formed concrete surfaces shall be per DEP 34.19.20.31 -Gen.

23. ADDITIONAL REQUIREMENTS ON REINFORCING STEEL

As a minimum, "Tempcore" cryogenic reinforcing bars tested to cryogenic temperature toughness on un-notched specimens shall be used for the horizontal reinforcement of the inner face of the outer tank wall, above the top level of the 9% Ni Thermal Corner Protection (TCP) up to the highest liquid level which would be in contact with the secondary containment following a major spill from the inner tank. For these bars, the splicing shall not be more than 50% in any given section, except around the temporary opening(s).

Testing for Crybar where used shall be in accordance with the requirements of EEMUA 207.

24. BASE SLAB HEATING SYSTEM

24.1 GENERAL

A heating system shall be installed in the concrete bottom slab to prevent frost heave of the subsoil. The bottom slab heating system shall comply with the requirement of DEP 33.68.30.31-Gen and project specifications.

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

System components shall be approved by a nationally recognised testing laboratory, such as Underwriters Laboratories Inc. (UL) or Factory Mutual Engineering & Research Corporation (FM), for the specified area classification. Heaters shall be approved for Class 1, Division 2 locations, as a minimum, and shall meet the cable construction requirements of IEEE 515.

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

Contractor base proposal heating system shall consist of constant wattage cable system installed in parallel, galvanised, steel conduits embedded through the concrete slab under the tank base. The conduits shall be spaced at appropriate intervals and not greater than 1.0m (3.3 ft) to provide an even heating layer for a designed 100% surplus heating system (available heat versus required heat). The system proposed shall include: power controller, temperature controller/monitor, temperature sensors, heating cable, junction boxes or marshalling cabinets (as required) and all cables necessary to provide a complete system from the distribution panels to the under tank components. The outdoor panels shall be located in non-hazardous areas.

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

24.2 HEATER DESIGN AND MATERIALS

The heater cable shall have proven capability in cryogenic or refrigerated base heating installations as applicable. Selection shall be limited to parallel resistance constant wattage (preferred) or series resistance mineral insulated (MI) cables. The latter may only be bid as an alternative with the approval by Company's Engineer. Self-limiting or self-regulating heater cables shall not be used.

Heater cables shall be manufactured by companies that have produced cables for undertank heating systems for at least five years.

Constant wattage parallel resistance heater cables shall be as follows:

- a. Fluoropolymer insulation, nickel-plated copper braid and fluoropolymer outer sheath; where the area or product stored is corrosive to copper, stainless steel braid shall be used.
- b. Heater cable bus wires shall be 4 mm² (0.006 in²) (12 AWG) minimum.

- c. Heater cable watt density shall be limited so that continuously energised heater cables shall not be damaged or have a reduced service life.

Mineral insulated (MI) cable requirements are as follows:

- a. The sheath shall be Inconel (preferred) or copper with a fluoropolymer jacket. Selection shall be based on economics and environment (assuming the nitrogen purge is inoperative).
- b. Each cable shall include a factory-installed pulling eye with a watertight seal to the cable.
- c. Each cable shall include a flexible section, compatible with the connecting power cable, for routing to junction boxes.

Calculated ratings shall be increased by a minimum 50% service factor to account for changes in items such as insulation conductivity, voltage and heater resistance.

Any large nozzle pit areas or other areas requiring special heating are considered as separate zones from the main area under the tank.

Heating circuits for each zone shall be selected to provide nearly balanced three-phase connections.

The heater circuits for each zone shall be designed to prevent subsoil freezing with the loss of one circuit. Adjacent heater conduits shall be connected to different heating circuits.

Within a zone, power shall be supplied to adjacent heater circuits from the opposite sides of the zone.

The expected duty cycle (percent of time that the heaters are energised) shall be approximately 60%. However, if one circuit is lost, the duty cycle of the remaining heater circuits may be as high as 100% and the minimum subsoil temperature shall be maintained above 0.6°C (33°F). The design duty cycle for each heater shall be 100%.

24.3 PROTECTIVE DEVICES

A main distribution panel board containing circuit breakers with an overcurrent and ground-fault equipment protective device (30 mA to 100 mA) and trip indication for each outgoing circuit shall be provided. Breaker indication and reset shall not require entry into the panel board. A common remote alarm shall be provided.

Heater cable circuits shall be designed to have a total earth leakage not exceeding 67 percent of the ground fault leakage protection trip value to prevent nuisance tripping.

An alarm system shall be provided to adequately monitor individual heater circuit failures not determined by the circuit breakers. A common remote alarm shall be provided. Systems that indicate system deterioration to predict failure shall be quoted, as an option.

24.4 SENSORS, INDICATORS, AND CONTROLLERS

Sufficient temperature sensors shall be provided under the tank in each zone for control, monitoring (to provide a temperature profile of the zone) and spares. The sensors shall be three-wire RTDs (preferred) or thermocouples and shall be water resistant and sealed.

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

- a. The input controllers shall be capable of control with $\pm 1\%$ repeatable accuracy.
- b. The input controllers shall provide alarms to detect open temperature sensor circuits and high/low temperatures.
- c. Control temperature is normally between 2°C (35.5°F) and 5°C (41°F).

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

- a. The main zone requires a minimum of three controllers.

- b. 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 a 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 Company.

- 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 a NEMA 4X stainless steel enclosure, free standing or wall mounted as per NEMA 250. 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 (0.009 psi).
- Loss of pressurisation shall initiate a remote alarm in the central control room.

24.5 HEATER CONDUITS

Conduits shall be a minimum of 19 mm (0.75 in) rigid galvanised steel in accordance with NEMA C80.1.

Conduit couplings shall be seal welded.

Conduits shall be installed in the concrete base slab and located at upper face of the bottom slab and attached to the base reinforcement.

Conduit spacing shall not exceed 1 m (3.3 ft) unless it can be shown that the requirements of (21.2.8) can be met with greater spacing.

Conduit bends shall be minimised to ease installation and maintenance. However, where unavoidable, they shall have the maximum radius feasible.

The minimum radius bend of the conduit shall be 10 times the conduit diameter.

To minimise internal corrosion and the potential for ice formation due to heater failure, a nitrogen system with provision for initial purge shall maintain the conduits pressurised with dry nitrogen. The nitrogen system shall include provision for remote alarming on loss of pressure.

Conduits for temperature sensors shall be located parallel to and halfway between adjacent heating conduits, generally near the centre of each zone. In addition, one conduit per zone shall be perpendicular to and slightly below the heating conduits to permit obtaining a temperature profile.

The space between the conduits and any pipe sleeves in a concrete ringwall shall be sealed against water entry by means of a nonhygroscopic, pliable material extending at least 10 cm (4 in) into the space.

Conduits shall slope upward to the tank centre to drain to the perimeter and to compensate for the predicted differential settlement between the tank edge and centre.

24.6 OTHER EQUIPMENT

As a minimum, two separate power sources shall be provided unless the Company's Engineer waives this requirement on the basis of the reliability of the single source and the time required to freeze the soil. Where two sources are provided, an automatic transfer switch shall be furnished.

All external connecting cable, junction boxes, conduits, raceways and/or cable ladder racks shall be in accordance with Project Specifications. Drains shall be provided in all junction and terminal boxes.

Circuit components shall be suitably sized for cable inrush currents due to temperature variations (cold start) and maximum cable tolerances.

24.7 INSTALLATION

Just prior to heater pulling, conduits shall be blown free of water and a mandrel and swab shall be pulled through the conduit until the conduit is clean and dry.

A length of corrosion resistant pulling wire attached to the pulling end of the heater shall remain coiled inside the conduit to facilitate pulling out the heater for replacement.

Heater cable terminations shall be doubly sealed with a heat shrink/adhesive outer seal for maximum water resistance.

24.8 INSPECTION AND TESTING

Prior to covering or encasing the conduit, it shall be air pressure tested at 103 kPa (15 psi) gauge with a soap solution applied to all joints.

Factory and field tests for heater cable in accordance with IEEE 515 shall be performed to ensure lengthy watertight service and high system availability. These tests shall be in addition to those specified in Project Specifications. Sufficient factory test data, such as resistance and load amperes, shall be taken to provide a base to determine adequacy after installation and during operation.

Assembled mineral insulated cable shall be factory hydrotested at 590 kPa (85.5 psi) gauge to 785 kPa (114 psi) gauge for 24 hours.

Cable integrity shall be confirmed by dielectric test and resistance measurements.

The factory high potential voltage test shall be conducted at twice rated voltage plus 1000 volts in a nonionic water bath.

24.9 VENDOR DATA

Documents submitted with bids shall include the following information:

- a. Heater arrangement and circuit drawings, including number of zones for separate control, heater spacing and location.
- b. Heater control scheme, including duty cycle, location of sensors, temperature control criteria and any provision for a forced frequency cycle.
- c. Calculated heat leak, heat flux, heating cable watt density, and conductor and sheath temperatures for each zone.
- d. Assumed thermal conductivity of the various layers on which the calculations are based.
- e. Heater rating service factor.
- f. Total kilowatts used for each zone.

- g. Component specifications, descriptive literature and proposed vendors and subcontractors.
- h. General QA/QC procedures.

Additional documents following bid award shall include:

- a. Shop and field testing and inspection procedures.
- b. Installation and heater replacement instructions.
- c. Instructions on raising the control temperature of adjacent heaters when one heating circuit fails, when required.
- d. Heating calculations by zone including tank heat leak, steady state and transient temperature distribution, transient power and temperature curves during heat startup and shutdown and sketches serving as the models (with boundary conditions) for the calculations.
- e. Test reports shall be submitted progressively as tests are completed.

25. 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

Electrical heating system for frost heave prevention of refrigerated hydrocarbon storage tanks	DEP 33.68.30.31-Gen.
Reinforced Concrete Structures	DEP 34.19.20.31-Gen.
Steel Structures	DEP 34.28.00.31-Gen

AMERICAN STANDARDS

AGA Operating Section Report, Purging Principles and Practice	AGA XK0101
---	------------

Issued by:

*American Gas Association
400 N. Capitol Street N.W.
Washington, DC 20001, USA*

Code Requirements for Design and Construction of Concrete Structures for the Containment of Refrigerated Liquefied Gases	ACI 376
--	---------

Issued by:

*American Concrete Association
38800 Country Club Drive
Farmington Hills, MI 48331, USA*

Venting Atmospheric and Low-pressure Storage Tanks	API STD 2000
--	--------------

Design and Construction of Large, Welded, Low-pressure Storage Tanks	API STD 620
--	-------------

Manual of Petroleum Measurement Standard Chapter 2 - Tank Calibration Section 2A, B and C	API MPMS 2
---	------------

Protection Against Ignitions Arising out of Static, Lightning, and Stray Currents	API RP 2003
---	-------------

Issued by:

*American Petroleum Institute
1220 L Street, NW
Washington, DC 20005, USA*

2009 ASHRAE Handbook—Fundamentals.	ISBN: 978-1-933742-54-0
------------------------------------	-------------------------

Issued by:

*American Society of Heating, Refrigerating and Air-Conditioning Engineers
1791 Tullie Circle, N.E.
Atlanta, GA 30329, USA*

Process Piping	ASME B31.3
----------------	------------

Nondestructive Examination	ASME Section V
----------------------------	----------------

Division 1 Rules for Construction of Pressure Vessels	ASME Section VIII
---	-------------------

Welding and Brazing Qualifications	ASME Section IX
------------------------------------	-----------------

Issued by:

*American Society of Mechanical Engineers (ASME)
Three Park Avenue, M/S 10E
New York, NY 10016-5990, USA*

Standard Specification for General Requirements for Steel Plates for Pressure Vessels	ASTM A20
Standard Specification for Stainless Steel Bars and Shapes	ASTM A276
Standard Specification for Carbon Structural Steel	ASTM A36
Standard Test Methods and Definitions for Mechanical Testing of Steel Products	ASTM A370
Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered 8 and 9 % Nickel	ASTM A553
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 Sieve Analysis of Fine and Coarse Aggregates	ASTM C136
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 Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing	ASTM D226
Standard Specification for Asphalt-Saturated and Coated Organic Felt Base Sheet Used in Roofing	ASTM D2626
<i>Issued by:</i> <i>ASTM International</i> <i>100 Barr Harbor Drive</i> <i>West Conshohocken, PA19428-2959, USA</i>	
Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding	AWS A5.11
Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods	AWS A5.14
<i>Issued by:</i> <i>American Welding Society</i> <i>550 N.W. LeJeune Road</i> <i>Miami, FL 33126, USA</i>	
Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book (Color Book Series)	IEEE 142
Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications	IEEE 515
<i>Issued by:</i> <i>The Institute of Electrical and Electronics Engineers, Inc.</i> <i>445 Hoes Lane, P.O. Box 1331,</i> <i>Piscataway, NJ 08855-1331, USA</i>	
Temperature Measurement Thermocouples	ISA MC96.1
<i>Issued by:</i> <i>International Society of Automation.</i> <i>67 Alexander Drive, P.O. Box 12277,</i> <i>Research Triangle Park, NC 27709, USA</i>	
Enclosures for Electrical Equipment (1000 volts maximum)	NEMA 250

Electrical Rigid Steel Conduit (ERSC)

NEMA C80.1

Issued by:

*National Electrical Manufacturers Association.
1300 North 17th Street; Suite 1752,
Rosslyn, VA 22209, USA*

Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)

NFPA 59A

Standard for the Installation of Lightning Protection Systems

NFPA 780

Issued by:

*National Fire Protection Association.
1 Batterymarch Park
Quincy, MA 02169-7471, USA*

INTERNATIONAL STANDARDS

Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods

ISO 1461

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

Issued by:

*International Organization for Standardization.
1, ch. de la Voie-Creuse, Case postale 56
CH-1211 Geneva 20, Switzerland*

Recommendations for acceptance and application of post-tensioning systems

ISBN 978-0-7210-1231-5

Issued by:

*International Federation for Structural Concrete
Case Postale 88,
CH-1015 Lausanne, Switzerland*

BRITISH STANDARDS

Methods of testing Refractory materials — Part 9: Chemical analysis by instrumental methods — Section 9.1 Analysis of alumino-silicate refractories by X-ray fluorescence

BS 1902-9.1

Issued by:

*British Standards Institution
389 Chiswick High Road
London, United Kingdom W4 4AL*

Double concrete tanks for liquefied gas – guide to design, construction and operation

EEMUA 207

Issued by:

*The Engineering Equipment and Materials Users Association
10-12 Lovat Lane
London, United Kingdom EC3R 8DN*

EUROPEAN STANDARDS

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
Installation and equipment for liquefied natural gas - Design of onshore installations	EN 1473
Eurocode 2 : design of concrete structures - Part 1 : general rules and rules for buildings	EN 1992-1
Eurocode 2 - Design of concrete structures - Part 3 : liquid retaining and containment structures	EN 1992-3

Issued by:

*European Committee for Standardization
Rue De Stassart 36
Bruxelles, Belgium B-1050*

APPENDIX A FIRE SCENARIOS AND RELATED DESIGN TEMPERATURES

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 need therefore not be considered as purpose of the design.

A.2 Pressure Relief Valve Fires

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:

Incident heat flux on the tank shall and structures be calculated for the maximum relieving rate associated with a wind velocity by Contractor subject to approval of Company or its Contractor. 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.

The calculation method may be Shell Jet Flame Model, which is available in DNV with Shell's FRED. Also, 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.

The most unfavourable condition shall be assumed in the calculation, a typical wind speed of 8m/s may be assumed, and in any case the wind speed shall be not less than the wind velocity corresponding to 90% occurrence probability.

The PRVs are assumed to release at full capacity.

APPENDIX B ULTRASONIC INSPECTION

B.1 INTRODUCTION

Ultrasonic inspection is specified, complementary to dye penetrant and radiographic testing, to inspect for solidification cracks and lack of side wall fusion defects, which cannot reliably be detected by radiography.

Material inspection with conventional shear wave probes leads to erroneous results, because of the coarse grained nature of the nickel-base weld metal. For such weld material special ultrasonic techniques are required, based on the use of compression wave angle beam probes.

B.2 Reference documents

1. "Handbook on the ultrasonic examination of austenitic welds", edition 1986, International Institute of Welding, Publ.: American Welding Society.
2. "Manual ultrasonic detection of defects normal to the surface in heavy wall steel structures", by J.J.M. van Nisselroij, 21th Annual Br. Conf. on NDT, 1986.

B.3 SCOPE OF APPLICATION

This specification is applicable for shell thickness of 3/8 inch and over, and is aimed at the detection of longitudinal defects (not transverse defects).

B.4 PERSONNEL REQUIREMENTS

The inspection shall be performed by ultrasonic operators qualified in accordance with ASNT level 2, CSWIP or equivalent, having proven experience with the inspection of welds with coarse grained materials and the calibration of and examination with compression wave angle beam probes.

B.5 PREPARATION OF, AND ACCESS TO WELDS

No weld cap preparation is required. However, undercut at the weld toe reduces significantly the sensitivity for detection of near surface defects. Close control on the quality of weld finish at the weld toe is required in order to prevent undercut. Close visual inspection and correction during welding shall prevent long length of undercut.

B.6 ULTRASONIC TECHNIQUES

The following techniques shall be used:

- Angle beam testing with compression wave probes;
- Round trip tandem testing with a compression wave probe; and
- Creepwave testing for near surface detection.

B.7 EXTENT OF INSPECTION

B.7.1 Weld length

The inspection shall cover 100% of the length of vertical welds of the inner shell.

Welds shall be scanned from the inside and outside surface and from both sides of the weld.

B.7.2 Weld volume

The weld fusion lines shall be scanned 100% using angle beam testing with at least one probe:

- For inspection of the root zone a probe shall be used with beam angle of at least 70 degrees; and

- For inspection of the weld bevel a probe shall be used with a beam angle that provides normal insonification on the fusion line (within +/- 5 degrees).

The weld body shall be examined with a 70 degrees probe. The near surface zone (with a depth of 10% of shell thickness) can be excluded. The weld body shall be examined, over the full width of the weld, with the round trip tandem probe.

B.8 CALIBRATION BLOCKS

Material of the calibration blocks shall be equal to the plate material of the shell.

Following blocks are required:

- V2-type calibration block (Ref.1);
- "Probe beam characterisation" block (Ref.1).

B.9 REFERENCE BLOCKS

Reference blocks shall be fabricated of the same material and containing identical welds as the welds to be examined. The blocks shall contain the following reference reflectors:

- Angle beam testing:
 - * Side drilled holes of 3 mm (1/8 in) diameter, along the fusion line;
 - * Side drilled holes of 3 mm (1/8 in) diameter, along the weld centre line;
- Round trip tandem: 3 mm (1/8 in) flat bottom holes at 1/3 and 2/3 depth (Ref.2).

The number of reference defects should be such that it allows preparation of a DAC curve, for all probes in use, based on at least three reflectors. Reflectors shall be located such that no point on the DAC is further from a reflector than a distance of 30% of the inspection range.

B.10 SETTING OF SENSITIVITY

The reference reflectors provide the primary reference sensitivity level. The disregard level shall be at 20% DAC level. The DAC curve shall at least span the working range of the probe.

The signal to noise ratio over the required working range should exceed 20 dB, measured with respect to the 100% DAC level.

B.11 EVALUATION OF INDICATIONS

All indications of which the amplitude exceeds 20% of the DAC have to be evaluated with regard to their length and location within the weld (depth, lateral position). Length shall be determined by using the -6 dB technique.

B.12 Acceptance/rejection criteria

Sections of weld shall be sentenced as unacceptable when having any of the following indications, shown by ultrasonic inspection only (thus excluding those indications accepted by radiography):

1. Indications with an amplitude exceeding the reference level and a non-interrupted length greater than 50 mm (2 in); and
2. Any group of indications with amplitudes exceeding the reference level, of which the sum of the lengths of all indications is greater than 100 mm (4 in) over a total length of 400 mm (16 in). If the space between two adjacent indications is greater than three times the length of the longer of the two, the indications may be regarded as not to be part of the same group.

All indications exceeding 30% of the reference level shall be reported, irrespective of length. If this generates reporting of insignificant imperfections, reporting criteria can be relaxed (higher amplitude, applying a length criterion) after written approval of Company.

B.13 QUALIFICATION TEST

A qualification test shall be performed prior to examination and the results reported to Company. The test shall comprise measurements on calibration and reference blocks, to demonstrate to Company that the examination meets the requirements of the specification with regard to scanning coverage and examination sensitivity. Where the standard reference blocks are not adequate for a sufficient qualification, additional reference blocks may be required.