APLNG UPSTREAM PH1 WTF

TECHNICAL SPECIFICATION – LINING SYSTEM Q-LNG01-20-TS-0002

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1. General

This Specification defines the minimum technical requirements for the supply and installation of Polyethylene (PE) liners for Storage Ponds including finishing surfaces to be lined, material quality, placing, jointing and testing. The following liner systems shall be installed in the following ponds:

Feed Pond

Primary Liner – Black Surface Double Textured PE Geomembrane

Secondary Liner – 300 mm Compacted Clay Liner

Brine Pond and Effluent Pond

Primary Liner –White Surface Double Textured PE Geomembrane

Secondary Liner – Black Double Textured PE Geomembrane

Export Pond

Primary Liner –Black Double Textured PE Geomembrane

Secondary Liner – None

Construction Water Pond

Primary Liner –Black Double Textured PE Geomembrane

Secondary Liner – None

It should be noted that the primary liner for the brine ponds will be exposed to significantly higher operating temperatures compared to the other ponds. The average temperature of the brine is estimated to be 60°C with maximum temperatures estimated to be around 100 °C. Therefore the physical properties for the primary liner proposed for the brine ponds should be thoroughly reviewed to ensure long-term performance.

2. Changes from previous Revisions

Table 2 details the changes to this specification from previous revisions.

Table 2 – Revision Changes

Revision	Section	Detail	Description
Rev 1	Section 6.2	Revised performance specifications	Revisions to performance specifications including strength properties and OIT

			values
Rev 1	Section 6.2	Inclusion of other polyethylene liners.	Revisions to specification to allow LLDPE and HDPE liners.

3. Abbreviations and Definitions

3.1. Abbreviations

The abbreviations listed below, where used in this Specification, have the following meaning:

AS	Australian Standard
PE	Polyethylene
NATA	National Association of Testing Authority
ASTM	American Society of Testing and Materials

3.2. Definitions

Approved	Approved by the Superintendant
Sub-grade	The prepared surface of the earth on which liners, footings, pavements, slabs, fill and embankments are constructed.
Superintendent	Representative appointed by the Owner to assess and monitor that the Contractor is performing the Work in accordance with the contract Documents. Superintendant is responsible for the release of Hold, Witness, and Milestone Points.

4. Referenced Publications

4.1. Codes and Standards

The Contractor shall ensure that design and construction comply with all relevant Australian codesand these specifications. Latest editions of published codes and standards, including any other standards referenced therein, shall apply as of the date of issue of this specification. Where any conflict occurs between standards and codes and these specifications, the Superintendent notified.

Where there is a discrepancy between the design drawings and this specification, the Contractor shall seek clarification from the Superintendent.

The requirements given in the following documents (but not limited to) shall be read in conjunction with this specification and other technical standards as appropriate:

Australian Standards

AS 1298	Methods of Testing Soils for Engineering Purposes.

AS/NZS ISO 9001	Quality Management Systems – Requirements

American Standards

ASTM D 6392:	Standard Test Methods For Determining the Integrity of Non-Reinforced Geomembrane Seams Produced Using Thermo Fusion Methods
ASTM D 5820:	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
ASTM D 6497:	Standard Practice for Geomembrane Seam Evaluation By Vacuum Chamber
ASTM D 792	Standard Test Method for density and specific gravity (Relative Density) of plastics by displacements.
ASTM D 1004	Standard Test Method for Tear Resistance (Graves Tear) of Plastic Film and Sheeting
ASTM D 1149	Standard Test Method for Rubber Deterioration Cracking in An ozone Controlled Environment
ASTM D 1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique
ASTM D 1603	Standard Test Method for Carbon Black Content in Olefin Plastics
ASTM D 3895	Standard Test Method for Oxidative Induction Time of Polyolefin's By Differential Scanning Calorimetry
ASTM D 4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle Furnace Technique
ASTM D 4437	Standard Practice for Non-Destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes.
ASTM D 5994	Standard Test Method for Measuring the Core Thickness of Textured Geomembrane.
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
ASTM D 5199	Standard Test Method for Measuring Nominal Thickness of Geosynthetics
ASTM D 5223	Standard Practice for Determination of 2% Secant Modulus of Polyethylene Geommebranes
ASTM D 5617	Standard Test Method for Multi-Axial Tension for Geosynthetics
ASTM D 5397	Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin Geomembrane practice for Geomembrane Seam Evaluation by vacuum chamber (4)
ASTM D 5721	Standard practice for air-oven aging of polyolefin geomembranes

ASTM D 5820	Standard practice for pressurised air channel evaluation testing of dual seamed geomembranes
ASTM D 5885	Test method for oxidative induction time of polyolefin geosynthetics by high pressure differential scanning calorimetry.
ASTM D 6365	Standard Practice for the Nondestructive Testing of Geomembrane Seams using the Spark Test.
ASTM D 6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo Fusion Methods.
ASTM D 6693	Standard Test Method for Determining Tensile Properties of Non-Reinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
ASTM D 6747	Standard Guide for Selection of Technologies for Electrical Detection of Potential Leak Paths in Geomembranes
ASTM D 7002	Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System
ASTM D 7007	Standard Practice for Electrical Method of Locating Leaks in Geomembrane Cover with Water or Earth Materials
ASTM D 7466	Standard Test Method for Measuring the Asperity Height of Textured Geomembrane
FTMS 101B	Puncture resistance
GRI Standard GM6	Pressurized Air Channel Test for Dual Seam Geomembranes
GRI Standard GM10	Specification for Stress Crack Resistance of HDPE
GRI Standard GM11	Accelerated Weathering of Geomembranes Using a Fluorescent UVA Condensation Exposure Device
GRI Standard GM12	Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gauge
GRI Standard GM13:	Test Properties, Testing Frequency and Recommended Warranty for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
GRI Standard GM14:	Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
GRI Standard GM19:	Standard Specification for Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

4.2. Standard Drawings

This specification shall be read in conjunction with project standard drawings where supplied, other relevant project specific drawings and other associated tender/contract documentation as referenced in the 'Scope of Work'.

5. Quality System Requirements

The Superintendent reserves the right to inspect the materials and workmanship at any time. Materials or workmanship found not to conform to this specification may be rejected during the execution of the work. The Contractor shall be responsible for the removal and re-execution of any work that is rejected, including any other work damaged as a result.

5.1. Hold Points, Witness Points, and Milestones

Hold Points and Witness Points for this specification are stated in Table 5.1. The Contractor shall not proceed past a Hold Point unless the Hold Point has been released by the Superintendent in writing (unless it has been agreed otherwise with the Superintendent). The Contractor shall ensure that 48 hours notice is given to the Superintendent for the release of Hold Points.

Table 5.1 – Hold Points and Witness Points

Clause	Hold Point	Witness Point	Milestone
5.2	1. Construction procedure (21 days)		Supply of the construction procedure (21 days)
6.8	2. Material compliance certification (14 days)		
8.1	3. Preparation of Ground prior to liner installation	Visual Inspection of prepared surface	
12	4. Installation of Leak Detector Drains		
13	5. Inspection and Testing of PE liner	Non-Destructive Testing. Test Welds. Destructive Testing. Repair and retesting of defect. Electrical leak detection testing.	
15	6. Handover		

The Contractor shall observe all relevant Milestones, and the Hold and Witness Points in associated technical specifications unless agreed otherwise with Superintendent. The Contractor shall provide written procedure for the Superintendent to review 21 days prior to the commencement of the work.

The Contractor shall provide at their expense suitable and adequate access to allow the Superintendent to inspect the works.

5.2. Construction Procedure

A construction procedure for the installation of the PE liner shall be submitted to the Superintendent at least 21 days prior to the commencement of installation **(Hold Point 1 and Milestone)**.

This construction procedure shall include but not be limited to detailing the materials and methods to be used for:

a) certification of welding Technicians;

b) preparation of subgrade;

c) installation of a leak detection systems;

d) placement of liner;

e) temporary liner ballasting systems;

f) liner layout drawings;

g) jointing;

h) anchorage;

i) testing;

j) storage of materials on site;

k) disposal of excess materials;

l) product identification and traceability; and

m) inspection and test plans.

6. Materials

6.1. General

All materials must strictly comply with the requirements of this Specification. For all materials, a certificate of such compliance shall be provided to the Superintendent before the materials are incorporated into the work at least 14 days before commencement of the work (**Hold Point 2)**.

Materials not protected against solar radiation shall be stored under cover to prevent damage by solar radiation. Materials and equipment damaged prior to, and/or during installation must not be used and must be replaced at the Contractor's expense.

Production samples of materials shall be provided to the Superintendent and will be held throughout the period of the contract for the purpose of providing a reference against which all subsequent items may be gauged for compliance with this Specification.

The PE membrane liner shall be a new, first-quality product designed specifically for the purpose of hydraulic containment and of the thickness specified. The membrane shall be uniform, free of holes, blisters, bubbles, gels, nicks, cuts, undispersed raw materials, or any sign of contamination by foreign matter.

6.2. Polyethylene Liner Material

The PE liners shall comply with the following minimum (or maximum where marked *) test values shown in Table 6.2. Textured PE liner shall be double sided co-extruded textured either black or white surfaced. The PE liner material physical properties shall comply with Table 6.2.

Table 6.2 - Liner Physical Properties

Tested Property	Test Method	Unit	Test Value	
			HDPE	LLDPE
Thickness mm (min. ave) • Lowest 8 out of 10 • Lowest for any 10 values	ASTM D 5994	Mm	Nom. (-5%) -10% -15%	Nom. (-5%) -10% -15%
Asperity Height (min. ave.)	ASTM D 7466	Mm	0.25	0.25
Density (min ave)	ASTM D 1505/D 792	g/cm^3	0.94	0.939
Tensile Properties (min. ave) • Yield strength • Break strength • Yield elongation • Break elongation	ASTM D 6693 Type IV	KN/m	 22 16 12% 100%	 NA 11 NA 250%
2% Modulus – (max.)	ASTM D 5323	KN/m	NA	420
Tear Resistance (min. ave.)	ASTM D1004	N	187	100
Puncture Resistance (min. ave.)	ASTM D4833	N	400	200
Axi-Symmetric Break Resistance Strain (min)	ASTM D5617	%	NA	30
Stress Crack Resistance (min ave.)	ASTM D5397	Hr	1000	1000
Carbon Black Content (range)	ASTM D4218	%	2-3	2-3
Carbon Black Dispersion	ASTM D5596		Note 6	Note 6
Oxidation Induction Time (OIT)		Min		

Tested Property	Test Method	Unit	Test Value	
			HDPE	LLDPE
• Standard OIT (ave.) • High Pressure OIT (ave.)	ASTM D 3895 ASTM D 5885		100 400	100 400
Oven Aging at 85°C % retained after 90 days • Standard OIT (min. ave.) • High Pressure OIT (min. ave.)	ASTM D 5721 ASTM D 3895 ASTM D 5885	%	 55% 80%	 55% 80%
UV Resistance • Standard OIT (min. ave.) • High Pressure OIT (min. ave.)-%retained after 1600 hrs	GM 11 ASTM D3895 ASTM D5885	 %	 N.R. (10) 50%	 N.R. (10) 50%
Typical Roll Dimensions				
Roll Length (minimum)	NA	M	155	
Roll Width	NA	M	6.5	
Roll Area	NA	m^2	1000	

6.3. Quality Control

The liner shall be monitored throughout the manufacturing process for product integrity and consistency. Manufacturer shall test rolls in accordance with Table 6.3 for the following physical properties and at the following minimum frequency or per batch of resin, whichever results in the greatest number of tests.

Table 6.3 – Liner QC Test Frequency

Tested Property	Test Method	Test Frequency (minimum)
Thickness mm (min. ave) • Lowest 8 out of 10 • Lowest for any 10 values	ASTM D 5994	Per roll
Asperity Height (min. ave.) (1)	ASTM D 7466	Every 2nd roll (2)

Tested Property	Test Method	Test Frequency (minimum)
Thickness (min. ave.)	ASTM D 5994	Per roll
Asperity Height (min. ave.) (1)	ASTM D 7466	Every 2nd roll (2)
Density (min ave)	ASTM D1505/D 792	90,000 kg
Tensile Properties (min. ave) (3) • Yield strength • Break strength • Yield elongation • Break elongation	ASTM D6693 Type IV	9,000 kg
2 % Modulus (min. ave.)	ASTM D 5323	Per each formulation
Tear Resistance (min. ave.)	ASTM D1004	20,000 kg
Puncture Resistance (min. ave.)	ASTM D4833	20,000 kg
Axi-Symmetric Break Resistance Strain (min)	ASTM D 5617	Per each formulation
Stress Crack Resistance (4)	ASTM D5397	Per GRI GM 10
Carbon Black Content (range)	ASTM D4218 (5)	9,000 kg
Carbon Black Dispersion (6)	ASTM D5596	20,000 kg
Oxidation Induction Time (OIT) (7) • Standard OIT (ave.) • High Pressure OIT (ave.)	 ASTM D 3895 ASTM D 5885	90,000 kg
Oven Aging at 85°C % retained after 90 days(7) (8) • Standard OIT (min. ave.) • High Pressure OIT (min. ave.)	ASTM D 5721 ASTM D 3895 ASTM D 5885	Per each formulation

Tested Property	Test Method	Test Frequency (minimum)
UV Resistance (9) • Standard OIT (min. ave.) • High Pressure OIT (min. ave.)-% retained after 1600 hrs.	GM 11 ASTM D 3895 ASTM D 5885	Per each formulation

Note :

(1) Of 10 readings; 8 out of 10 must be 0.18 mm, and lowest individual reading must be 0.13 mm; also see Note 6.
(2) Alternate the measurement side for double sided textured sheet
(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gage length of 33 mm Break elongation is calculated using a gage length of 50 mm
(4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials. The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.
(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views: 9 in Categories 1 or 2 and 1 in Category 3
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60¤C.
(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
(11) UV resistance is based on percent retained value regardless of the original HP-OIT value.
(12) NA – not applicable for the type of material.

Certified test results shall be submitted to and approved by the Superintendent at least 14 days prior to geomembrane delivery to site. The Contractor shall submit a list which indicates date of production, plant location, resin batch number, manufacturing line number and identification number and square meter of each geomembrane roll. Rolls shall be listed in the order of production with the status of the roll (rejected or approved for shipment). All rolls shall be included in the list whether or not approved for shipment.

6.4. Resin

Resin used in the manufacture of geosynthetics shall be first quality single source, compounded polyethylene resin manufactured specifically for the purpose of producing PE liners. The type of PE resin to be used shall be reported to the Superintendent. There shall be no intermixing with other resin types. Reclaimed polymer shall not be added to the resin. The manufacturer may recycle edge trim from the roll being produced. Edge trim shall be returned immediately to the process but shall not exceed 2% of the total resin required. Edge trim which has been stored or sourced from other manufacturing lines shall not be recycled.

PE resin shall meet the requirements as listed in Table 6.4.

Table 6.4 – Resin Physical Properties

Physical property	Test method	Unit	Requirement
Density[1]	ASTM D-1505	g/cm^3	≥0.932
Melt Flow Index	ASTM D-1238 Condition E	g/10 min	≤1.0

[1] Base resin density without carbon black added

The manufacturer shall sample and test for the properties listed in per batch of resin. Certified test results shall be submitted to and approved by the Superintendent at least 14 days prior to shipping the liner to the site.

6.5. Extrudate Material Requirement

The extrudate rod or bead shall be high quality polyethylene and shall be of the same formulation and same supplier as the resin used to produce the geomembrane. All additives shall be thoroughly dispersed throughout the extrudate rod or bead. There shall be no contamination by foreign matter in the extrudate rod or bead.

6.6. Roll Identification

Liner shall be supplied in rolls of a minimum width of 6.5 metres with no longitudinal joints in the width. As a minimum, each roll shall be labelled as follows:

a) roll number;
b) name of Manufacturer;
c) batch number of raw material;
d) date of manufacture;
e) material thickness;
f) roll length and area;
g) product type and grade; and
h) reference to manufacturer's quality assurance report.

6.7. Manufacture's Certification

The Contractor shall submit, to the Superintendent for approval, written Manufacturer's Certification that the liner material:

- conforms to the material requirements of these Specifications;
- is similar to and of the same formulation as that for which certification is submitted; and
- has been demonstrated by actual usage to be satisfactory for the intended application.

Manufacturer's certification shall include the minimum average roll values for material to be furnished on this project. The Contractor shall obtain the Superintendent's approval of the liner and all other materials to be used, prior to shipment to the site. The Contractor will not be allowed to unload or store on site, any material that is delivered prior to obtaining such approval. Hold Point 2

6.8. Liner Samples

The Contractor shall submit for approval by the Superintendent samples of liner material and field seams prior to the start of construction. The Contractor shall submit 200mm x 250mm samples of liner materials which have been made in conformance with this Specification. Hold Point 2

6.9. Liner Warranty

6.9.1. Material Warranty

The liner manufacturer shall furnish a written liner warranty for a period of 20 years. The warranty shall be against manufacturing defects or workmanship and against deterioration due to ozone, ultraviolet light rays, and/or other normal weather aging. The warranty shall be limited to replacement of material only.

6.9.2. Installer Warranty

The Geomembrane Installer shall guarantee the geomembrane installation against defects in the installation and workmanship for 1 year commencing with the date of final acceptance. A written liner warranty will be required.

7. Drawing

The Contractor shall prepare liner panel layout drawings allocating a logical sequence of numbers to panels and joints. Three copies shall be submitted to the Superintendent as part of the overall procedure for approval. (Refer to Hold Point 1).

The panel layout should minimise the number of panels and the length of joints. Joints shall be oriented perpendicular to the batter slopes not across the batter slope wherever practical. No horizontal joint should be located within 1.5m of a batter toe line. Horizontal joints should be staggered across each width of roll. The panel layout may be varied in the field from that shown on the drawings only with the approval of the Superintendent.

In addition to the panel layout drawing and in accordance with the Construction Procedure, refer to Section 5.2, the following should be included:

- proposed starting position for the placement of the PE liner;
- panel numbering system;
- panel diagram showing panel dimensions and panel layout proposed to be used to a suitable scale;
- relevant experience of geomembrane installer;and
- typical installation rates (m^2/day) for both cell floor and side slopes.

8. Surfaces to be Lined

8.1. Surface Preparation

The Contractor shall ensure that all surfaces to be lined including corners and around penetrations shall be finished smooth and free of all rocks, stones, sticks, roots, sharp objects and debris of any kind or any object which may damage the liner in accordance with Specification Q-LNG01-20-TS-0001. The surface is to provide a firm unyielding compacted sub-grade for the liner.

Where a suitable surface cannot be achieved by treatment of the in situ material, an imported smoothing fine course fill shall be placed. The smoothing fine course shall consist of sandy clay which shall be free of organic matter and coarse or sharp particles. The smoothing course shall be the minimum thickness necessary to maintain 150 mm minimum cover over irregularities or protrusions in the sub-grade formation unless shown otherwise on the Drawings. The surface shall be watered and rolled with a smooth steel drum roller to obtain a smooth uniform finish.

The Geomembrane Installer Supervisor shall provide daily written subgrade acceptance certifications to the Superintendant for the surface to be covered by the geomembrane in that day's operation. The surface shall be maintained in a manner, during installation, to ensure subgrade suitability. **(Hold Point 3 and Witness Point)**

All subgrade damaged by construction equipment and deemed unsuitable for geomembrane deployment shall be repaired prior to placement of the geomembrane. All repairs shall be approved by the Superintendent and the Geomembrane Installer Supervisor.

Surfaces to be lined shall be flat on any plane within ±50mm vertical tolerance in any area of $10m^2$. All intersections between planes shall be made along straight lines.

8.2. Maintenance

Where surface finishing is completed ahead of liner installation, the surface shall be maintained until immediately prior to liner installation. This surface will need to be re-inspected again by the Superintendent and approved prior to installation of the liner. Sufficient equipment shall remain on the site until and during installation to enable reinstatement of the surface in the event of damage due to inclement weather. Any reinstatement work shall be at the expense of the Contractor. The Superintendent reserves the right to instruct the Contractor to perform remedial work to satisfy the criteria.

9. Liner Installation

Liner installation shall be performed in accordance with the International Association of Geosynthetic Installers HDPE and LLDPE Geomembrane Installation Specification. Rolls of liner shall be handled and securely stored to prevent damage prior to installation. Geomembrane shall be unrolled in a controlled manner directly into the final position. The method of unrolling shall not cause scratches or crimps in the material, nor shall it disrupt the integrity of the finished sub-grade. (refer to Hold Point 1)

The liner should be placed in a relaxed state such that the material can respond to thermal changes without excessive buckling, wrinkling or tensioning. No geomembrane material shall be unrolled and deployed if the material temperatures are lower than 0°C unless otherwise approved in writing by the Superintendent. Typically only the quantity of geomembrane that will be anchored and seamed together in one day should be deployed.

In general, seams shall be orientated parallel to the line of maximum slope. In corners and odd shaped geometric locations, the total length of the field seam shall be minimized. Seams shall not be located at low points in the subgrade unless geometry requires seaming at such locations and if approved by the Superintendent.

The geomembrane shall not be allowed to "bridge over" voids or low areas in the subgrade. The geomembrane shall rest in intimate contact with the subgrade.

Temporary loading such as sand bags or tyres shall be placed on the liner to prevent wind damage during and after installation. It should be noted that this temporary loading should be of a suitable construction to prevent against damage of the liner. The Contractor shall be required to ensure that the spacing of these sand bags/tyres are appropriately designed (this could include tying the sand bags/tyres together in a horizontal and vertical direction) to prevent against uplift and potential damage of the liner.

All personnel working on the liner surface shall wear soft-soled shoes, and shall not engage in any activity which may damage the liner.

Machinery other than joint welding machinery shall not be operated on the liner.

10. Jointing

10.1. General

Jointing of liners shall be carried out strictly in accordance with the manufacturer's written instructions and GRI GM 19. The Contractor shall provide a complete description of the processes to be used, and shall identify the equipment proposed for accomplishing the jointing. (refer to Hold Point 1)

No geomembrane material shall be seamed when the sheet temperature is below 0°C and above 75 °C as measured by an infrared thermometer or surface thermocouple unless otherwise approved by the Superintendent.

Fishmouths or excessive wrinkles at the seam overlap shall be minimized and when necessary cut along the ridge of the wrinkles back into the panel so as to effect a flat overlap. The cut shall be terminated with a keyhole cut (nominal 10 mm diameter hole) so as to minimize crack/tear propagation. The overlay shall subsequently be seamed. The keyhole cut shall be patched with an oval or round patch of the same base geomembrane material extending a minimum of 150 mm beyond the cut in all directions.

10.2. Personnel

The Contractor shall nominate a Project Joint Welding Superivisor before commencing work and shall demonstrate that the Superintendent has a proven background in installation of lining systems and materials similar to those specified. All personnel employed in welding shall be competent and experienced in the use of the equipment. The Contractor shall ultimately be responsible for ensuring the quality assurance programme is followed. The Superintendent shall be notified to be able to inspect Welds in accordance with the requirements of Section 16.

10.3. Joint Welding Equipment

Only specialised purpose-designed equipment approved by the liner manufacturer and the Superintendent shall be used. For long-run work the machine shall be mounted on a carriage to operate at controlled speed. In all cases the temperature at the point of fusion

shall be monitored and controlled with an interlock to the drive mechanism so that welding is stopped if the temperature falls outside the range at which satisfactory welding can be achieved.

Where the welding procedure includes provision for heated extrudate to be incorporated in the weld, any degraded extrudate, which has been overheated or heated and cooled in the barrel, shall be purged with fresh material prior to the resumption of welding.

Equipment shall be maintained on a regular basis to ensure efficient performance throughout.

The field tensiometer (NATA certified) shall have a current certificate of calibration in accordance with the manufacturer's calibration recommendations.

10.4. Joint Strength Requirements

Each test specimen should fail in the parent material and not in the weld as demonstrated by test welds and destructive test samples in accordance with Section 13. Breadth and depth of fusion between sheets shall be as required to meet these criteria. Where extrudates are included in the weld the extrudate material after fusion shall be fully compatible physically and chemically with the liner material.

The liner material shall not be overheated during welding so that crystallisation, oxidation, perforation or degradation of the liner does not occur.

10.5. Weather Conditions

Welding shall not be commenced or continued during rain, fog, excessive winds, or ambient temperatures outside the range of 10°C to 40°C and relative humidity is more than 80% or in accordance with the manufacturer guidelines. The joints adjacent to the corners of the ponds and the toe of the batters shall be made during the coolest part of the day and shall not be made when the liner is exposed to direct sunlight.

10.6. Liner Preparation

The surface of the liner to be welded shall be clean, dry and free from any foreign matter and contaminants, such as, clay and sand.

Where the liner manufacturer's instructions require the surfaces to be abraded prior to welding, this shall be carried out no more than one hour prior to welding, using appropriate mechanical abrading equipment recommended by the manufacturer. Care shall be taken to restrict grinding to the immediate area of the joint, and to avoid over-grinding which may reduce the effective liner thickness adjacent to the joint.

10.7. Joint Lap

The minimum lap of adjacent liner sheets shall be 100mm, unless specified as greater by the liner manufacturer or the welding equipment supplier. "

Fish mouths" along the joint should be minimised, but should they occur the material shall be cut, overlapped, and welded normal to the joint.

10.8. Fusion Welding (Primary Welds)

Seam welding of PE liners shall be accomplished primarily by fusion welding using either a hot wedge or hot air welder.

The joint shall consist of a double weld produced by surface fusion with an air gap between. Pressure nipping rollers shall press the molten surfaces together immediately behind the hot air or hot wedge welder to complete the weld.

10.9. Extrusion Welding (Secondary Welds)

Extrusion welding shall be used where fusion welding is not possible such as at pipe penetrations, patched, repairs, and short (less than a roll width) runs of seams.

Fusion welding shall be achieved by fusion of an extrudate on to the top surface of both sheets at the lap. The depth and width of engagement of the extrudate shall be as required to achieve the strength requirements. The means of deposition of the extrudate shall provide for full integration with the surface of the sheets, so that the weld becomes homogeneous with the liner.

10.10. Connections at Penetrations and to Structure

Connections to liner penetrations and adjoining structures shall be made in accordance with the details shown on the construction drawings. Connections shall be at least equivalent in strength to the normal lap joints and the security of containment shall not be diminished. Local stresses in the liner at connections shall be minimised.

Penetrations shall be constructed from the base geomembrane material, flat stock, prefabricated boots and accessories as shown in the construction drawings.

11. Anchorage

Anchor trenches shall be excavated in accordance with the details on the construction drawings and shall be kept well drained to avoid softening during rain periods and maintained so as to not dry, desiccate and crack. Trenches shall be filled in early morning when the liner is at maximum contraction. Filling shall be carried out in a planned, logical sequence to avoid overstressing of the liner.

Fill Material for the anchor trench shall conform to the following requirements:

- 100% by mass passing the 37.5mm AS sieve;
- a minimum of 35% by mass passing the 0.075mm AS sieve size; and
- a plasticity index when tested in accordance with AS 1289.3.3.1 greater than 15%.

The fill material shall be compacted to 95% standard proctor, as determined by AS 1289.5.1.1 and AS 1289.5.5.1, Standard Compaction Method. The compacted anchor trench fill shall be tested for moisture content and maximum dry density at the rate of two tests for per side per pond.

12. Leak Detection and Removal System

The leak detection and removal system (LDRS) beneath the primary liner for the brine and effluent ponds shall be constructed, where specified, to the layout and details shown on the construction drawings and in accordance with Specification Q-LNG01-20-TS-0003 **(Hold Point 4)**.

13. Inspections, Testing, and Repair

All areas found to be defective shall be repaired at the expense of the Contractor. The Superintendent shall be notified of defective areas prior to the repair taking place. Hold Point 5 and Witness Points

The Contractor shall ensure a plan is marked up showing the locations of repairs made and the type of repair made. The marked up drawing shall be handed to the Superintendent at completion and agreed upon with the Contractor.

13.1. Visual Inspections

The entire surface of every sheet of liner material shall be inspected by the Contractor during placing to identify any tears, abrasions, indentations, cracks, thin areas, or other defects.

Any defects such as holes, tears, blisters, lamination, undispersed raw materials or visible non-uniformity or contamination by foreign matter which in the opinion of the Superintendent is detrimental to the long service life required of the membrane liner, shall be grounds for rejection of the membrane liner material. Hold Point 5 Witness Point

Where additional faults are found, the Superintendent reserves the right to reject the roll. The Contractor shall replace any rejected rolls and repair any defects to the Superintendent's satisfaction at the Contractor's expense.

13.2. Field Seam Testing

All field seams shall be subjected to both non-destructive and destructive field testing. Additionally, representative samples of field seams shall be taken for laboratory testing by an independent, appropriately qualified geosynthetic laboratory. The following tests shall be carried out at the specified frequencies. Testing of each length of seam shall be carried out within 48 hours of its completion.

13.2.1. Test Welds (In Field)

Test welds shall be made as follows:

- prior to commencement of each shift
- following any break in operation; and
- following any significant adjustment to welder controls.

Test seams shall be made by each welding technician and tested in accordance with ASTM D4437 at the beginning of each seaming period. Test seaming shall be performed under the same conditions and with the same equipment and operator combination as production seams. The test seam shall be approximately 3.3 m long for fusion welding and 1 meter long for extrusion welding with the seam centered lengthwise **(Witness Point)**. At a minimum, tests should be made by each technician 1 time every 4-6 hours; additonal tests may be required with changes in environmental conditions.

Two 25 mm wide specimens shall be die-cut by the Geomembrane Installer from each end of the test seam. These specimens shall be tested by the Geomembrane Installer using a field tensiometer testing both tracks for peel strength and direct shear strength tests. The weld will be considered acceptable if the test piece fails in the un-welded liner away from the joint. If the field test fails then further test welds shall be made after appropriate

adjustment of the welder controls, and retested until an acceptable weld is obtained. Field test results shall be recorded and test pieces marked and stored. The Superintendent reserves the right to take further test pieces from the test welds for independent tests off-site.

The acceptance criteria for peel and shear strength testing are as specified below or as recommended by the manufacturer of the liner. The Superintendent will be required to agree to the alternative acceptance criteria prior to commencement of the work. The minimum acceptance criteria for a 1.5mm liner are as follows:

- Peel Strength (fusion weld) > 15.9kN/m
- Peel Strength (extrusion weld) > 13.6kN/m
- Shear Strength (fusion and extrusion welds) > 21kN/m

13.2.2. Non-Destructive Testing (In Field)

Air Pressure Testing

Double fusion seams with and enclosed channel shall be air pressure tested by the Geomembrane Installer in accordance with ASTM D5820 and ASTM D4437.Every liner joint shall be subject to close visual inspection and to continuous non-destructive testing. Double-welded joints shall be subject to air pressure testing. The testing shall be achieved by inflation of the space between the welds to approximately 210kPa pressure or in accordance with the manufacturers recommended pressure and following the 2 minute 'relaxing period' (whereby the air temperature and pressure stabilises), the air pressure will be monitored for 5 minutes and the pressure loss recorded (**Witness Point).**

The acceptance criteria for loss of pressure are as specified below or as recommended by the manufacturer of the liner. The Superintendent will be required to agree to the alternative acceptance criteria prior to commencement of the works. If pressure loss does not exceed 28 kPa after 5 minutes, the seam shall be considered leak tight.

Vacuum Testing

For single welded joints testing shall be achieved using vacuum testing. Vacuum testing shall be performed by the Geomembrane Installer in accordance with ASTM D4437 and ASTM D5641 **(Witness Point)**.

The vacuum pump shall be charged and the tank pressure adjusted to approximately 35 kPa. The acceptance criteria is as specified: if no bubbles appear while the vacuum is held for 5 seconds then the joint is satisfactory.

Spark Testing

Where field non-destructive testing cannot be performed, seams shall be field spark tested by standard holiday leak detectors in accordance with ASTM D6365. Spark testing shall be performed in areas where both air pressure testing and vacuum testing are not possible.

Equipment for Spark Testing shall be comprised of but not limited to: a hand held holiday spark tester and conductive wand that generates a high voltage. The testing activities shall be performed by the Geomembrane Installer by placing an electrical conductive tape or wire beneath the seam prior to welding. A trial seam containing a non welded segment shall be subject to a calibration test to ensure that such a defect (non welded segment) will be identified under the planned machine settings and procedures. Upon completion of

the weld, the spark tester shall be held approximately 25 mm above the weld moving slowly over the entire length of the weld in accordance with ASTM D6365. If there is no spark the weld is considered to be leak free.

13.2.3. Destructive Testing (In Field & In Laboratory)

Samples for destructive testing may be taken from finished joints at locations as directed by the Superintendent at a frequency of up to one sample per 150 metres of seam length or another predetermined length in accordance with ASTM D6392. The sample shall be taken by the Geomembrane Installer from a location specified by the Superintendent.

If any samples fail field testing then additional samples may be taken to define the extent of sub-standard joint. Destructive testing of the joints must be carried out on a continuous basis and not at the end of the works.

Each sample shall be 1000 mm long parallel to the joint by 300mm wide, with the joint central in width. The sample shall be cut into three equal sections and distributed as follow:

- field test sections for five peel tests and five shear strength tensiometer tests to be made, as described above; Witness Point
- independent test section for five peel tests and five shear strength tests to be performed at an offsite testing laboratory; and
- record section to be marked and submitted to the Superintendent with the corresponding field test report, and with reference to submission of the independent test specimen.

For field testing, the Geomembrane Installer shall cut 10 identical 25 mm wide replicate specimens from his sample. The Geomembrane Installer shall test five specimens for seam shear strength and five for peel strength. Peel tests will be performed on both inside and outside weld tracks. To be acceptable, 4 of 5 test specimens must pass the stated criteria in section 2.02 with less than 25% separation. If 4 of 5 specimens pass, the sample qualifies for testing by the testing laboratory.

Independent seam testing shall be conducted in accordance with ASTM 5820 or ASTM D4437 or GRI GM 6.

For field seams, if a laboratory test fails, that shall be considered as an indicator of the possible inadequacy of the entire seamed length corresponding to the test sample. Additional destructive test portions shall then be taken by the Geomembrane Installer at locations indicated by the Engineer; typically 3 m on either side of the failed sample and laboratory seam tests shall be performed. Passing tests shall be an indicator of adequate seams. Failing tests shall be an indicator of non-adequate seams and all seams represented by the destructive test location shall be repaired with a cap-strip extrusion welded to all sides of the capped area. All cap-strip seams shall be non-destructively vacuum box tested until adequacy of the seams is achieved. Cap strip seams exceeding 50 m in length shall be destructively tested.

The acceptance criteria for peel and sheer strength testing, is as specified in Section 13.2.1 or as recommended by the manufacturer of the liner.

13.3. Identification of Defects

Panels and seams shall be inspected by the Installer and Owner's Representative during and after panel deployment to identify all defects, including holes, blisters, undispersed raw materials and signs of contamination by foreign matter.

13.4. Evaluation of Defects

Each suspect location on the liner (both in geomembrane seam and non-seam areas) shall be non-destructively tested using one of the methods described in Section 13.2. Each location which fails non-destructive testing shall be marked, numbered, measured and posted on the daily "installation" drawings and subsequently repaired.

If a destructive sample fails the field or laboratory test, the Geomembrane Installer shall repair the seam between the two nearest passed locations on both sides of the failed destructive sample location.

13.5. Post Installation Testing

The Contractor shall undertake electrical leak detection testing of the primary liner in accordance with ASTM D6747 as soon as practical after construction. Installation and material defects detected by the electrical testing process shall be covered under the Installer warranty and shall be repaired to the approval of the Superintendent.

13.6. Repair Procedures

Any portion of the PE liner with a flaw or that fails a non-destructive or destructive test shall be repaired by one of the following methods:

- Patching for holes, defects or tears 10mm or larger in diameter or length – used to repair large holes, tears, large panel defects, and destructive sample locations that are less than $2m^2$ in total area;
- Extrusion – used to repair relatively small defects in panels and seams not greater than 10mm in length;
- Capping – used to repair failed welds or liner seams where welds cannot be non-destructively tested; and
- Removal – used to replace areas with large defects where the preceding methods are not appropriate. Also used to remove excess material (wrinkles) from the installed liner.

Once the repair has been completed, further non-destructive or destructive testing shall be carried out to ensure the repairs are completed to the requirements of this Specification.

13.6.1. Wrinkles

Any wrinkles that can fold over shall be repaired either by cutting out excess material or, if possible, allowing the liner to contract as the temperature decreases. In no case shall material be placed over the liner that could result in the liner folding. All folded liner shall be removed. No material shall be placed in areas where the liner is not in contact with the supporting sub-grade.

13.6.2. Verification of Repairs on Seams

Each repair shall be non-destructively tested using either vacuum box or spark testing methods. Tests which pass the non-destructive test shall be taken as an indication of a successful repair. Failed tests shall be reseamed and retested until a passing test results. The number, date, location, technician and test outcome of each patch shall be recorded.

13.7. Records

Full records of liner testing and inspection shall be submitted progressively to the Superintendent as the work proceeds. Final completion will not be certified until all records have been submitted. Records shall include the following:

- Contractor's panel layout drawing showing panel numbers and joint numbers, to be marked up progressively with the roll number used for each panel, and with the locations of samples taken for destructive testing;
- manufacturer's roll production test reports for all rolls used in the work
- subgrade certification reports;
- daily vacuum box or joint inflation test reports referenced to joint numbers
- daily test weld field test reports referenced to joint numbers, equipment identification, and operator, and including weather conditions and any adjustments to equipment controls
- destructive test field report and record of submission for laboratory testing referenced to joint number; and
- laboratory test reports to be available within two weeks of testing.
- record drawing indicating liner seam locations, destructive test locations, cap strip locations as well as patches and all repairs for the liner system.

14. Cleaning Up

On completion of the work on site, the Contractor shall clean up and leave the whole area ready for use by following Contractors to the satisfaction of the Superintendent.

15. Acceptance Criteria

The Superintendent shall release the work as being complete upon the following but not limited to, and in line with the manufacturer's recommendations **(Hold Point 6)**:

- Checks on application and final finish;
- The installation of PE liners has been completed and signed off
- Repairs to defects have been completed;
- Site has been left Clean with no litter; and
- All required documentation has been provided to the Superintendent in accordance with Section 13.7.

Any work that does not comply shall result in a Non-conformance.