Preparing Activity: USACE

Superseding
UFGS-33 56 19 (May 2015)

**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

**References are in agreement with UMRL dated July 2023**
**********

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DIVISION 33 - UTILITIES

SECTION 33 56 19

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**11/22**

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|---|---|
| **USACE / NAVFAC / AFCEC / NASA** | **UFGS-33 56 19 (November 2022)** |
| | **----------** |
| **Preparing Activity: USACE** | **Superseding** |
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**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

**References are in agreement with UMRL dated July 2023**

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SECTION 33 56 19

FUEL IMPERMEABLE LINER SYSTEM
**11/22**

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**NOTE: This guide specification covers the requirements for a fuel impermeable liner system intended to serve a diked tank enclosure (petroleum applications only). The liner system typically consists of a combination of a geomembrane (to provide liquid tight containment) and geotextile (to protect the geomembrane). This specification includes requirements for two types of geomembrane: Non-reinforced (HDPE - high-density polyethylene) and fabric reinforced (FML - flexible membrane liner). Non-reinforced (HDPE) is only acceptable for use where completely covered with a material (concrete, aggregate, etc) to avoid the effects of thermal expansion from temperature change, degradation from UV light and environmental stress cracking.**

**For liner to be installed under tank bottoms, see UFGS 33 56 21.18 SINGLE WALL POL TANK UNDERTANK INTERSTITIAL SPACE.**

**Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

**Remove information and requirements not required in respective project, whether or not brackets are present.**

**Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).**

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## PART 1 GENERAL

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**NOTE: Coordinate specific dike and liner installation requirements with the latest published version of UFC 3-460-01.**

**********

### 1.1 MEASUREMENT AND PAYMENT

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**NOTE: Delete this paragraph when lump sum bidding is used.**

**********

Measure the total surface area in square meters feet covered by liner system. Final quantities will be based on as-built conditions. Allowance will be made for liner system in anchor and drainage trenches; however, no allowance will be made for waste, overlap, repairs, or materials used for the convenience of the Contractor. Liner system installed and accepted by the Contracting Officer will be paid for at the respective contract unit price in the bidding schedule.

### 1.2 REFERENCES

**********

**NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.**

**Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.**

**References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.**

**********

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

| | |
|---|---|
| ASTM C920 | (2018) Standard Specification for Elastomeric Joint Sealants |
| ASTM D413 | (1998; R 2017) Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate |

| | |
|---|---|
| ASTM D638 | (2014) Standard Test Method for Tensile Properties of Plastics |
| ASTM D696 | (2016) Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30 degrees C and 30 degrees C With a Vitreous Silica Dilatometer |
| ASTM D751 | (2006; R 2011) Coated Fabrics |
| ASTM D1004 | (2013) Initial Tear Resistance of Plastic Film and Sheeting |
| ASTM D1505 | (2018) Standard Test Method for Density of Plastics by the Density-Gradient Technique |
| ASTM D1603 | (2020) Carbon Black Content in Olefin Plastics |
| ASTM D2136 | (2002; R 2012) Coated Fabrics - Low-Temperature Bend Test |
| ASTM D3776/D3776M | (2009a; R 2017) Standard Test Methods for Mass Per Unit Area (Weight) of Fabric |
| ASTM D3895 | (2014) Oxidative-Induction Time of Polyolefins by Differential Scanning Calorimetry |
| ASTM D4218 | (2020) Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique |
| ASTM D4437/D4437M | (2016; R 2018) Standard Practice for Non-destructive Testing (NDT) for Determining the Integrity of Seams Used in Joining Flexible Polymeric Sheet Geomembranes |
| ASTM D4533 | (2011) Trapezoid Tearing Strength of Geotextiles |
| ASTM D4632/D4632M | (2015a) Grab Breaking Load and Elongation of Geotextiles |
| ASTM D4833/D4833M | (2007; R 2020) Standard Test Method forIndex Puncture Resistance of Geomembranes and Related Products |
| ASTM D5199 | (2012) Measuring Nominal Thickness of Geosynthetics |
| ASTM D5261 | (2010; R 2018) Standard Test Method for Measuring Mass Per Unit Area of Geotextiles |
| ASTM D5397 | (2019a) Standard Test Method for Evaluation of Stress Crack Resistance of |

| | |
|---|---|
| | Polyolefin Geomembranes Using Notched Constant Tensile Load Test |
| ASTM D5596 | (2003; R 2016) Standard Test Method For Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics |
| ASTM D5641/D5641M | (2016) Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber |
| ASTM D5721 | (2008; R 2013) Air-Oven Aging of Polyolefin Geomembranes |
| ASTM D5820 | (1995; R 2018) Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes |
| ASTM D5884/D5884M | (2004a; R 2015; E 2015) Standard Test Method for Determining Tearing Strength of Internally Reinforced Geomembranes |
| ASTM D5885/D5885M | (2017) Standard Test Method for Oxidative Induction Time of Polyolefin Geosynthetics by High-Pressure Differential Scanning Calorimetry |
| ASTM D5893/D5893M | (2016) Standard Specification for Cold Applied, Single Component, Chemically Curing Silicone Joint Sealant for Portland Cement Concrete Pavements |
| ASTM D5994/D5994M | (2010; R 2015; E2015) Standard Test Method for Measuring Core Thickness of Textured Geomembranes |
| ASTM D6241 | (2014) Standard Test Method for the Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe |
| ASTM D6392 | (2012; R 2018) Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods |
| ASTM D6693/D6693M | (2004; R 2015; E 2015) Standard Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes |
| ASTM D7238 | (2006; R 2012) Standard Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus |
| ASTM D7466 | (2010) Standard Test Method for Measuring Asperity Height of Textured Geomembranes |

| | |
|---|---|
| ASTM E96/E96M | (2022a; E 2023) Standard Test Methods for Gravimetric Determination of Water Vapor Transmission Rate of Materials |
| ASTM E228 | (2022) Standard Test Method for Linear Thermal Expansion of Solid Materials with a Push-Rod Dilatometer |
| ASTM G152 | (2013; R 2021) Standard Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials |
| ASTM G153 | (2013; R 2021) Standard Practice for Operating Enclosed Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials |

## 1.3 SUBMITTALS

**********

**NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.**

**For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.**

**The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.**

**Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.**

**********

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are

[for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Installation; G[, [_____]]

Liner Projections; G[, [_____]]

As-Built Drawings; G[, [_____]]

SD-03 Product Data

Fabric Reinforced Geomembrane Liner; G[, [_____]]

Non-Reinforced Smooth Geomembrane Liner; G[, [_____]]

Non-Reinforced Textured Geomembrane Liner; G[, [_____]]

Nonwoven Geotextile; G[, [_____]]

Liner Fittings; G[, [_____]]

Embedment Strips; G[, [_____]]

Mounting Strip System; G[, [_____]]

Sealant; G[, [_____]]

Permanent Sand Bags; G[, [_____]]

Precast Concrete Pavers

Rock Ballast

Slip Resistant Walking Surface

Manufacturer's Warranty

Installer's Warranty

SD-04 Samples

Destructive Field Seam Test Sample; G[, [_____]]

SD-05 Design Data

Wind Uplift Calculations; G[, [_____]]

SD-06 Test Reports

Trial Seam Logs

Non-Destructive Field Seam

Destructive Field Seam

SD-07 Certificates

Field Engineer Qualifications

Installer Qualifications

Fabricator Certification

Liner Manufacturer's Certification

Surface Preparation

SD-08 Manufacturer's Instructions

Liner Manufacturer's Installation Instructions

SD-10 Operation and Maintenance Data

Geomembrane Liner; G[, [_____]]

## 1.4 QUALITY ASSURANCE

### 1.4.1 Material and Equipment Qualifications

Provide materials and equipment that are standard products of a manufacturer regularly engaged in the manufacturing of such products, that are of a similar material, design and workmanship. Materials and equipment must have been in satisfactory commercial or industrial use for a minimum 2 years prior to bid opening. The 2 year period must include applications of the equipment and materials under similar circumstances and of similar size. Materials and equipment must have been for sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2 year period. Products having less than a 2 year field service record will be acceptable if a certified record of satisfactory field operation, for not less than 6000 hours, exclusive of the manufacturer's factory tests, can be shown.

### 1.4.2 Field Engineer Qualifications

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**NOTE: Include any local regulatory requirements that must be met by the Contractor.**
**********

Provide a field engineer who has successfully completed manufacturer's training on handling and installing of the fuel impermeable liner to be installed. Demonstrate that the engineer has at least one million square feet of liner installation experience. Submit a letter providing evidence of the field engineer's experience, training, and licensing. In regard to the field engineer's experience, include in the submittal a point of contact, a phone number, the address, the type of installation, and the current status of each installation mentioned.

### 1.4.3 Installer Qualifications

The installer is responsible for field handling, deploying, seaming, anchoring, and field Quality Control (QC) testing of the geomembrane. Demonstrate that the installer has installed the proposed geomembrane

material for at least 5 completed projects and a total minimum area of [93,000] [_____] square meters [1] [_____] million square feet. At least one seamer must have experience seaming a minimum of [46,500] [_____] square meters [500,000] [_____] square feet of the proposed geomembrane using the same type of seaming equipment and same geomembrane specified for this project.

### 1.4.4 Factory Seams

**********

**NOTE: Factory seaming only applies to fabric reinforced geomembranes which can be rolled or folded after fabrication prior to shipping to the project site for deployment. Due to the stiff nature of non-reinforced (HDPE) geomembranes, factory seaming/fabrication is not possible.**

**********

Where possible, use geomembrane factory fabricated to project specific panels in order to minimize field seams. Fabricator must conduct visual inspections on completed seams, as well as non-destructive and destructive testing to verify compliance with the seam strength requirements stated in Table [1][2][3]. Provide fabricator certification of factory seams, including documentation of and results from quality control testing conducted.

### 1.4.5 Liner Manufacturer's Certification

Following the successful installation and testing of the liner, an authorized representative from the liner manufacturer must submit a letter certifying that the liner installation and testing results are satisfactory and that each meets the company's quality expectations and warranty. The letter must also certify that the liner installed is compatible with and recommend for use with the fuel to be stored. Include in the letter the representative's name, address, phone number, and qualifications for being a manufacturer's representative.

## 1.5 DESIGN REQUIREMENTS

**********

**NOTE: Include the following paragraph where the liner is intended to be left exposed without full coverage by concrete, aggregate, or other ballast material.**

**********

Provide certified engineering wind uplift calculations to determine required placement of permanent [sandbags] [precast concrete pavers] [_____] based upon the proposed liner and ballast materials.

## 1.6 DELIVERY, STORAGE, AND HANDLING

Handle, store, and protect equipment and materials to prevent damage before and during installation in accordance with the manufacturer's recommendations, and as approved by the Contracting Officer.

### 1.6.1 Delivery

The QC inspector must be present during delivery and unloading of the

geomembrane. Label each geomembrane roll/panel with the manufacturer's name, product identification number, roll/panel number, and roll/panel dimensions.

### 1.6.2 Storage

Store geomembranes and geotextiles elevated off of the ground and covered to provide protection from precipitation, sunlight/ultraviolet light, puncture/abrasion, undesirable chemicals (as recommended by the manufacturer), and flames/welding sparks. Storage in temperatures between 32 degrees F 0 degrees C and 160 degrees F 71 degrees C, or as recommended by the manufacturer. Storage must not result in crushing the core of roll goods or flattening of the rolls. Do not store rolls more than two high. Store palleted materials on level surfaces and not stacked on top of one another. Remove damaged geomembrane from the site and replace with geomembrane that meets the specified requirements.

### 1.6.3 Handling

Do not drag, lift by one end, or drop rolls and panels. Use a pipe or solid bar, of sufficient strength to support the full weight of a roll without significant bending but small enough to be easily inserted through the core of the roll, for all handling activities. Link the ends of the pipe or bar to the ends of a spreader bar with chains. Use a spreader bar wide enough to prevent the chains from rubbing against the ends of the roll. Alternatively, a stinger bar protruding from the end of a forklift or other equipment may be used. Use a stinger bar at least three-fourths the length of the core and capable of supporting the full weight of the roll without significant bending. If recommended by the manufacturer, a sling handling method utilizing appropriate loading straps may be used.

## 1.7 AMBIENT CONDITIONS

Do not deploy or field-seam geomembrane in the presence of excess moisture (i.e., rain, fog, dew), in areas of ponded water, or in the presence of winds above 20km/hr 12 mph. The relative humidity must be less than 80 percent, and temperature above the dew point. Unless authorized by the Contracting Officer, do not attempt placement or seaming at ambient temperatures below 5 degrees C 40 degrees F or above 40 degrees C 104 degrees F. Measure ambient temperature at a height no greater than 150 mm 6 inches above the ground or geomembrane surface. Seaming is only allowed below 5 degrees C 40 degrees F if recommended by the geomembrane manufacturer and if destructive tests of trial seams at the proposed temperature meet the seam property requirements listed in Table [1][2][3].

## 1.8 WARRANTY

State in the manufacturer's warranty that the installed geomembrane liner is warranted for 10 years against deterioration as installed for containment of the intended liquid. State in the installer's warranty that the geomembrane liner won't fail due to improper installation within 2 years.

# PART 2 PRODUCTS

## 2.1 MATERIALS

**********

**NOTE: Indicate on the drawings the exact type of**

**fuel that each liner system will be expected to contain.**

**The liner types specified herein is compatible with a variety of fuels and liquids. Note that the liner is specifically compatible with Jet A, JP-4, JP-5, JP-8, diesel fuel, motor gasoline, kerosene, No. 2 Fuel Oil, and No. 6 Fuel Oil. If any other fuel is to be contained by the liner system, specifically coordinate with the liner manufacturers for any additional requirements that may need to be added.**

**If multiple liner systems are required, clearly indicate where each liner system is required.**

**********

### 2.1.1 Fabric Reinforced Geomembrane Liner

Provide a flexible, internally fabric reinforced geomembrane liner that is factory fabricated into widths that are designed to minimize field fabricated seams. Make factory seams with a 50 mm 2 inch overlap plus or minus 6 mm 1/4-inch. Provide liner that, as a minimum, meets the physical properties in Table 1. Include liner's routine maintenance requirements as well as procedures for liner repair and troubleshooting.

TABLE 1 - FABRIC REINFORCED GEOMEMBRANE PROPERTIES (ENGLISH)

| PROPERTY | TEST VALUE | TEST METHOD |
|---|---|---|
| Overall Finished Thickness (minimum) | 0.76 mm30 mils | ASTM D751 or ASTM D5199 |
| Base Fabric Material | aramid fibre, polyester, or nylon | |
| Base Fabric Weight (minimum) | 254 g/m27.5 oz/yd2 | ASTM D3776/D3776M |
| Fabric Coating Adhesion (minimum) | 2.6 kN/m15 lbf/inch | ASTM D751 or ASTM D413 |
| Tensile Strength, Grab (minimum) | 2.67 kN 600 lbf in both warp and fill directions | ASTM D751, Grab Test Method |
| Bursting Strength (minimum) | 3.55 kN800 lbf | ASTM D751, Ball Tip Method |
| Hydrostatic Resistance (minimum) | 5515 kN/m2800 psi | ASTM D751, Procedure A |
| Trapizoid Tearing Strength (minimum) | 0.22 kN 50 lbf in both the warp and fill directions | ASTM D4533 or ASTM D751, Trapazoidal Tear Method |
| Puncture Strength (minimum) | 1.11 kN250 lbf | ASTM D4833/D4833M |
| Tearing Resistance (minimum) | 0.53 kN120 lbf | ASTM D5884/D5884M |
| Low Temperature Bend (minimum) | -34 degrees C-30 degrees F | ASTM D2136 |

| TABLE 1 - FABRIC REINFORCED GEOMEMBRANE PROPERTIES (ENGLISH) | | |
|---|---|---|
| PROPERTY | TEST VALUE | TEST METHOD |
| Vapor Transmission (maximum) | 3.78 ml/m2 0.0119 oz/ft2 over 24 hours | ASTM E96/E96M, Procedure BW, Inverted Water Method, using kerosene instead of water |
| Coefficient of Thermal Expansion (maximum) | 0.000038 cm/cm/degree C 0.000021 in/in/degree F | ASTM E228 or ASTM D696 |
| Weathering Resistance | No appreciable changes, stiffening or cracking of coating for a minimum of 8000 hours | ASTM G152 or ASTM G153 |
| Bonded Seam Shear Strength(minimum) | 2.33 kN525 lbf | ASTM D751 |
| Bonded Seam Peel Strength (minimum) | 88.9 N20 lbf | ASTM D413 |
| Dead Load Seam Shear Strength (minimum) | 1110 N at 21 degrees C; 555 N at 71 degrees C250 lbf at 70 degrees F; 125 lbf at 160 degrees F | ASTM D751 |

### 2.1.2 Non-Reinforced Smooth Geomembrane Liner

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**NOTE: Non-reinforced (HDPE) is only acceptable for use where completely covered with a material to avoid the effects of thermal expansion from temperature change and degradation from UV light.**

**********

Provide non-reinforced smooth geomembrane liner of unreinforced high density polyethylene (HDPE), manufactured as wide as possible to minimize factory and field seams. Geomembrane sheets must be uniform in color, thickness, and surface texture. The sheets must be free of and resistant to fungal or bacterial attack and free of cuts, abrasions, holes, blisters, contaminants and other imperfections. Provide liner meeting the physical properties of Table 2.

Make resin used in manufacturing geomembrane sheets of virgin uncontaminated ingredients. Use no more than [10] [_____] percent regrind, reworked, or trim material in the form of chips or edge strips to manufacture the geomembrane sheets. All regrind, reworked, or trim materials must be from the same manufacturer and exactly the same formulation as the geomembrane sheet being produced. Do not use post consumer materials or water-soluble ingredients to produce the geomembrane. For geomembranes with plasticizers, use only primary plasticizers that are resistant to migration. Submit a copy of the test reports and QC certificates for materials used in the manufacturing of the geomembrane shipped to the site.

| TABLE 2 - SMOOTH HDPE GEOMEMBRANE PROPERTIES (ENGLISH) | | |
|---|---|---|
| PROPERTY | TEST VALUE | TEST METHOD |
| Thickness (min ave) | [1.50] [_____] mm[60] [_____] mils | ASTM D5199 |
| Lowest individual of 10 values | -10 percent | ASTM D5199 |
| Density (min) | 0.940 g/cc | ASTM D1505 |
| Tensile Properties(1)(min ave) | | ASTM D6693/D6693M Type IV |
| Yield Strength | [22] [_____] kN/m[126] [_____] lb/in | |
| Break Strength | [40] [_____] kN/m[228] [_____] lb/in | |
| Yield Elongation | [12] [_____] percent | |
| Break Elongation | [700] [_____] percent | |
| Tear Resistance (min ave) | [187] [_____] N[42] [_____] lb | ASTM D1004 |
| Puncture Resistance(min ave) | [480] [_____] N[108] [_____] lb | ASTM D4833/D4833M |
| Stress Crack Resistance (2) | [300] [_____] hr | ASTM D5397 (Appendix) |
| Carbon Black Content | 2.0-3.0 percent | ASTM D1603 (3) |
| Carbon Black Dispersion | Note (4) | ASTM D5596 |
| Oxidative Induction Time (OIT)(min ave)(5) | | |
| Std OIT | 100 min | ASTM D3895 |
| High Pres OIT | 400 min | ASTM D5885/D5885M |
| Oven Aging at 85 deg C 185 deg F (min ave) (5), (6) | | ASTM D5721 |
| Std OIT | 55 percent at 90 days | ASTM D3895 |
| or High Pres OIT | 80 percent at 90 days | ASTM D5885/D5885M |
| UV Resistance (min ave) (7) | | ASTM D7238 |
| High Pres OIT(8)(9) | 50 percent at 1600 hours | ASTM D5885/D5885M |
| Seam Shear Strength (min) Hot Wedge, Hot Air, Ultrasonic, Extrusion Fillet (10)(12) | [525] [_____] N/25mm [120] [_____] lb/in | ASTM D6392 |
| Seam Peel Strength (min) Hot Wedge, Hot Air, Ultrasonic (10)(11)(12) | [398] [_____] N/25mm [91] [_____] lb/in | ASTM D6392 |

| TABLE 2 - SMOOTH HDPE GEOMEMBRANE PROPERTIES (ENGLISH) | | |
|---|---|---|
| PROPERTY | TEST VALUE | TEST METHOD |
| Seam Peel Strength (min) Extrusion Fillet (10)(11)(12) | [340] [_____] N/25mm<br>[78] [_____] lb/in | ASTM D6392 |
| (1) Base minimum average machine direction and minimum average cross machine direction values on 5 test specimens in each direction. For HDPE geomembrane, yield elongation is calculated using a gauge length of 33 mm 1.3 inches. For HDPE geomembrane, break elongation is calculated using a gauge length of 50 mm 2.0 inches. | | |
| (2) For HDPE geomembrane, use the manufacturer's mean value yield stress used to calculate the applied load for test method ASTM D5397 (Appendix). | | |
| (3) Other methods such as ASTM D4218 or microwave methods are acceptable if an appropriate correlation to ASTM D1603 can be established. | | |
| (4) Carbon black dispersion for 10 different views:<br>- minimum 8 of 10 in Categories 1 or 2<br>- all 10 in Categories 1,2, or 3 | | |
| (5) The manufacturer has the option to select either one of the OIT methods to evaluate the antioxidant content. | | |
| (6) Evaluate samples at 30 and 60 days and compare with the 90 day response. | | |
| (7) The condition of the test must be a 20 hour UV cycle at 75 degrees C 167 degrees F followed by a 4 hour condensation cycle at 60 degrees C 140 degrees F. | | |
| (8) Do not use the standard OIT test (ASTM D3895) in determining UV resistance. | | |
| (9) UV resistance is based on percent retained value regardless of the original HP-OIT value. | | |
| (10) Seam tests for peel and shear must fail in the Film Tear Bond mode. This is a failure in the ductile mode of one of the bonded sheets by tearing or breaking prior to complete separation of the bonded area. | | |
| (11) Where applicable, test both tracks of a double hot wedge seam for peel adhesion. | | |
| (12) For five samples tested, four must meet or exceed the given value, with the fifth within 80 percent of the given value. | | |

### 2.1.3 Non-Reinforced Textured Geomembrane Liner

**********

**NOTE: Non-reinforced (HDPE) is only acceptable for**

**use where completely covered with a material to avoid the effects of thermal expansion from temperature change and degradation from UV light.**

**Specify textured geomembrane where slopes are 1V on 5H or greater, such as on sloped dikes.**

**********

Provide non-reinforced textured geomembrane liner composed of unreinforced high density polyethylene (HDPE), uniform in color, thickness, and surface texture, manufactured as wide as possible to minimize factory and field seams. For slopes greater than or equal to 1V on 5H, texture sheets on both faces. Provide textured surface features consisting of raw materials identical to that of the parent sheet material and uniform over the entire face of the geomembrane. The sheets must be free of and resistant to fungal or bacterial attack and free of cuts, abrasions, holes, blisters, contaminants and other imperfections. Provide liner meeting the physical properties of Table 3.

Use virgin uncontaminated ingredients resin in manufacturing geomembrane sheets. Use no more than [10] [_____] percent regrind, reworked, or trim material in the form of chips or edge strips to manufacture the geomembrane sheets. The same manufacturer regrinds, reworks, or trims materials, using exactly the same formulation as the geomembrane sheet being produced. No post consumer materials or water-soluble ingredients may be used to produce the geomembrane. For geomembranes with plasticizers, use only primary plasticizers that are resistant to migration. Submit a copy of the test reports and QC certificates for materials used in the manufacturing of the geomembrane shipped to the site.

TABLE 3 - TEXTURED HDPE GEOMEMBRANE PROPERTIES (ENGLISH)

| PROPERTY | TEST VALUE | TEST METHOD |
|---|---|---|
| Nominal Thickness | [1.50] [_____] mm[60] [_____] mils | |
| Thickness (min ave) | -5 percent of nominal | ASTM D5994/D5994M |
| Lowest individual for 8 out of 10 values | -10 percent of nominal | ASTM D5994/D5994M |
| Lowest individual of 10 values | -15 percent of nominal | ASTM D5994/D5994M |
| Asperity Height (min ave) (13) | 0.25 mm10 mils | ASTM D7466 (14) |
| Density (min) | 0.940 g/cc | ASTM D1505 |
| Tensile Properties(1)(min ave) | | ASTM D638 Type IV or ASTM D6693/D6693M |
| Yield Strength | [22] [_____] kN/m[126] [_____] lb/in | |

| TABLE 3 - TEXTURED HDPE GEOMEMBRANE PROPERTIES (ENGLISH) | | |
|---|---|---|
| PROPERTY | TEST VALUE | TEST METHOD |
| Break Strength | [16] [_____] kN/m[90] [_____] lb/in | |
| Yield Elongation | [12] [_____] percent | |
| Break Elongation | [100] [_____] percent | |
| Tear Resistance (min ave) | [187] [_____] N[42] [_____] lb | ASTM D1004 |
| Puncture Resistance(min ave) | [400] [_____] N[90] [_____] lb | ASTM D4833/D4833M |
| Stress Crack Resistance (2) | [300] [_____] hr | ASTM D5397 (Appendix) |
| Carbon Black Content | 2.0-3.0 percent | ASTM D1603 (3) |
| Carbon Black Dispersion | Note (4) | ASTM D5596 |
| Oxidative Induction Time (OIT)(min ave)(5) | | |
| Std OIT | 100 min | ASTM D3895 |
| or High Pres OIT | 400 min | ASTM D5885/D5885M |
| Oven Aging at 85 deg C 185 deg F (min ave) (5), (6) | | ASTM D5721 |
| Std OIT | 55 percent at 90 days | ASTM D3895 |
| or High Pres OIT | 80 percent at 90 days | ASTM D5885/D5885M |
| UV Resistance (min ave) (7) | | ASTM D7238 |
| High Pres OIT(8)(9) | 50 percent at 1600 hours | ASTM D5885/D5885M |
| Seam Shear Strength (min) Hot Wedge, Hot Air, Ultrasonic, Extrusion Fillet (10)(12) | [525] [_____] N/25mm[120] [_____] lb/in | ASTM D6392 |
| Seam Peel Strength (min) Hot Wedge, Hot Air, Ultrasonic (10)(11)(12) | [398] [_____] N/25mm[91] [_____] lb/in | ASTM D6392 |
| Seam Peel Strength (min) Extrusion Fillet (10)(11)(12) | [340] [_____] N/25mm[78] [_____] lb/in | ASTM D6392 |

| TABLE 3 - TEXTURED HDPE GEOMEMBRANE PROPERTIES (ENGLISH) | | |
|---|---|---|
| PROPERTY | TEST VALUE | TEST METHOD |
| (1) Base minimum average machine direction and minimum average cross machine direction values on 5 test specimens in each direction. For HDPE geomembrane, yield elongation is calculated using a gauge length of 33 mm 1.3 inches. For HDPE geomembrane, break elongation is calculated using a gauge length of 50 mm 2.0 inches. | | |
| (2) For HDPE geomembrane, use the manufacturer's mean value yield stress to calculate the applied load for test method ASTM D5397 (Appendix). | | |
| (3) Other methods such as ASTM D4218 or microwave methods are acceptable if an appropriate correlation to ASTM D1603 can be established. | | |
| (4) Carbon black dispersion for 10 different views:<br>- minimum 8 of 10 in Categories 1 or 2<br>- all 10 in Categories 1,2, or 3 | | |
| (5) The manufacturer has the option to select either one of the OIT methods to evaluate the antioxidant content. | | |
| (6) Evaluate samples at 30 and 60 days and compare with the 90 day response. | | |
| (7) The condition of the test must be a 20 hour UV cycle at 75 degrees C 167 degrees F followed by a 4 hour condensation cycle at 60 degrees C 140 degrees F. | | |
| (8) Do not use the standard OIT test (ASTM D3895) in determining UV resistance. | | |
| (9) UV resistance is based on percent retained value regardless of the original HP-OIT value. | | |
| (10) Seam tests for peel and shear must fail in the Film Tear Bond mode. This is a failure in the ductile mode of one of the bonded sheets by tearing or breaking prior to complete separation of the bonded area. | | |
| (11) Where applicable, test both tracks of a double hot wedge seam for peel adhesion. | | |
| (12) For five samples tested, four must meet or exceed the given value, with the fifth within 80 percent of the given value. | | |
| (13) Of 10 readings; 8 out of 10 must be equal to or greater than 0.18 mm 7 mil, and lowest individual reading must not be less than 0.13 mm 5 mil. | | |
| (14) Alternate the measurement side for double sided textured sheet. | | |

### 2.1.4 Nonwoven Geotextile

**********

**NOTE: Include the following paragraphs where a geotextile is required above or below the geomembrane liner system. Installation of a geotextile underneath the secondary containment liner is required if the subgrade is rough or sharp in nature (i.e., sharp limestone or granite rock, rough gunnite, rough or exposed concrete aggregate, etc.). Include the installation of a geotextile above the secondary containment liner where the liner is not left exposed to protect the liner from cover materials and from equipment during the placement of cover material.**

**********

Provide a nonwoven, polypropylene, needle punched geotextile fabric. Provide geotextile having the following physical properties as a minimum. No substitute methods are allowed for verification of any property.

#### 2.1.4.1 General Properties

Retard the growth of mildew and be compatible with the soil in contact.

#### 2.1.4.2 Nominal Unit Weight

Provide a nominal unit weight of 407 g/m2 12 oz/yd2 as measured in accordance with ASTM D5261.

#### 2.1.4.3 Grab Tensile Strength

Provide a minimum grab tensile strength of 1335 N 300 lbf when tested in accordance with ASTM D4632/D4632M.

#### 2.1.4.4 Grab Tensile Elongation

Provide a minimum grab tensile elongation of 50 percent when tested in accordance with ASTM D4632/D4632M.

#### 2.1.4.5 Puncture Strength

Provide a minimum puncture strength of 620 N 140 lbf when tested in accordance with the pin strength methods of ASTM D4833/D4833M, or 3.56 kN 800 lbf when tested in accordance with the CBR methods of ASTM D6241.

#### 2.1.4.6 Trapezoid Tear Strength

Provide a minimum trapezoid tear strength of 512 N 115 lbf when tested in accordance with ASTM D4533.

#### 2.1.4.7 Ultraviolet (UV) Resistance

Maintain 70 percent of its original strength after 500 hours of testing in accordance with ASTM D4533.

## 2.2 ACCESSORIES

### 2.2.1 Liner Fittings

Provide liner fittings (for example, boots and sleeves) that are factory prefabricated components produced from the same manufacturer that produces the fuel impermeable liner and having the same fabrication characteristics as the liner.

### 2.2.2 Embedment Strip

Provide embedment strips for attachment to new cast-in-place concrete structures by the same manufacturer as the geomembrane, and made of the same materials as the geomembrane to be used or otherwise be certified by the manufacturer for use with the geomembrane.

### 2.2.3 Batten / Mounting Strip System

**********

**NOTE: Show mounting strips around the perimeter of liner terminations on existing or precast concrete structures. The strips prevent the nut on the concrete anchor from penetrating and damaging the liner.**

**********

Provide [minimum 5 mm 1/4-inch thick by 50 mm 2 inches wide stainless steel] [or] [minimum 9 mm 3/8-inch thick by 50 mm 2 inches wide aluminum] mounting strips. Provide pre-punched bolt holes in the strip at maximum 300 mm 12 inches on center to accommodate the concrete anchor bolts.

#### 2.2.3.1 Gasket

Provide a minimum 6 mm 1/4-inch thick by 50 mm 2-inches wide nitrile gasket on one or both sides of the geomembrane as recommended by the geomembrane manufacturer at mounting strip locations to seal and protect the geomembrane from the concrete and the mounting strip.

#### 2.2.3.2 Concrete Anchor Bolts

Use minimum 9 mm 3/8-inch diameter mechanical wedge-type concrete anchors, constructed of type 304 or 316 stainless steel. Provide nuts, washers, and other accessories of the same materials.

### 2.2.4 Sealant

Use sealant conforming to ASTM C920, Type S, Grade NS, Class 25 or better, or ASTM D5893/D5893M, Type NS, or other sealant recommended by the geomembrane manufacturer. Sealant used must be compatible with the material being stored, as recommended by the sealant manufacturer.

### 2.2.5 Temporary Ballast

Temporary ballast used during geomembrane installation may include sandbags, tires, or other material as recommended by the geomembrane manufacturer. Use non-abrasive material, free of sharp edges or other features that may damage the geomembrane liner.

2.2.6 Permanent Ballast

Provide permanent ballast as indicated [below].

**********
**NOTE: Select permanent ballast materials from the following section. Delete options that are not desired on this project. If alternate ballast materials are desired, include specific requirements, and ensure that the proposed material provides adequate ballast without damaging the geomembrane liner.**
**********

**********
**NOTE:Some jurisdictions require periodic inspection, testing, or certification of secondary spill containment systems. Designers must verify State and local requirements and specify appropriate ballast materials to accommodate the requirements. I.E. Do not specify ballast materials that cannot be readily removed when the liner underneath will need to be visually inspected.**
**********

2.2.6.1 Sand Bags

**********
**NOTE: Suggest bags be filled with dry, clean sand however if sand is not readily available at the project site, then require the bags to be filled with another more indigenous material. The material selected should not have any sharp points or edges.**
**********

Permanent sand bags fabricated of the same material as the liner. Provide approximately 23 kg 50 lbs of [dry, clean sand] [_____] inside of each bag. Completely seal each bag using the same field seam weld procedures used on the liner's field seams.

2.2.6.2 Precast Concrete Pavers

Provide precast concrete pavers that have a smooth finish with rounded edges where in contact with the liner and are free of sharp points or protrusions that may damage the geomembrane liner.

2.2.6.3 Cast in Place Concrete

Provide concrete cover over the containment geomembrane in accordance with Section 32 13 15.20 CONCRETE PAVEMENTS FOR CONTAINMENT DIKES.

2.2.6.4 Rock Ballast

Provide rock ballast consisting of clean, well graded river rock or cobble stone, sized 3.81 cm to 7.62 cm 1-1/2 inch to 3 inch. Use rock free of sharp points, protrusions, or edges.

### 2.2.7 Slip Resistant Walking Surface

**********
**NOTE: Include the following paragraph where the liner is intended to be left exposed without full coverage by concrete, aggregate, or other ballast material. Ensure that the design drawings indicate the pathways where non-slip surfaces are required**
**********

Provide an additional layer of geomembrane with an integral slip-resistant coating or sprayed on slip-resistant coating for slip resistant walking surfaces. Weld additional geomembrane layers to the base geomembrane. Use pprayed on coatings recommended by both the geomembrane and coating manufacturer for combined use and adhesion.

## 2.3 EQUIPMENT

Utilize equipment in performance of the work in accordance with the geomembrane manufacturer's recommendations and maintain in satisfactory working condition.

# PART 3 EXECUTION

## 3.1 INSTALLATION

Make equipment/parts subject to degradation or requiring adjustment, inspection or repair accessible and capable of convenient removal. Prior to any fabrication or erection, submit detailed installation drawings that show the proposed panel layout of the liner over the entire containment area. As a minimum, indicate the direction and location of factory and field fabricated seams, the termination of the panels at the perimeter of lined areas, details and methods of sealing around penetrations, details and methods for anchoring, [placement of permanent [sandbags][precast concrete pavers] [_____] for ballast, ]and any applicable site specific installation instructions.

### 3.1.1 Field Engineer

Provide a field engineer to supervise the complete installation of the liner and perform each liner inspection and test.

### 3.1.2 Surface Preparation

**********
**NOTE: Include the bracketed sentences if a geotextile is required beneath the geomembrane for the project.**
**********

Prepare surfaces in accordance with Section 31 00 00 EARTHWORK. Surfaces to be covered must be free of vegetation, gravel, rocks, debris, etc., graded true, compacted, and be smooth with no abrupt projections. [ Install the geotextile in direct contact with the existing subgrade to be covered. Install the geotextile in strict accordance with manufacturer's recommendations. Install geotextile to closely fit around projections (for example, pipe penetrations, concrete foundations/pads, conduit penetrations, etc.).] Submit a signed letter from the field engineer, prior to placing any geotextile or liner, that states the subgrade and

surface preparation were adequate and in accordance with the liner manufacturer's recommendations.

### 3.1.3 Anchor Trenches

Where an anchor trench is required, place it [610] [_____] mm [24] [_____] inches back from the edge of the slope to be covered. Make the anchor trench [600] [_____] mm [24] [_____] inches deep and [300] [_____] mm [12] [_____] inches wide, unless otherwise recommended by the geomembrane manufacturer. If the anchor trench is excavated in cohesive soil susceptible to desiccation, excavate only the amount of anchor trench required for placement of geomembrane in a single day. Remove ponded water from the anchor trench while the trench is open. Slightly round trench corners to avoid sharp bends in the geomembrane. Remove loose soil, rocks larger than [13] [_____] mm [1/2] [_____] inch in diameter, and any other material which could damage the geomembrane from the surfaces of the trench. Extend the geomembrane down the front wall and across the bottom of the anchor trench. Backfill and compact the anchor trench in accordance with Section 31 00 00 EARTHWORK.

### 3.1.4 Embedment Strip Installation

Install embedment strips in new cast-in-place concrete structures using methods and materials recommended by the embedment strip/geomembrane manufacturer. Extrusion weld all joints and intersections of embedment material together or otherwise join as recommended by the manufacturer to provided a continuous surface for attachment of the geomembrane. Fill any holes through the face of the embed material resulting from the concrete forming or placement process with material recommended by the manufacturer.

### 3.1.5 Liner Installation

See paragraph AMBIENT CONDITIONS. Place the liner over the prepared surface in accordance with the liner manufacturer's installation instructions. The procedures and equipment used cannot elongate, wrinkle, scratch, or otherwise damage the geomembrane, [geotextile, ]or the underlying subgrade. Place the liner in such a manner as to assure minimum handling and field seams. Use sand bags (or other manufacturer approved means) to hold the lining down in position during installation. Do not drag or slide materials, equipment or other items across the surface of the liner at anytime. Do not allow personnel walking or working on the lining to damage it. Replace or repair geomembrane damaged during installation. Allow adequate slack in the geomembrane to prevent the creation of tensile stress and avoid "trampolining" or "bridging". Do not exceed a wrinkle height to width ratio of 0.5 for installed geomembrane. In addition, geomembrane wrinkles must not exceed 75 mm 3 inches in height. Cut and repair wrinkles that do not meet the above criteria in accordance with paragraph REPAIRS.

#### 3.1.5.1 Liner Projections

Install lining sheets to closely fit around liner projections (for example, pipe penetrations, concrete foundations/pads, conduit penetrations, etc.). Install and center manufacturer supplied sleeves/boots around liner projections in strict accordance with manufacturer's recommendations. Compress the end of pipe sleeves to a pipe with a stainless steel band clamp assembly. For liner anchorage to precast or existing concrete, install a batten / mounting strip around the liner edge and mount with concrete anchor bolts. Apply sealant to the

perimeter edge of exposed liner to include the edge of sleeves/boots. For liner anchorage to new cast-in-place concrete, install an embedment strip in the concrete using methods and materials recommended by the embedment strip/geomembrane manufacturer.

## 3.2 FIELD SEAMING

### 3.2.1 Trial Seams

Make trial seams under field conditions on strips of excess geomembrane. Make trial seams each day prior to production seaming, whenever there is a change in seaming personnel or seaming equipment settings, whenever environmental conditions change significantly (more than 10 degrees 25 degrees), and at least once every four hours, by each seamer and each piece of seaming equipment used that day. Collect and test trial seam samples in accordance with [ASTM D6392 for non-reinforced liner] [or] [ ASTM D751 and ASTM D413 for fabric-reinforced liner]. Obtain one sample from each trial seam. This sample must be at least 450 mm long by 305 mm wide 18 inches long by 12 inches wide with the seam centered lengthwise. Cut ten random specimens from the sample, 25.4 mm 1 inch wide. Field test five seam specimens for seam shear strength and field test 5 seam specimens for seam peel adhesion. To be acceptable, 4 out of 5 replicate test specimens must meet seam strength requirements specified in Table [1][2][3]. If the field tests fail to meet these requirements, repeat the entire operation. If the additional trial seam fails, do not use the seaming apparatus or seamer until the deficiencies are corrected by the installer and 2 consecutive successful trial seams are achieved. Maintain logs of trial seams, which include date, time, weather, seaming personnel, seaming equipment, equipment settings, and trail seam field test results. Submit trial seam logs following the completion of installation.

### 3.2.2 Field Seams

Seam panels in accordance with the geomembrane manufacturer's recommendations. Comply with the geomembrane manufacturer's recommnedation for the overlap between panels being seamed together; however, in no overlap less than 50 mm 2 inches. In sumps, corners and odd-shaped geometric locations, minimize the number of field seams. Extend seaming to the outside edge of panels. Compact soft subgrades prior to seaming. Provide a clean and free of moisture, dust, dirt, debris, markings, and foreign material area at the time of seaming. Completely unroll and layout adjacent liner panels/sheets before performing field seam welds. Repair fish mouths in seams.

## 3.3 FIELD QUALITY CONTROL

### 3.3.1 Visual Inspection of Field Seams

Visually inspect each field seam to confirm that the seams are tightly bonded. Perform the inspection of a seam within 30 hours after the manufacturer's suggested application, curing, and cooling time. Repair and re-inspect seams found to be defective in accordance with manufacturer's recommendations.

### 3.3.2 Non-Destructive Field Seam Testing

Perform non-destructive testing on all field seams over the full seam length and on any other areas showing damage or other distresses. Allowable methods are stated below. Alternate methods approved by the

geomembrane manufacturer may be submitted upon approval by the Contracting Officer. Submit non-destructive field seam test reports following the completion of installation and prior to covering the geomembrane liner.

3.3.2.1 Liner Vacuum Box Test

Perform a vacuum box test in accordance with ASTM D5641/D5641M on each field seam, the area around the seams, and each liner surface showing injury due to scuffing, penetration by foreign objects, or distress from rough subgrade. If the vacuum box test indicates a continuous stream of bubbles on repeated testing at the same location, then the area being tested is considered damaged and must be repaired and retested. Perform repairs in accordance with manufacturer's recommendations.

3.3.2.2 Liner Air Lance Test

Perform an air lance test on seams to detect an unbonded area in accordance with ASTM D4437/D4437M. Perform the test using a minimum 345 kPa 50 psig jet of air regulated and directed through a 5 mm 3/16-inch diameter nozzle. Apply the jet of air to the lip of a seam in a near perpendicular direction to the length of the seam. Hold the nozzle a maximum of 100 mm 2 inches from the seam and travel at a rate of not to exceed 12 mpm 40 fpm. Inflation of any section of the seam by the impinging air stream is indicative of an unbonded area. Repair unbonded areas in accordance with manufacturer's recommendations and retest.

3.3.2.3 Liner Air Pressure Test

Perform air pressure testing in accordance with ASTM D5820. Upon completion of the test, relieve pressure from the opposite end of the seam being tested to verify continuity of the seam.

3.3.2.4 Liner Point Stress Test

Where other non-destructive test methods are not possible, perform point stress testing in accordance with ASTM D4437/D4437M.

3.3.3 Destructive Field Seam Testing

Obtain a minimum of one destructive test sample per [230] [_____] m [500] [_____] feet of field seam at locations specified by the Contracting Officer. Recommended locations include the ends of seams or anchor trenches, so as to minimize the impact of required repairs to the geomembrane; however, final sample locations will be determined by the Contracting Officer. Sample locations will not be identified prior to seaming. Collect samples a minimum of 305 mm 12 inches wide by 910 mm 36 inches long with the seam centered lengthwise. Cit each sample into two equal pieces, with one piece retained by the installer for field testing and the remaining destructive field seam test sample given to the Contracting Officer for QA testing and/or permanent record. Number each sample and cross reference to a field log which identifies: (1) panel number; (2) seam number; (3) date and time cut; (4) ambient temperature within 150 mm 6 inches above the geomembrane; (5) seaming unit designation; (6) name of seamer; and (7) seaming apparatus temperature and pressures (where applicable). Field test in accordance with [ASTM D6392 for non-reinforced liner] [or] [ASTM D751 and ASTM D413 for fabric-reinforced liner]. Cut ten 25 mm 1 inch wide replicate specimens from the installer's sample. Test five specimens for shear strength and 5 for peel adhesion. Jaw separation speed must be in accordance with the

approved QC manual. To be acceptable, 4 out of 5 replicate test specimens must meet the seam strength requirements specified in Table [1][2][3]. If the field tests fail, repair the seam in accordance with paragraph REPAIRS. Repair holes for destructive seam samples the same day they are cut. Submit destructive field seam test reports following completion of installation and prior to covering the geomembrane liner.

## 3.4 REPAIRS

Patch damaged areas, destructive testing areas, or other areas requiring repair with the geomembrane material. Round the corners of the patch material and extend a minimum of 150 mm 6 inches in each direction from the damaged area. Small holes or snags less than 6 mm 1/4 inch in diameter may be repaired by extrusion welding where such process is approved by the geomembrane manufacturer.

## 3.5 PROTECTION AND BACKFILLING

**********

**NOTE: Retain the bracketed paragraph if the geomembrane liner is to be covered with permanent ballast material, such as concrete or river rock.**

**********

Prior to installation of permanent ballast material, the deployed geomembrane must be in intimate contact with the underlying surface, with no areas in sufficient tension to form "bridges" or "trampolines". Minimize waves/wrinkles in the geomembrane prior to placement of ballast materials; in no case allow wrinkles to fold over during placement of ballast materials.[ Install the cover geotextile in direct contact with the geomembrane liner to be covered, in strict accordance with manufacturer's recommendations. Install geotextile to closely fit around projections (for example, pipe penetrations, concrete foundations/pads, conduit penetrations, etc.). Cover the deployed and seamed geomembrane with the specified permanent ballast material within [14] [_____] calendar days of acceptance. Do not drop ballast material onto the geomembrane or overlying geotextile from a height greater than 1 m 3 feet. Push the material out over the geomembrane in an outward/upward tumbling motion. Place ballast material from the bottom of the slope upward.]

### 3.5.1 Ballast Placement Equipment

**********

**NOTE: Avoid the use of construction equipment on the deployed geomembrane as much as possible to avoid potential damage. Include the first bracketed option where geomembrane is to be left uncovered or where the covered containment areas are sufficiently small to allow placement of cover material utilizing equipment positioned outside of the geomembrane covered area, such as a crane, backhoe, or concrete pump truck. Include the second bracketed option where use of small equipment (skidloader or similar) for placement of the cover material is necessary.**

**********

[Place ballast material utilizing construction equipment that is positioned off of the deployed geomembrane. Do not drive construction

equipment on or above the geomembrane at any time.][Equipment with ground pressures less than 50 kPa 7 psi may be used to place the ballast material over the geomembrane; do not drive equipment exceeding this pressure on the geomembrane. Do not abruptly stop equipment placing ballast material, make sharp turns, spin wheels, or travel at speeds exceeding [2.2] [_____] m/s [5] [_____] mph. Operate equipment driving on the geomembrane on a cushion layer of ballast material with a minimum thickness of 150 mm 6 in over the geomembrane; at no time operate equipment directly on the geomembrane or geotextile.]

## 3.6 PERMANENT BALLAST

**********
**NOTE: Delete inapplicable ballast materials.**
**********

### 3.6.1 Sand Bags

**********
**NOTE: For liners exposed to the elements, show bags to be permanently placed on top of the liner at regularly spaced intervals in order to keep the liner held down in the event of strong winds. A typical location for such bags would be at the base of a dike wall/berm.**
**********

Determine sand bag placement and spacing by wind uplift calculations as specified in paragraph DESIGN REQUIREMENTS.

### 3.6.2 Precast Concrete Pavers

Determine paver placement and spacing by wind uplift calculations as specified in paragraph DESIGN REQUIREMENTS. Install an additional layer of geomembrane under each paver, welded to the base geomembrane.

### 3.6.3 Cast in Place Concrete

Place concrete cover over containment geomembrane in accordance with Section 32 13 15.20 CONCRETE PAVEMENTS FOR CONTAINMENT DIKES.

### 3.6.4 Rock Ballast

Compact rock ballast with two passes of a walk-behind vibratory compactor. Provide ballast thickness[ as indicated][ 200 mm 8 inches for the containment area floor][ and][ 150 mm 6 inches for dike slopes].

## 3.7 SLIP RESISTANT WALKING SURFACE

**********
**NOTE: Include the following paragraph where the liner is intended to be left exposed without full coverage by concrete, aggregate, or other ballast material. Ensure that the design drawings indicate the pathways where non-slip surfaces are required.**
**********

Install slip resistant walking surface materials [in the areas indicated] [on top of dike slopes and between the dike stairs and tank concrete

apron].

## 3.8 PROJECT CLOSEOUT

Provide As-Built Drawings which show the as constructed panel layout, factory and field seam locations, penetrations, destructive field seam testing location, and repair locations. Provide operation and maintenance data package for the geomembrane liner to include material cut sheets, liner's routine maintenance requirements as well as procedures for liner repair and troubleshooting.

-- End of Section --