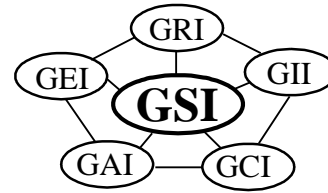


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## **GRI Test Method GM13\***

Standard Specification for

“Test Methods, Test Properties and Testing Frequency for  
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

### 1. Scope

- 1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.
- 1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.
- 1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

- 1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

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\*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

## 2. Referenced Documents

### 2.1 ASTM Standards

- D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
- D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
- D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
- D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
- D 1603 Test Method for Carbon Black in Olefin Plastics
- D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
- D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
- D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
- D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
- D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
- D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
- D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
- D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
- D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
- D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
- D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
- D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
- D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

### 2.2 GRI Standards

- GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

- 2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

### 3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.

ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.

ref. EPA/600/R-93/182

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

### 4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

## 5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of  $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$ . Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of  $21^{\circ}\text{C} \pm 2^{\circ}\text{C}$ . The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of  $23^{\circ}\text{C} \pm 2^{\circ}\text{C}$  should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

## 6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

- 7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.
- 7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.
- 7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

- 8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

- 9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

- 10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

**Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth**

| Properties  | Test Method       | Test Value              |                         |                          |                          |                          |                          |                          | Testing Frequency (minimum) |
|---|-------------------|-------------------------|-------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|
|   |                   | 30 mils                 | 40 mils                 | 50 mils                  | 60 mils                  | 80 mils                  | 100 mils                 | 120 mils                 |                             |
| Thickness (min. ave.)   | D5199             | nom.                    | nom.                    | nom.                     | nom.                     | nom.                     | nom.                     | nom.                     | Per roll                    |
| • lowest individual of 10 values                                  |                   | -10%                    | -10%                    | -10%                     | -10%                     | -10%                     | -10%                     | -10%                     |                             |
| Formulated Density mg/l (min.)                                    | D 1505/D 792      | 0.940 g/cc              | 0.940 g/cc              | 0.940 g/cc               | 0.940 g/cc               | 0.940 g/cc               | 0.940 g/cc               | 0.940 g/cc               | 200,000 lb                  |
| Tensile Properties (1) (min. ave.)                                | D 6693<br>Type IV | 63 lb/in.<br>114 lb/in. | 84 lb/in.<br>152 lb/in. | 105 lb/in.<br>190 lb/in. | 126 lb/in.<br>228 lb/in. | 168 lb/in.<br>304 lb/in. | 210 lb/in.<br>380 lb/in. | 252 lb/in.<br>456 lb/in. | 20,000 lb                   |
| • yield strength  |                   | 12%                     | 12%                     | 12%                      | 12%                      | 12%                      | 12%                      | 12%                      |                             |
| • break strength  |                   | 700%                    | 700%                    | 700%                     | 700%                     | 700%                     | 700%                     | 700%                     |                             |
| • yield elongation  |                   |                         |                         |                          |                          |                          |                          |                          |                             |
| • break elongation  |                   |                         |                         |                          |                          |                          |                          |                          |                             |
| Tear Resistance (min. ave.)                                       | D 1004            | 21 lb                   | 28 lb                   | 35 lb                    | 42 lb                    | 56 lb                    | 70 lb                    | 84 lb                    | 45,000 lb                   |
| Puncture Resistance (min. ave.)                                   | D 4833            | 54 lb                   | 72 lb                   | 90 lb                    | 108 lb                   | 144 lb                   | 180 lb                   | 216 lb                   | 45,000 lb                   |
| Stress Crack Resistance (2)                                       | D5397<br>(App.)   | 500 hr.                 | 500 hr.                 | 500 hr.                  | 500 hr.                  | 500 hr.                  | 500 hr.                  | 500 hr.                  | per GRI-GM10                |
| Carbon Black Content (range)                                      | D 4218 (3)        | 2.0-3.0%                | 2.0-3.0%                | 2.0-3.0%                 | 2.0-3.0%                 | 2.0-3.0%                 | 2.0-3.0%                 | 2.0-3.0%                 | 20,000 lb                   |
| Carbon Black Dispersion   | D 5596            | note (4)                | note (4)                | note (4)                 | note (4)                 | note (4)                 | note (4)                 | note (4)                 | 45,000 lb                   |
| Oxidative Induction Time (OIT) (min. ave.) (5)                    |                   |                         |                         |                          |                          |                          |                          |                          | 200,000 lb                  |
| (a) Standard OIT  | D 3895            | 100 min.                | 100 min.                | 100 min.                 | 100 min.                 | 100 min.                 | 100 min.                 | 100 min.                 |                             |
| — or —  |                   |                         |                         |                          |                          |                          |                          |                          |                             |
| (b) High Pressure OIT   | D 5885            | 400 min.                | 400 min.                | 400 min.                 | 400 min.                 | 400 min.                 | 400 min.                 | 400 min.                 |                             |
| Oven Aging at 85°C (5), (6)                                       | D 5721            |                         |                         |                          |                          |                          |                          |                          |                             |
| (a) Standard OIT (min. ave.) - % retained after 90 days           | D 3895            | 55%                     | 55%                     | 55%                      | 55%                      | 55%                      | 55%                      | 55%                      | per each formulation        |
| — or —  |                   |                         |                         |                          |                          |                          |                          |                          |                             |
| (b) High Pressure OIT (min. ave.) - % retained after 90 days      | D 5885            | 80%                     | 80%                     | 80%                      | 80%                      | 80%                      | 80%                      | 80%                      |                             |
| UV Resistance (7)   | D 7238            |                         |                         |                          |                          |                          |                          |                          |                             |
| (a) Standard OIT (min. ave.)                                      | D 3895            | N.R. (8)                | N.R. (8)                | N.R. (8)                 | N.R. (8)                 | N.R. (8)                 | N.R. (8)                 | N.R. (8)                 | per each formulation        |
| — or —  |                   |                         |                         |                          |                          |                          |                          |                          |                             |
| (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9) | D 5885            | 50%                     | 50%                     | 50%                      | 50%                      | 50%                      | 50%                      | 50%                      |                             |

- (1) 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 1.3 inches  
 Break elongation is calculated using a gage length of 2.0 in.
- (2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer’s mean value via MQC testing.
- (3) 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.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:  
 9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) 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.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

**Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth**

| Properties   | Test Method                    | Test Value                        |                                   |                                   |                                   |                                   |                                   |                                   | Testing Frequency (minimum) |
|--|--------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------|
|  |                                | 0.75 mm                           | 1.00 mm                           | 1.25 mm                           | 1.50 mm                           | 2.00 mm                           | 2.50 mm                           | 3.00 mm                           |                             |
| Thickness - mils (min. ave.)<br>• lowest individual of 10 values   | D5199                          | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | nom. (mil)<br>-10%                | per roll                    |
| Formulated Density (min.)  | D 1505/D 792                   | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 90,000 kg                   |
| Tensile Properties (1) (min. ave.)<br>• yield strength<br>• break strength<br>• yield elongation<br>• break elongation   | D 6693<br>Type IV              | 11 kN/m<br>20 kN/m<br>12%<br>700% | 15 kN/m<br>27 kN/m<br>12%<br>700% | 18 kN/m<br>33 kN/m<br>12%<br>700% | 22 kN/m<br>40 kN/m<br>12%<br>700% | 29 kN/m<br>53 kN/m<br>12%<br>700% | 37 kN/m<br>67 kN/m<br>12%<br>700% | 44 kN/m<br>80 kN/m<br>12%<br>700% | 9,000 kg                    |
| Tear Resistance (min. ave.)  | D 1004                         | 93 N                              | 125 N                             | 156 N                             | 187 N                             | 249 N                             | 311 N                             | 374 N                             | 20,000 kg                   |
| Puncture Resistance (min. ave.)  | D 4833                         | 240 N                             | 320 N                             | 400 N                             | 480 N                             | 640 N                             | 800 N                             | 960 N                             | 20,000 kg                   |
| Stress Crack Resistance (2)  | D 5397<br>(App.)               | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | per GRI GM-10               |
| Carbon Black Content - %   | D 4218 (3)                     | 2.0-3.0%                          | 2.0-3.0%                          | 2.0-3.0%                          | 2.0-3.0%                          | 2.0-3.0%                          | 2.0-3.0%                          | 2.0-3.0%                          | 9,000 kg                    |
| Carbon Black Dispersion  | D 5596                         | note (4)                          | note (4)                          | note (4)                          | note (4)                          | note (4)                          | note (4)                          | note (4)                          | 20,000 kg                   |
| Oxidative Induction Time (OIT) (min. ave.) (5)<br>(a) Standard OIT<br>— or —<br>(b) High Pressure OIT  | D 3895<br><br>D 5885           | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 100 min.<br><br>400 min.          | 90,000 kg                   |
| Oven Aging at 85°C (5), (6)<br>(a) Standard OIT (min. ave.) - % retained after 90 days<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 90 days | D 5721<br>D 3895<br><br>D 5885 | 55%<br><br>80%                    | 55%<br><br>80%                    | 55%<br><br>80%                    | 55%<br><br>80%                    | 55%<br><br>80%                    | 55%<br><br>80%                    | 55%<br><br>80%                    | per each formulation        |
| UV Resistance (7)<br>(a) Standard OIT (min. ave.)<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)                                 | D 7238<br>D 3895<br><br>D 5885 | N. R. (8)<br><br>50%              | N.R. (8)<br><br>50%               | N.R. (8)<br><br>50%               | N.R. (8)<br><br>50%               | N.R. (8)<br><br>50%               | N.R. (8)<br><br>50%               | N.R. (8)<br><br>50%               | per each formulation        |

- (1) 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
- (2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer’s mean value via MQC testing.
- (3) 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.
- (4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:  
9 in Categories 1 or 2 and 1 in Category 3
- (5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (8) 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.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.



**Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured**

| Properties   | Test Method                | Test Value                            |                                       |  |  |   |   |   | Testing Frequency (minimum)    |
|--|----------------------------|---------------------------------------|---------------------------------------|--|--|---|---|---|--------------------------------|
|  |                            | 30 mils                               | 40 mils                               | 50 mils                                | 60 mils                                | 80 mils                                 | 100 mils                                | 120 mils                                |                                |
| Thickness mils (min. ave.)<br>• lowest individual for 8 out of 10 values<br>• lowest individual for any of the 10 values   | D 5994                     | nom. (-5%)<br>-10%<br>-15%            | nom. (-5%)<br>-10%<br>-15%            | nom. (-5%)<br>-10%<br>-15%             | nom. (-5%)<br>-10%<br>-15%             | nom. (-5%)<br>-10%<br>-15%              | nom. (-5%)<br>-10%<br>-15%              | nom. (-5%)<br>-10%<br>-15%              | per roll                       |
| Asperity Height mils (min. ave.)   | D 7466                     | 16 mil                                | 16 mil                                | 16 mil                                 | 16 mil                                 | 16 mil                                  | 16 mil                                  | 16 mil                                  | every 2 <sup>nd</sup> roll (1) |
| Formulated Density (min. ave.)   | D 1505/D 792               | 0.940 g/cc                            | 0.940 g/cc                            | 0.940 g/cc                             | 0.940 g/cc                             | 0.940 g/cc                              | 0.940 g/cc                              | 0.940 g/cc                              | 200,000 lb                     |
| Tensile Properties (min. ave.) (2)<br>• yield strength<br>• break strength<br>• yield elongation<br>• break elongation   | D 6693<br>Type IV          | 63 lb/in.<br>45 lb/in.<br>12%<br>100% | 84 lb/in.<br>60 lb/in.<br>12%<br>100% | 105 lb/in.<br>75 lb/in.<br>12%<br>100% | 126 lb/in.<br>90 lb/in.<br>12%<br>100% | 168 lb/in.<br>120 lb/in.<br>12%<br>100% | 210 lb/in.<br>150 lb/in.<br>12%<br>100% | 252 lb/in.<br>180 lb/in.<br>12%<br>100% | 20,000 lb                      |
| Tear Resistance (min. ave.)  | D 1004                     | 21 lb                                 | 28 lb                                 | 35 lb                                  | 42 lb                                  | 56 lb                                   | 70 lb                                   | 84 lb                                   | 45,000 lb                      |
| Puncture Resistance (min. ave.)  | D 4833                     | 45 lb                                 | 60 lb                                 | 75 lb                                  | 90 lb                                  | 120 lb                                  | 150 lb                                  | 180 lb                                  | 45,000 lb                      |
| Stress Crack Resistance (3)  | D 5397<br>(App.)           | 500 hr.                               | 500 hr.                               | 500 hr.                                | 500 hr.                                | 500 hr.                                 | 500 hr.                                 | 500 hr.                                 | per GRI GM10                   |
| Carbon Black Content (range)   | D 4218 (4)                 | 2.0-3.0 %                             | 2.0-3.0 %                             | 2.0-3.0 %                              | 2.0-3.0 %                              | 2.0-3.0 %                               | 2.0-3.0 %                               | 2.0-3.0 %                               | 20,000 lb                      |
| Carbon Black Dispersion  | D 5596                     | note (5)                              | note (5)                              | note (5)                               | note (5)                               | note (5)                                | note (5)                                | note (5)                                | 45,000 lb                      |
| Oxidative Induction Time (OIT) (min. ave.) (6)<br>(a) Standard OIT<br>— or —<br>(b) High Pressure OIT  | D 3895<br>D 5885           | 100 min.<br>400 min.                  | 100 min.<br>400 min.                  | 100 min.<br>400 min.                   | 100 min.<br>400 min.                   | 100 min.<br>400 min.                    | 100 min.<br>400 min.                    | 100 min.<br>400 min.                    | 200,000 lb                     |
| Oven Aging at 85°C (6), (7)<br>(a) Standard OIT (min. ave.) - % retained after 90 days<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 90 days | D 5721<br>D 3895<br>D 5885 | 55%<br>80%                            | 55%<br>80%                            | 55%<br>80%                             | 55%<br>80%                             | 55%<br>80%                              | 55%<br>80%                              | 55%<br>80%                              | per each formulation           |
| UV Resistance (8)<br>(a) Standard OIT (min. ave.)<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (10)                                | D 7238<br>D 3895<br>D 5885 | N.R. (9)<br>50%                       | N.R. (9)<br>50%                       | N.R. (9)<br>50%                        | N.R. (9)<br>50%                        | N.R. (9)<br>50%                         | N.R. (9)<br>50%                         | N.R. (9)<br>50%                         | per each formulation           |

- (1) Alternate the measurement side for double sided textured sheet
- (2) 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 1.3 inches  
Break elongation is calculated using a gage length of 2.0 inches
- (3) P-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.
- (4) 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.
- (5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:  
9 in Categories 1 or 2 and 1 in Category 3
- (6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
- (7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (9) 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.
- (10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

| Properties   | Test Method                | Test Value                       |                                   |                                   |                                   |                                   |                                   |                                   | Testing Frequency (minimum) |                                |
|--|----------------------------|----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------|--------------------------------|
|  |                            | 0.75 mm                          | 1.00 mm                           | 1.25 mm                           | 1.50 mm                           | 2.00 mm                           | 2.50 mm                           | 3.00 mm                           |                             |                                |
| Thickness mils (min. ave.)<br>• lowest individual for 8 out of 10 values<br>• lowest individual for any of the 10 values   | D 5994                     | nom. (-5%)<br>-10%<br>-15%       | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%        | nom. (-5%)<br>-10%<br>-15%  | per roll                       |
| Asperity Height mils (min. ave.)   | D 7466                     | 0.40 mm                          | 0.40 mm                           | 0.40 mm                           | 0.40 mm                           | 0.40 mm                           | 0.40 mm                           | 0.40 mm                           | 0.40 mm                     | every 2 <sup>nd</sup> roll (1) |
| Formulated Density (min. ave.)   | D 1505/D 792               | 0.940 g/cc                       | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                        | 0.940 g/cc                  | 90,000 kg                      |
| Tensile Properties (min. ave.) (2)<br>• yield strength<br>• break strength<br>• yield elongation<br>• break elongation   | D 6693<br>Type IV          | 11 kN/m<br>8 kN/m<br>12%<br>100% | 15 kN/m<br>10 kN/m<br>12%<br>100% | 18 kN/m<br>13 kN/m<br>12%<br>100% | 22 kN/m<br>16 kN/m<br>12%<br>100% | 29 kN/m<br>21 kN/m<br>12%<br>100% | 37 kN/m<br>26 kN/m<br>12%<br>100% | 44 kN/m<br>32 kN/m<br>12%<br>100% | 9,000 kg                    |                                |
| Tear Resistance (min. ave.)  | D 1004                     | 93 N                             | 125 N                             | 156 N                             | 187 N                             | 249 N                             | 311 N                             | 374 N                             | 20,000 kg                   |                                |
| Puncture Resistance (min. ave.)  | D 4833                     | 200N                             | 267 N                             | 333 N                             | 400 N                             | 534 N                             | 667 N                             | 800 N                             | 20,000 kg                   |                                |
| Stress Crack Resistance (3)  | D 5397<br>(App.)           | 500 hr.                          | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                           | 500 hr.                     | per GRI GM10                   |
| Carbon Black Content (range)   | D 4218 (4)                 | 2.0-3.0 %                        | 2.0-3.0 %                         | 2.0-3.0 %                         | 2.0-3.0 %                         | 2.0-3.0 %                         | 2.0-3.0 %                         | 2.0-3.0 %                         | 2.0-3.0 %                   | 9,000 kg                       |
| Carbon Black Dispersion  | D 5596                     | note (5)                         | note (5)                          | note (5)                          | note (5)                          | note (5)                          | note (5)                          | note (5)                          | note (5)                    | 20,000 kg                      |
| Oxidative Induction Time (OIT) (min. ave.) (6)<br>(a) Standard OIT<br>— or —<br>(b) High Pressure OIT  | D 3895<br>D 5885           | 100 min.<br>400 min.             | 100 min.<br>400 min.              | 100 min.<br>400 min.              | 100 min.<br>400 min.              | 100 min.<br>400 min.              | 100 min.<br>400 min.              | 100 min.<br>400 min.              | 100 min.<br>400 min.        | 90,000 kg                      |
| Oven Aging at 85°C (6), (7)<br>(a) Standard OIT (min. ave.) - % retained after 90 days<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 90 days | D 5721<br>D 3895<br>D 5885 | 55%<br>80%                       | 55%<br>80%                        | 55%<br>80%                        | 55%<br>80%                        | 55%<br>80%                        | 55%<br>80%                        | 55%<br>80%                        | 55%<br>80%                  | per each formulation           |
| UV Resistance (8)<br>(a) Standard OIT (min. ave.)<br>— or —<br>(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (10)                                | D 7238<br>D 3895<br>D 5885 | N.R. (9)<br>50%                  | N.R. (9)<br>50%                   | N.R. (9)<br>50%                   | N.R. (9)<br>50%                   | N.R. (9)<br>50%                   | N.R. (9)<br>50%                   | N.R. (9)<br>50%                   | N.R. (9)<br>50%             | per each formulation           |

(1) Alternate the measurement side for double sided textured sheet

(2) 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

(3) 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.

(4) 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.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) 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.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

**Adoption and Revision Schedule  
for  
HDPE Specification per GRI-GM13**

“Test Methods, Test Properties, Testing Frequency for  
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

- Adopted: June 17, 1997
- Revision 1: November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
- Revision 2: April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: “(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)” and to Note (4) in the property tables.
- Revision 3: June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
- Revision 4: December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to “strength” and “elongation”.
- Revision 5: May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
- Revision 6: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
- Revision 7: February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
- Revision 8: Removed recommended warranty from specification.
- Revision 9: June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
- Revision 10: April 11, 2011: Added alternative carbon black content test methods
- Revision 11: December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
- Revision 12: November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
- Revision 13: November 4, 2015: Removed Footnote (1) on asperity height from tables.
- Revision 14: January 6, 2016: Removed Trouser Tear from Note 5.