

# Geosynthetic Research Institute

475 Kedron Avenue Folsom, PA 19033-1208 USA TEL (610) 522-8440 FAX (610) 522-8441



Rev. 5: May 15, 2003 Revision schedule on pg. 13

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

Standard Specification for

"Test Properties, Testing Frequency and Recommended Warranty 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 It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part.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

<sup>\*</sup>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.

- 1.5 This specification also presents a recommended warrant which is focused on the geomembrane material itself.
- 1.6 The recommended warrant attached to this specification does not cover installation considerations which is independent of the manufacturing of the geomembrane.
  - 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 638 Test Method for Tensile Properties of Plastics
  - 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
- 2.2 GRI Standards
  - GM10 Specification for the Stress Crack Resistance of Geomembrane Shet

- GM 11 Accelerated Weathering of Geomembranes using a Fluorescent UVA-Condensation Exposure Device
- GM 12 Measurement of the Asperity Height of Textured Geomembranes Using a Depth Gage
- 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: 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 4: 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
- Note 5: 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).
- Note 6: There are several GRI tests currently included in this standard. Since these topics are not covered in ASTM standards, this is necessary. They are the following:
  - UV Fluorescent Light Exposure
  - Asperity Height Measurement
- 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 7: 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.
- 11. Warranty
  - 11.1 Upon request of the purchaser in the contract or order, a manufacturer's warrant of the quality of the material shall be furnished at the completion of the terms of the contract.
  - 11.2 A recommended warranty for smooth and textured HDPE geomembranes manufactured and tested in accordance with this specification is given in Appendix A.
  - 11.3 The warranty in Appendix A is for the geomembrane itself. It does not cover subgrade preparation, installation, seaming, or backfilling. These are separate operations that are often beyond the control, or sphere of influence, of the geomembrane manufacturer.
    - Note 8: If a warrant is required for installation, it is to be developed between the installation contractor and the party requesting such a document.

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

Properties	Test	Test Value T					Testing Frequency		
	Method	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	(minimum)
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%	
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	200,00 lb
Tensile Properties (1) (min. ave.)	D 638 Type IV								20,000 lb
• yield strength		63 lb/in.	84 lb/in.	105 lb/in.	126 lb/in.	168 lb/in.	210 lb/in.	252 lb/in.	
break strength		114 lb/in.	152 lb/in.	190 lb/in.	228 lb/in.	304 lb/in.	380 lb/in.	456 lb/in.	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
break elongation		700%	700%	700%	700%	700%	700%	700%	
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	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	per GRI-GM10
	(App.)								-
Carbon Black Content (range)	D 1603 (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
— or —									formulation
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance (7)	GM 11								
(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
— or —									formulation
(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 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube 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	Test Value				Testing Frequency			
	Method	0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	(minimum)
Thickness - mils (min. ave.)	D5199	nom. (mil)	nom. (mil)	nom. (mil)	per roll				
<ul> <li>lowest individual of 10 values</li> </ul>		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg				
Tensile Properties (1) (min. ave.)	D 638 Type IV								9,000 kg
• yield strength		11 kN/m	15 kN/m	18 kN/m	22 kN/m	29 kN/m	37 kN/m	44 kN/m	
• break strength		20kN/m	27 kN/m	33 kN/m	40 kN/m	53 kN/m	67 kN/m	80 kN/m	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
break elongation		700%	700%	700%	700%	700%	700%	700%	
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	300 hr.	300 hr.	300 hr.	per GRI GM-10				
	(App.)								
Carbon Black Content - %	D 1603 (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)	20,000 kg				
Oxidative Induction Time (OIT) (min. ave.) (5)									90,000 kg
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.					
— or —									
(b) High Pressure OIT	D 5885	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
— or —									formulation
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance (7)									
(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
— or —									formulation
(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 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 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube 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  $75^{\circ}$ C followed by 4 hr. condensation at  $60^{\circ}$ 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		
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	(minimum)
Thickness mils (min. ave.)	D 5994	nom. (-5%)	nom. (-5%)	per roll					
<ul> <li>lowest individual for 8 out of 10 values</li> </ul>		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-
<ul> <li>lowest individual for any of the 10 values</li> </ul>		-15%	-15%	-15%	-15%	-15%	-15%	-15%	
Asperity Height mils (min. ave.) (1)	GM 12	10 mil	10 mil	every $2^{nd}$ roll (2)					
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	200,000 lb					
Tensile Properties (min. ave.) (3)	D 638								20,000 lb
• yield strength	Type IV	63 lb/in.	84 lb/in.	105 lb/in.	126 lb/in.	168 lb/in.	210 lb/in.	252 lb/in.	
<ul> <li>break strength</li> </ul>		45 lb/in.	60 lb/in.	75 lb/in.	90 lb/in.	120 lb/in.	150 lb/in.	180 lb/in.	
<ul> <li>yield elongation</li> </ul>		12%	12%	12%	12%	12%	12%	12%	
<ul> <li>break elongation</li> </ul>		100%	100%	100%	100%	100%	100%	100%	
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 (4)	D 5397	300 hr.	300 hr.	per GRI GM10					
	(App.)								-
Carbon Black Content (range)	D 1603 (5)	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 (6)	note (6)	45,000 lb					
Oxidative Induction Time (OIT) (min. ave.) (7)									200,000 lb
(a) Standard OIT	D 3895	100 min.	100 min.						
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.						
Oven Aging at $85^{\circ}C(7)$ , (8)	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each
	D 5005	0004	0004	0004	0004	0.004	0.004	0004	formulation
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance (9)	GM11							N.D. (10)	
(a) Standard OIT (min. ave.)	D 3895	N.R. (10)	N.K. (10)	N.K. (10)	per each				
(b) High Pressure OIT (min_ave.) - % retained after 1600 hrs (11)	D 5885	50%	50%	50%	50%	50%	50%	50%	iormutation
	2 2000	2070	2070	2070	2070	2070	2070	2070	

(1) Of 10 readings; 8 out of 10 must be  $\geq$  7 mils, and lowest individual reading must be  $\geq$  5 mils

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

(3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gage length of 1.3 inches

Break elongation is calculated using a gage length of 2.0 inches

(4) 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.

(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

- (6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
   9 in Categories 1 or 2 and 1 in Category 3
- (7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

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

(9) The condition of the test should be 20 hr. UV cycle at  $75^{\circ}$ C followed by 4 hr. condensation at  $60^{\circ}$ C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

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

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

0.75 mm         1.00 mm         1.25 mm         1.50 mm         2.00 mm         3.00 mm         (minur           Thickness mils (min. ave.)         D 5994         nom. (-5%)         nom. (-5%) <t< th=""><th>ls (min. ave.) west individual for 8 out of 10 values west individual for any of the 10 values west mile (min. ava) <math>(1)</math></th></t<>	ls (min. ave.) west individual for 8 out of 10 values west individual for any of the 10 values west mile (min. ava) $(1)$
Thickness mils (min. ave.)         D 5994         nom. (-5%)	ls (min. ave.) west individual for 8 out of 10 values west individual for any of the 10 values
• lowest individual for 8 out of 10 values	west individual for 8 out of 10 values west individual for any of the 10 values
	west individual for any of the 10 values
• lowest individual for any of the 10 values -15% -15% -15% -15% -15% -15% -15%	the mile $(\min_{i=1}^{n} ovo_{i})(1)$
Asperity Height mils (min. ave.) (1)         GM 12         0.25 mm	gin mins (min. ave.) (1)
Density (min. ave.) D 1505/D 792 0.940 g/cc 90,000 k	. ave.)
Tensile Properties (min. ave.) (3)         D 638         9,000 kg	erties (min. ave.) (3)
• yield strength Type IV 11 kN/m 15 kN/m 18 kN/m 22 kN/m 29 kN/m 37 kN/m 44 kN/m	d strength
break strength	ak strength
• yield elongation 12% 12% 12% 12% 12% 12% 12%	d elongation
• break elongation 100% 100% 100% 100% 100% 100% 100% 100	ak elongation
Tear Resistance (min. ave.)         D 1004         93 N         125 N         156 N         187 N         249 N         311 N         374 N         20,000 k	ce (min. ave.)
Puncture Resistance (min. ave.)         D 4833         200N         267 N         333 N         400 N         534 N         667 N         800 N         20,000 k	istance (min. ave.)
Stress Crack Resistance (4)         D 5397         300 hr.         900	Resistance (4)
(App.)	
Carbon Black Content (range)         D 1603 (5)         2.0-3.0 %         2.0-3	c Content (range)
Carbon Black Dispersion         D 5596         note (6)	Dispersion
Oxidative Induction Time (OIT) (min. ave.) (7) 90,000 k	luction Time (OIT) (min. ave.) (7)
(a) Standard OIT D 3895 100 min.	TIC
or	- or —
(b) High Pressure OIT         D 5885         400 min.         400 min.         400 min.         400 min.         400 min.         400 min.	sure OIT
Oven Aging at 85°C (7), (8)         D 5721	at 85°C (7), (8)
(a) Standard OIT (min. ave.) - % retained after 90 days D 3895 55% 55% 55% 55% 55% 55% 55% 55% per each	OIT (min. ave.) - % retained after 90 days
formulation formulation and the second	- or —
(b) High Pressure OIT (min. ave.) - % retained after 90 days D 5885 80% 80% 80% 80% 80% 80% 80% 80%	sure Off (min. ave.) - % retained after 90 days
UV Resistance (9) GM11 GM11 ND (10) ND (10) ND (10) ND (10) ND (10)	ce (9)
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	OII (min. ave.)
- or $-$ or $-$ If the pressure of $T$ (min ave) $+$ ratained after 1600 brs (11) D 5885 50% 50% 50% 50% 50% 50% 50% 50% 50% 50	- OF — (min ave.) % retained after 1600 brs (11)
100 $1100$ $1$	sure of $(\min ave.) - \pi$ retained after 1000 $\lim (11)$

(1) Of 10 readings; 8 out of 10 must be  $\ge 0.18$  mm, and lowest individual reading must be  $\ge 0.13$  mm

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

- (3) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gage length of 33 mm Break elongation is calculated using a gage length of 50 mm
- (4) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.

The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(5) Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.

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

9 in Categories 1 or 2 and 1 in Category 3

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

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

(9) The condition of the test should be 20 hr. UV cycle at  $75^{\circ}$ C followed by 4 hr. condensation at  $60^{\circ}$ C.

(10) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

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

Appendix "A"

Typical HDPE Geomembrane Warranty

Reviewed by: Donald J. Weiss, Esq. General Council for GSI

#### ABC GEOMEMBRANE COMPANY LIMITED WARRANTY

		Warmonty No.	
		Project No:	
		Effective Date:	
PURCHASER NAME:		PROJECT NAME:	
ADDRESS:		ADDRESS/LOCATION:	
CITY, STATE, ZIP, COUNTRY		CITY, STATE, ZIP, COUN	ſRY
		GEOMEMBRANE TYPE/D	ESCRIPTION
ABC Geomembrane Company wa to be able to withstand normal we	arrants each ABC geomembrane to be free athering for a period of 5 years from the at	e from manufacturing defects ( pove effective date for normal	as defined by the contract's material specifications) and use in approved applications.
This Limited Warranty does not ince earthquakes, floods, piercing hail, geomembranes to harmful chemic pressures or stresses from any sou for the consumer as defined in the commercial or industrial use only.	clude damages or defects in the ABC geom tornadoes or force majeure. The term "m als, abuse of ABC geomembranes by mac rce or improper application or installation. Al Magnuson Moss Warranty or any similar fe	embrane resulting from acts of ormal use" as used herein doe hinery, equipment or people; ir BC geomembrane material warra ederal, state, or local statues.	God, casualty or catastrophe including but not limited to: as not include, among other things the exposure of ABC nproper site preparation or covering materials, excessive anty is intended for commercial use only and is not in effect The parties expressly agree that the sale hereunder is for
Should defects or premature loss o geomembrane on a pro-rata basis since purchase of the material. AB to take appropriate steps to repair of geomembrane, and does not extend	f use within the scope of the above Limited N at the then current price in such manner as C Geomembrane Company will have the righ or replace the ABC geomembrane if a defect d to the installation service of ABC Geomemb	Warranty occur, ABC Geomemb to charge the Purchaser/User c nt to inspect and determine the exists which is covered under t prane Company or third parties.	rane Company will, at its option, repair or replace the ABC inly for that portion of the warranted life which has elapsed cause of any alleged defect in the ABC geomembrane and his warranty. This Limited Warranty extends only to ABC's
Any claim for any alleged breach of of the alleged defect. Should the r this warranty. ABC Geomembrane replaced is clean, dry, and unencur all water, dirt, sludge, residuals and ABC Geomembrane Company for it	this warranty must be made in writing, by ce equired notice not be given, the defect and a company shall not be obligated to perform nbered. This includes, but is not limited to, th d liquids of any kind. If after inspection it is is costs associated with the site inspection.	rtified mail, to the President of A all warranties are waived by the n repairs or replacements unde he area made available for repai determined that there is no clai	BC Geomembrane within ten (10) days of becoming aware Purchaser, and Purchaser shall not have any rights under r this warranty unless and until the area to be repaired or r and/or replacement of ABC geomembrane to be free from im under this Limited Warranty, Purchaser shall reimburse
In the event the exclusive remedy p so much of the material as ABC Ge direct, indirect, special, consequen profits, personal injury or property alterations made by Purchaser unlet them having been made. ABC Geo for the particular installation in which	provided herein fails in its essential purpose, comembrane Company determines to have v tial or incidental damages resulting from a damage. ABC Geomembrane Company sha ss ABC Geomembrane Company specifically omembrane Company's liability under this wa h it failed.	and in that event only, the Purc iolated the warranty provided he breach of this warranty includin all not be obligated to reimburs y authorized, in writing, said repa urranty shall in no event exceed	chaser shall be entitled to a return of the purchase price for erein. ABC Geomembrane Company shall not be liable for ig, but not limited to, damages for loss of production, lost e Purchaser for any repairs, replacement, modifications or airs, replacements, modifications or alteration in advance of the replacement cost of the material sold to the Purchaser
ABC Geomembrane Company neit additional liability in connection with in lieu of all other possible materia except those specifically given.	ther assumes nor authorizes any person oth the ABC geomembrane made on the basis al warranties, either expressed or implied, a	her than the undersigned of AB of the Limited Warranty. The L nd by accepting delivery of the	C Geomembrane Company to assume for it any other or imited Warranty on the ABC geomembrane herein is given material, Purchaser waives all other possible warranties,
Limited Warranty is extended to the	purchaser/owner and is non-transferable and	d non-assignable; i.e., there are	no third-party beneficiaries to this warranty.
Purchaser acknowledges by accept	ance that the Limited Warranty given herein	s accepted in preference to any	and other possible materials warranties.
ABC GEOMEMBRANE COMPA WARRANTIES, BOTH EXPRES WARRANTY THAT APPLIES TO OTHER PERSON OR ENTITY, E	NY MAKES NO WARRANTY OF AN SED OR IMPLIED, OF MERCHANTAE THE MATERIALS REFERRED TO HERE ITHER WRITTEN OR ORAL.	Y KIND OTHER THAN THA BILITY AND FITNESS FOR IN AND ABC DISCLAIMS AN	AT GIVEN ABOVE AND HEREBY DISCLAIMS ALL A PARTICULAR PURPOSE. THIS IS THE ONLY Y LIABILITY FOR ANY WARRANTIES GIVEN BY ANY
ABC GEOMEN	MBRANE COMPANY'S WARRANTY BEC TO PERFORM UNDER THE WAR	COMES AN OBLIGATION OF RRANTY ONLY UPON RECEI	ABC GEOMEMBRANE COMPANY PT OF FINAL
I hereby state that I have read and Limited Warranty and agree to su	d understand the above and foregoing ch by signing hereunder.	DATE:	
PURCHASER NAME:		ABC GEOMEMBRANE CO	MPANY:
			(President or Authorized Representative)
SIGNATURE:	DAIE	SIGNATURE:	DATE

## **Adoption and Revision Schedule**

for

## HDPE Specification per GRI-GM13

"Test Properties, Testing Frequency and Recommended Warrant 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:	Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.