

## GRI-GM13 Specification High Density Polyethylene Geomembranes

- spec covers smooth and textured HDPE
- thicknesses 0.75-3.00 mm (30-120 mils)
- formulated density  $\geq 0.940$  g/cc
- silent on flat die or blown film
- lists properties, test methods, test values and test frequencies
- covers eleven (11) properties

## Preliminary Comments

- definition of “formulation”  
The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE geomembranes a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.
- regarding quantities referred to in spec  
90,000 kg = 200,000 lb  $\simeq$  1 railcar  
20,000 kg = 45,000 lb  $\simeq$  25 rolls of 1.5 mm (60 mil)  
9,000 kg = 20,000 lb  $\simeq$  10 rolls of 1.5 mm(60 mil)

### Physical Properties

1. thickness
2. density

### Mechanical Properties

3. tensile
4. tear
5. puncture
6. stress crack

### Endurance Properties

7. CB content
8. CB dispersion
9. OIT
10. oven aging
11. UV resistance

## 1. Thickness

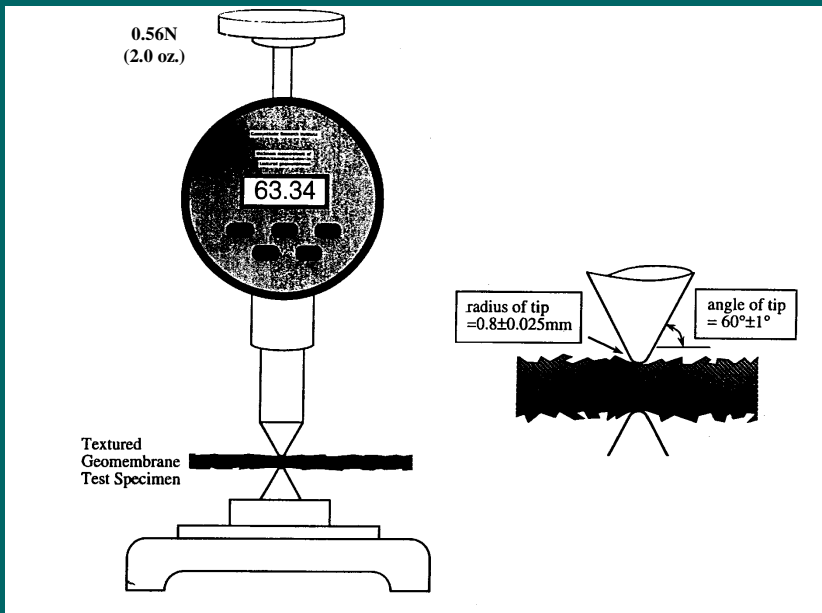
### (a) smooth sheet

- follows ASTM D5199
- dead weight micrometer with flat tip
- 10-specimens across roll width
- required for each roll
- average must equal nominal
- lowest individual is  $-10\%$



## (b) textured sheet – core thickness

- follows ASTM D5994
- dead weight micrometer with tapered tip (screw micrometer)
- 10-specimens across roll width
- required for each roll
- average equal nominal -5%
- lowest individual is -15%



Details of Dead Weight Measurement Device for Textured Geomembrane



## (c) textured sheet – asperity height

- follows GRI GM12
- uses a stylus to measure height
- 10 specimens across roll width
- required every 2<sup>nd</sup> roll
- alternate for double sided sheet
- min. ave.  $\geq 0.25$  mm (10 mil)

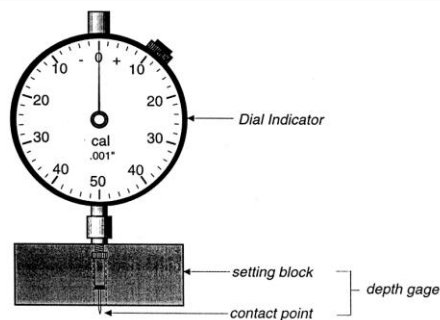


Figure 1 - The configuration of the asperity height test device (Federal Part No. 75P/W40812)

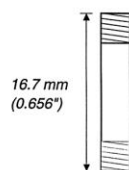


Figure 2 - Indicator Rack Extension (Federal # EZ 108)

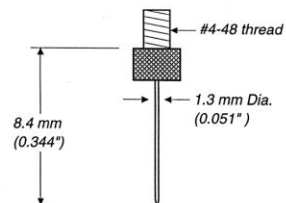
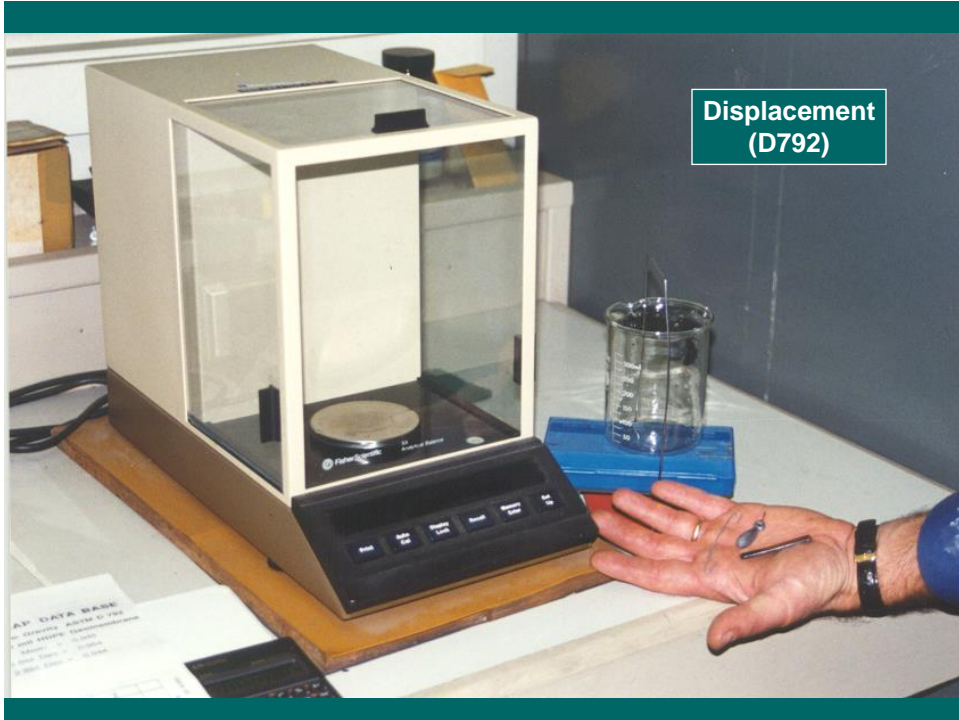


Figure 3 - The dimensions of the contact point (Federal # PT-2265)

## 2. Density

- uses ASTM D1505 (gradient column) or ASTM D792 (displacement)
- min. ave. of 3 tests for D1505
- min. ave. of 2 tests for D792
- D1505 is the more accurate test
- value  $\geq 0.940$  g/cc (resin is lower)
- each railcar: 90,000 kg or 200,000 lb





### 3. Tensile Properties

- uses ASTM D6693 (replaced D638)
- min. ave. of 5 MD and 5 XMD
- lower value applies

Property	Smooth	Textured
yield str.	15 MN/m <sup>2</sup> (2100 lb/in <sup>2</sup> )	15 MN/m <sup>2</sup> (2100 lb/in <sup>2</sup> )
break str.	27 MN/m <sup>2</sup> (3800 lb/in <sup>2</sup> )	10 MN/m <sup>2</sup> (1500 lb/in <sup>2</sup> )
yield elong.	12%	12%
break elong.	700%	100%

- every 9000 kg (20,000 lb)  $\approx$  10 rolls

**ASTM D6693  
Test Specimens**



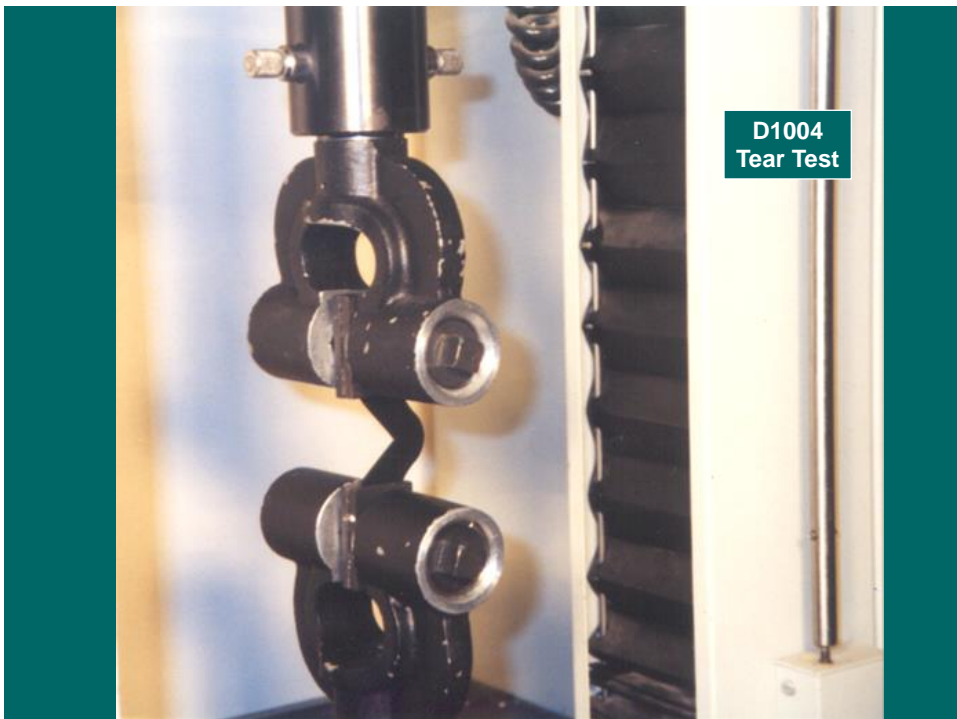
**D6693  
"Dogbone"  
Test in Progress**





## 4. Tear Resistance

- uses ASTM D1004
- called 90 deg. tear test
- min. ave. of 10 MD and 10 XMD
- lesser value  $\geq 125$  N/mm (700 lb/in)
- every 20,000 kg (45,000 lb)  $\simeq$  25 rolls



## 5. Puncture Resistance

- follows ASTM D4833
- called “pin” puncture
- min. ave. of 15-tests  
smooth  $\geq 320$  N/m (1800 lb/in)  
textured  $\geq 267$  N/mm (1500 lb/in)
- every 20,000 kg (40,000 lb)  $\approx$  25 rolls

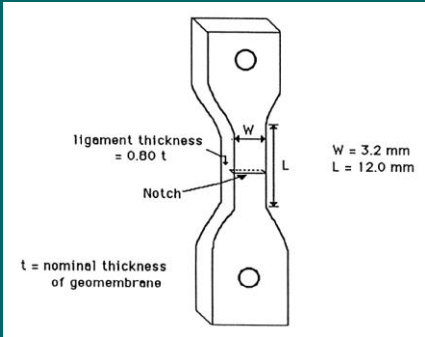


## 6. Stress Crack Resistance

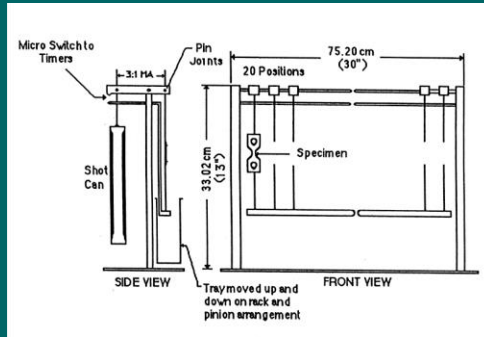
- follows ASTM D5397 App. A
- called SP-NCTL test (Grace's Test)
- dogbone specimen (D-1822) in MD
- 20% notch depth in XMD
- loaded at 30%  $\sigma_y$  (based on mfgs. data)
- 10% Igepal in tap water at 50°C
- each railcar: 90,000 kg (200,000 lb)

## Pass/Fail Criteria

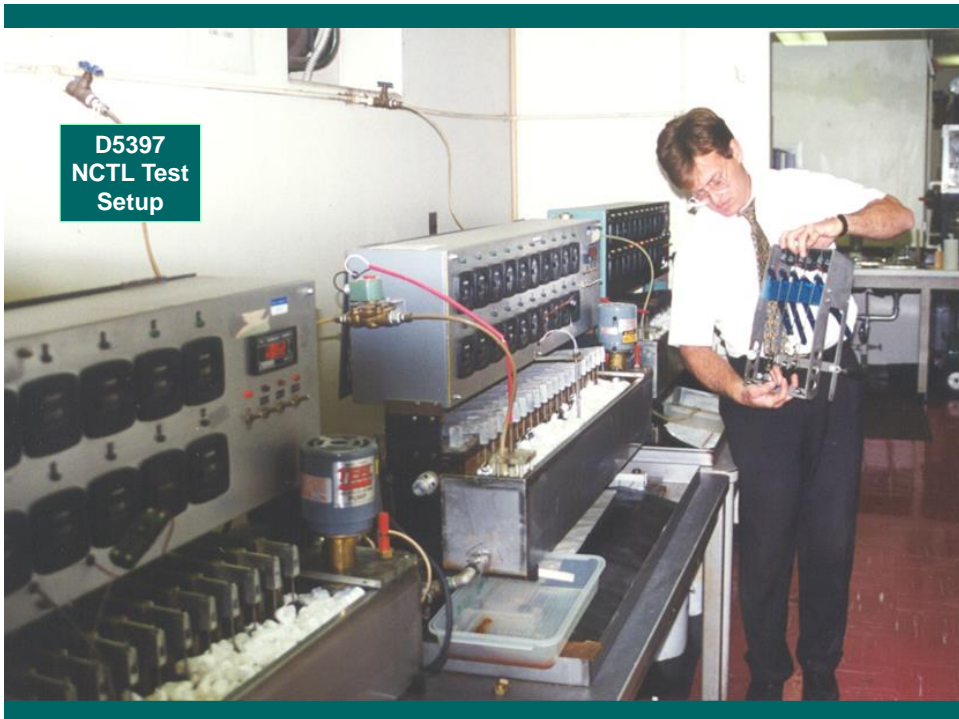
- follows GRI GM10
- 4/5  $\geq$  500 hr; 1/5  $\geq$  200 hr.
- if failure, repeat entire process
- if failure again, do entire curve requiring  $T_t \geq$  100 hr
- if still failure, reject railcar



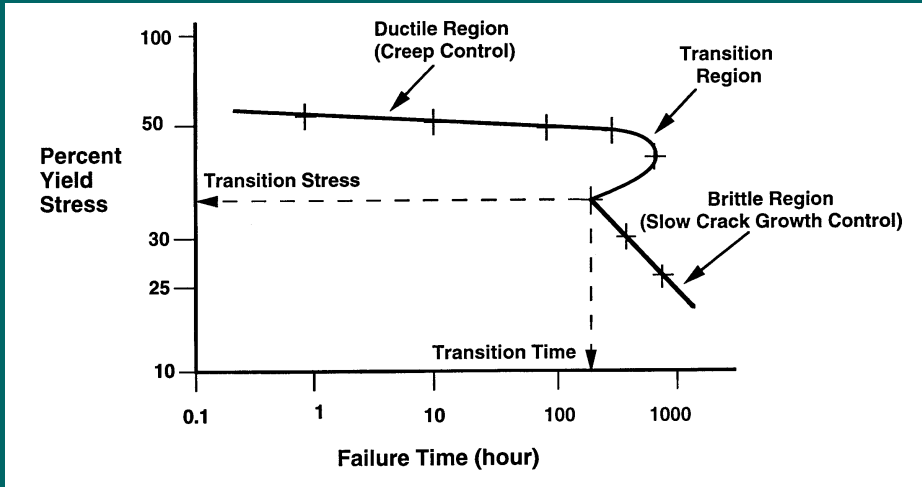
**D1822 Specimen  
With Notch**



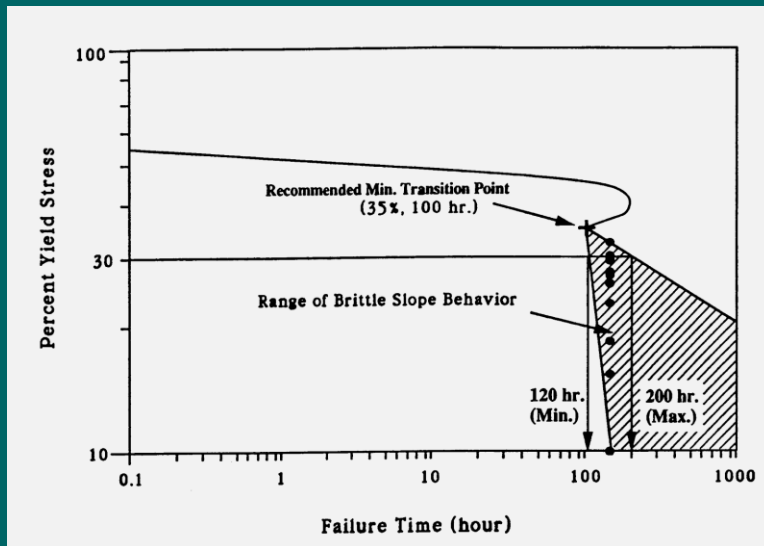
**20 Station  
Test Facility**



## NCTL Test Result - Full Curve

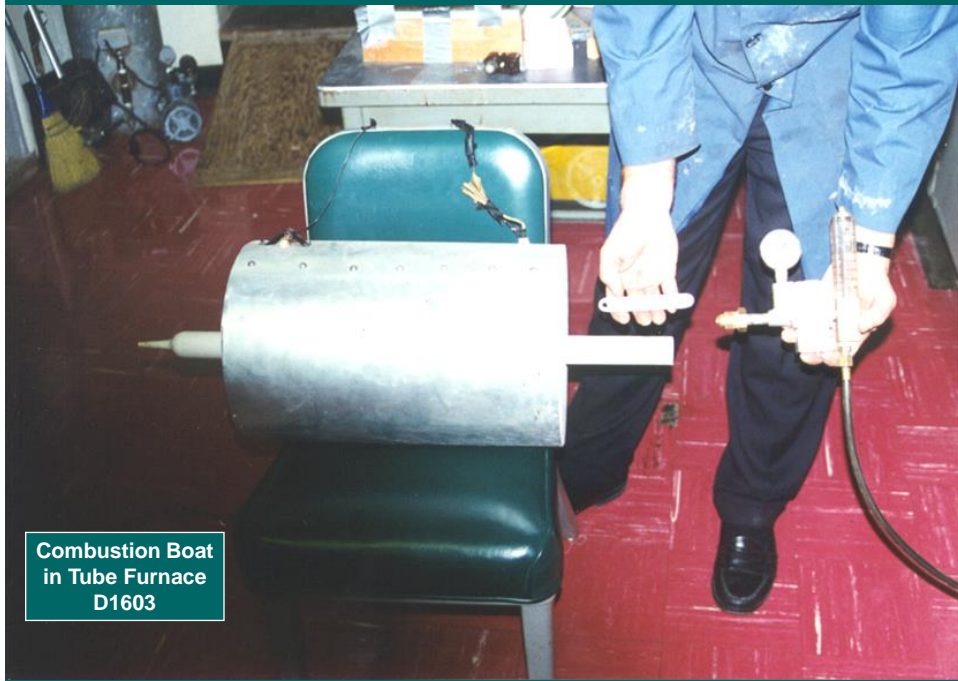


## SP-NCTL Test Result @ 30% $\sigma_y$



## 7. Carbon Black Content

- follows ASTM D1603 (combustion boat placed in tube furnace)
- muffle furnace (D4218) or microwave O.K. if correlation is established
- ave. of two tests in 2.0 to 3.0% range
- every 9000 kg (20,000 lb)  $\approx$  10 rolls



Combustion Boat  
in Tube Furnace  
D1603



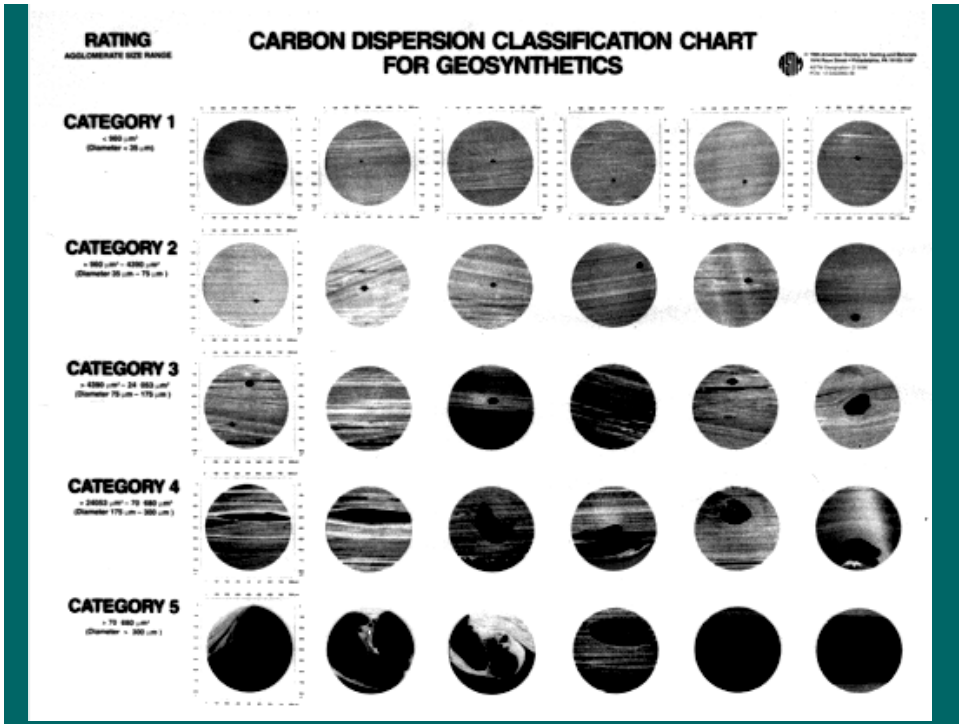
## 8. Carbon Black Dispersion

- follows ASTM D5596
- microtome section (8-15 mm thick)
- view under microscope at 100X
- 10 views are compared to chart
- 9 in Cat. 1 or 2; 1 in Cat. 3
- only considers “near spherical” shapes (this is not CB distribution)
- every 20,000 kg (45,000 lb)  $\approx$  25 rolls





Microtoming Thin Sections per D5596





## Commentary

- “dispersion” is concerned over CB agglomerates, i.e., flocs with no resin
- can lead to low tensile values or even stress crack initiation
- “distribution” is concerned with incomplete mixing
- leads to streaking with different shades of darkness but CB is dispersed
- distribution has not been shown to be a problem...

## 9. Oxidative Induction Time

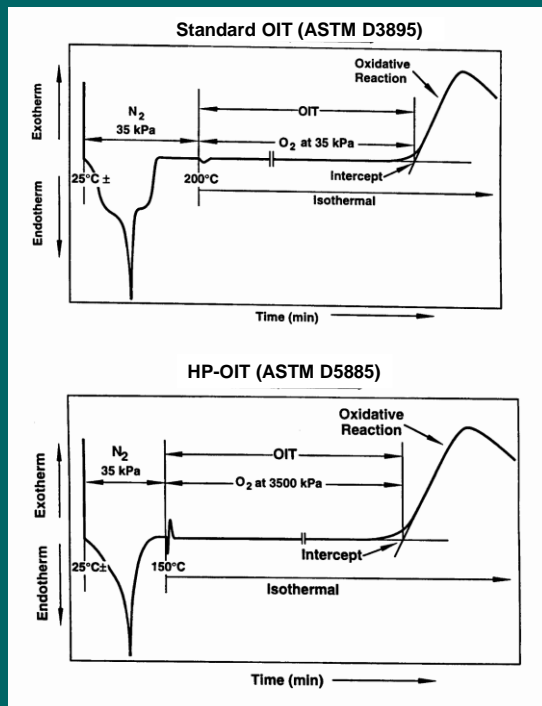
- OIT is an indirect measurement of the amount of antioxidants

Item	Standard	High Pressure
ASTM	D3985	D5885
Specimen	≈ 2 mg	≈ 2 mg
Pressure	35 kPa (5 lb/in <sup>2</sup> )	3500 kPa (500 lb/in <sup>2</sup> )
Temperature	200°C in N <sub>2</sub> ; 1 min. dwell; switch to O <sub>2</sub>	150°C to N <sub>2</sub> ; 1 min. dwell; switch to O <sub>2</sub>
Spec Value	≥ 100 min.	≥400 min.

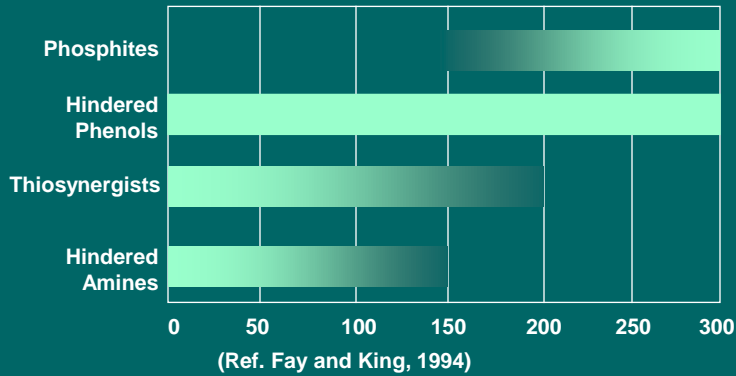
- Frequency is each railcar: 90,000 kg (200,000 lb)



High Pressure (Left) and Standard (Right) Cells for Measuring OIT



## On choice of Std. or HP-OIT



- Std-OIT misrepresents AO packages with thiosynergists and/or hindered amines
- HP-OIT is always applicable (but \$10,000 cell and longer test time)

## 10. Oven Aging

- assessment of thermal stability of antioxidants (AOs)
- follows ASTM D5721
- forced air oven at 85°C
- Std.-OIT  $\geq 55\%$  ret. after 90 days exposure
- HP-OIT  $\geq 80\%$  ret. after 90 days
- frequency is per formulation



## 11. Ultraviolet Resistance

- assessment of UV stability of the AOs and CB (there should be synergy)
- uses a laboratory weatherometer
- follows GRI GM11 ( $\approx$  ASTM G154)
- called “ultraviolet fluorescent device”
- 20 hr. UV cycle at 75°C, then 4 hr. condensation at 60°C
- HP-OIT  $\geq$  50% ret. after 1600 hrs.
- frequency is per formulation



## Regarding the Warranty

- manufacturers requested so as to avoid 20-year warranties and foolish expenses
- based on GRI Report #16, i.e., if AOs are present lifetime  $\approx$  200 yrs.
- GM13 was crafted to be sure the AOs are present and of proper type, i.e., OIT and oven aging verification
- also, for geomembrane used in exposed conditions a UV exposure is included
- recommended material warranty using GM13 spec is for 5-years (it promises to be 100's)
- GM13 is silent on any type of installation warranty (this is the major concern)

## Concluding Comments

- specification was essential due to NSF dropping its Std. 54 in 1997
- mfgs. want spec for both covered and exposed GM installations
- this is MQC specification i.e., the manufacturers required tests, minimum values and frequencies
- if MQA project specific spec is more restrictive, manufacturer may ask for additional compensation

## The Basic Tables Follow

**HDPE – Smooth (SI Units)**

**HDPE – Smooth (English)**

**HDPE – Textured (SI Units)**

**HDPE – Textured (English)**

**Note:** The most recent version of this specification (text and tables) is available on the GSI Web Site <[geosynthetic-institute.org](http://geosynthetic-institute.org)>.

SI (METRIC UNITS)

Table 1(b) – High Density Polyethylene (HDPE) 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.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
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	0.940 g/cc	90,000 kg
Tensile Properties (1) (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 20kN/m 12% 700%	15 kN/m 27 kN/m 12% 700%	18 kN/m 33 kN/m 12% 700%	22 kN/m 40 kN/m 12% 700%	29 kN/m 53 kN/m 12% 700%	37 kN/m 67 kN/m 12% 700%	44 kN/m 80 kN/m 12% 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 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.		per GRI GM-10
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)	note (4)	note (4)	note (4)	note (4)		20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (5) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.		90,000 kg
Oven Aging at 85°C (5), (6) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%		per each formulation
UV Resistance (7) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)	D 3895 D 5885	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%		per each formulation

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- (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. It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (7) 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.
- (8) UV resistance is based on percent retained value regardless of the original HP-OIT value.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ENGLISH UNITS

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.) • lowest individual of 10 values	D5199	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	nom. -10%	Per roll
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	0.940 g/cc	200.00 lb
Tensile Properties (1) (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	63 lb/in. 114 lb/in. 12% 700%	84 lb/in. 152 lb/in. 12% 700%	105 lb/in. 190 lb/in. 12% 700%	126 lb/in. 228 lb/in. 12% 700%	168 lb/in. 304 lb/in. 12% 700%	210 lb/in. 380 lb/in. 12% 700%	252 lb/in. 456 lb/in. 12% 700%		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	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb		45,000 lb
Stress Crack Resistance (2)	D5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.		per GRI-GM10
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) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.		200,000 lb
Oven Aging at 85°C (5), (6) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%		per each formulation
UV Resistance (7) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)	GM 11 D 3895 D 5885	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%	N.R. (8) 50%		per each formulation

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- (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. It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
- (6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
- (7) 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.
- (8) UV resistance is based on percent retained value regardless of the original HP-OIT value.
- (9) UV resistance is based on percent retained value regardless of the original HP-OIT value.



SI (METRIC UNITS)

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 min. (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) (1)	GM 12	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	0.25 mm	every 2 <sup>nd</sup> roll (2)
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.) (3) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	11 kN/m 8 kN/m 12% 100%	15 kN/m 10 kN/m 12% 100%	18 kN/m 13 kN/m 12% 100%	22 kN/m 16 kN/m 12% 100%	29 kN/m 21 kN/m 12% 100%	37 kN/m 26 kN/m 12% 100%	44 kN/m 32 kN/m 12% 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 (4)	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.		per GRI GM10
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 %		9,000 kg
Carbon Black Dispersion	D 5596	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)	note (6)		20,000 kg
Oxidative Induction Time (OIT) (min. ave.) (7) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.		90,000 kg
Oven Aging at 85°C (7), (8) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%		per each formulation
UV Resistance (9) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (11)	GM11 D 3895 D 5885	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%		per each formulation

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- (1) Of 10 readings; 8 out of 10 must be ≥ 0.18 mm, and lowest individual reading must be ≥ 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.  
 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 Sid-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.  
 (11) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ENGLISH UNITS

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 min. (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.) (1)	GM 12	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	10 mil	every 2 <sup>nd</sup> roll (2)
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	200,000 lb
Tensile Properties (min. ave.) (3) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	63 lb/in. 45 lb/in. 12% 100%	84 lb/in. 60 lb/in. 12% 100%	105 lb/in. 75 lb/in. 12% 100%	126 lb/in. 90 lb/in. 12% 100%	168 lb/in. 120 lb/in. 12% 100%	210 lb/in. 150 lb/in. 12% 100%	252 lb/in. 180 lb/in. 12% 100%		45,000 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 (4)	D 5397 (App.)	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.	300 hr.		per GRI GM10
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)	note (6)	note (6)	note (6)	note (6)	note (6)		45,000 lb
Oxidative Induction Time (OIT) (min. ave.) (7) (a) Standard OIT — or — (b) High Pressure OIT	D 3895 D 5885	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.	100 min. 400 min.		200,000 lb
Oven Aging at 85°C (7), (8) (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 3895 D 5885	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%	55% 80%		per each formulation
UV Resistance (9) (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (11)	GM11 D 3895 D 5885	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%	N.R. (10) 50%		per each formulation

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- (1) Of 10 readings; 8 out of 10 must be ≥ 7 mils, and lowest individual reading must be ≥ 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.  
 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 Sid-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.  
 (11) UV resistance is based on percent retained value regardless of the original HP-OIT value.