GRI-GM18 Specification
Flexible Polypropylene Geomembranes

- specification a result of NSF dropping its Standard 54 in 1997
- covers unreinforced and reinforced fPP
- thicknesses 0.75-1.14 mm (30-45 mils)
- silent on method of manufacturing
- lists properties, test methods, test values and test frequencies
- covers eleven (11) properties

fPP ≠ TPO

Component	fPP	TPO*
fPP resin	≥ 85%	-
olefin (PE or PP)	-	≥ 50%
CB	2-2.5%	(?)
additives	≤ 12%	≤ 49%

* ASTM 6878, Spec for Thermoplastic Polyolefin Roofing

Preliminary Comments

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

- **referenced quantities in specification**
  22,000 kg = 45,000 lb ~ 50 rolls of 0.75 mm (30 mil)
  7,500 kg = 15,000 lb ~ 20 rolls of 0.75 mm (30 mil)

Physical Properties

1. **mass/unit area**
2. **thickness**

Mechanical Properties

3. **tensile**
4. **multiaxial**
5. **tear**
6. **puncture**
7. **ply-adhesion**
8. **low temp. flex.**

Endurance Properties

9. **CB content**
10. **oven aging**
11. **UV resistance**

1. Mass per Unit Area

- generally referred as “weight”
- follows ASTM D5261
- 5 specimens across roll width
- values averaged and compared to spec value stated as “min. ave.”
- straightforward test

2. Thickness

- follows ASTM D5199
- dead weight micrometer with flat tip
- includes scrim when reinforced
- 10-specimens across roll width
- required for each roll
- average must equal nominal
- lowest individual is –10%

3. Tensile Properties

- ASTM D6693 for unreinforced (dogbone)
- ASTM D751 for reinforced (grab)
- min. ave. of 5 MD and 5 XMD

Property	Method	Unreinforced	Reinforced
strength	dogbone grab	13 MN/m^2 (1900 lb/in^2)	n/a 965 N/mm (5600 lb/in.)
elongation	dogbone grab	700% n/a	n/a 22%

- every 7500 kg (15,000 lb) ~ 20 rolls



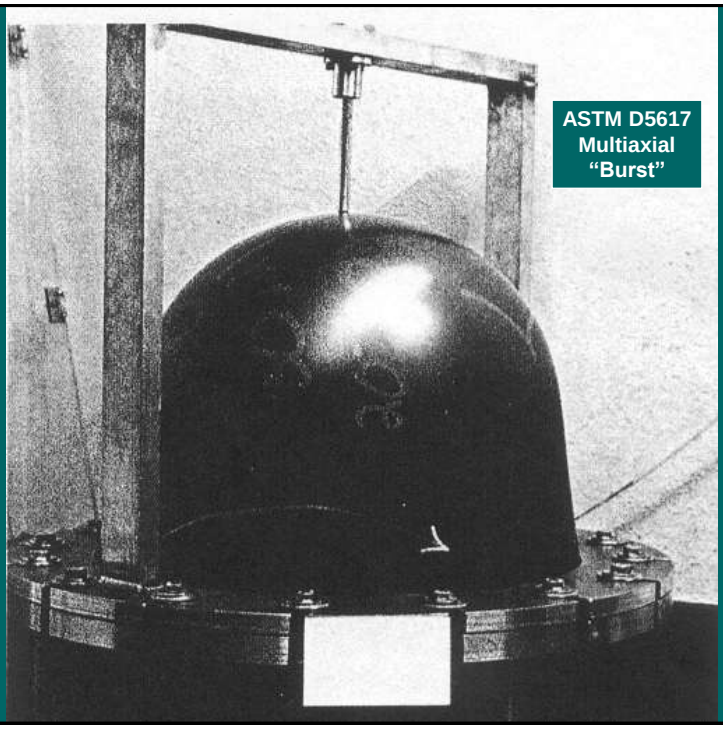

D6693 Type IV "Dogbone" Test in Progress



ASTM D751 – Grab Tensile Test (Measures Strength and Elongation)

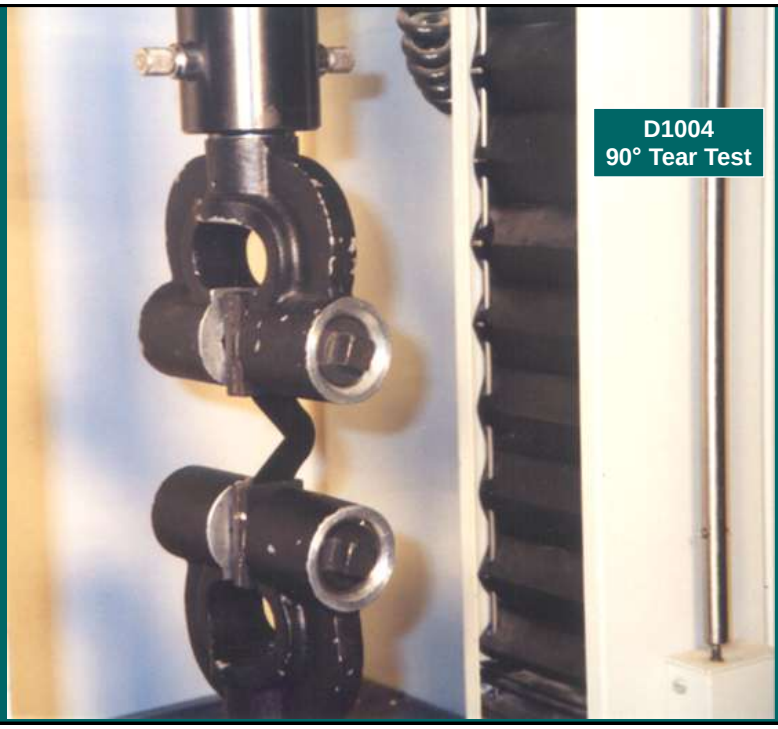
4. Multiaxial Tension
(also called axisymmetric)

- follows ASTM D5617
- it's a huge "burst" type of test
- simulates out-of-plane deformation
- measures pressure and deformation
- calculations give strength and elongation
- spec only requires elongation ≥ 120%
- only for nonreinforced fPP
- required for each formulation



5. Tear Resistance

- uses ASTM D1004 (90 deg. tear test) for nonreinforced – 10 MD and 10 XMD
- uses ASTM D5884 (tongue tear test) for reinforced – 5 MD and 5 XMD
- nonreinforced ≥ 50 N/mm (300 lb/in.)
- reinforced ≥ 245 N (55 lb)
- every 7500 kg (15,000 lb) ~ 20 rolls



6. Puncture Resistance

- follows ASTM D4833
- called “pin” puncture
- min. ave. of 15 tests
- nonreinforced ≥ 130 N/mm (800 lb/in.)
- reinforced ≥ 350 N/mm (2000 lb/in.)
- every 7,500 kg (15,000 lb) ~ 20 rolls

ASTM D4833 – “Pin” Puncture Resistance

7. Ply Adhesion

- follows ASTM D6636
- for scrim reinforced fPP only
- specimen is 25 mm wide (1.0 in.) wide
- length ≥ 200 mm (8.0 in.)
- average of 5 tests (MD only)
- average value ≥ 65 N (15 lb)
- every 7500 kg (15,000 lb) ~ 20 rolls

ASTM D6636 – Ply Adhesion Test

8. Low Temperature Flexibility

- follows ASTM D2136
- must resist cracking at -40°C (-40°F)
- incubation for 4-hours followed by bending over a mandrel
- bent over 3.2 mm (1/8 in.) mandrel
- performed once per formulation

D 2136

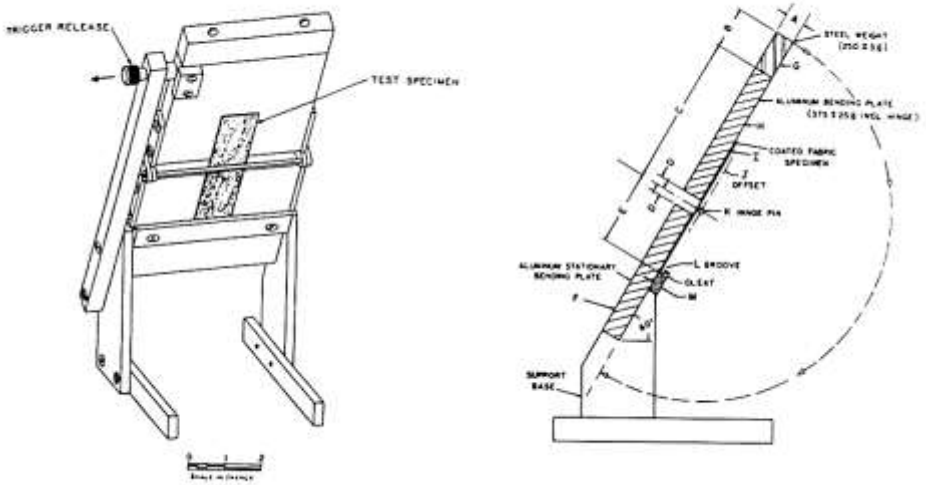
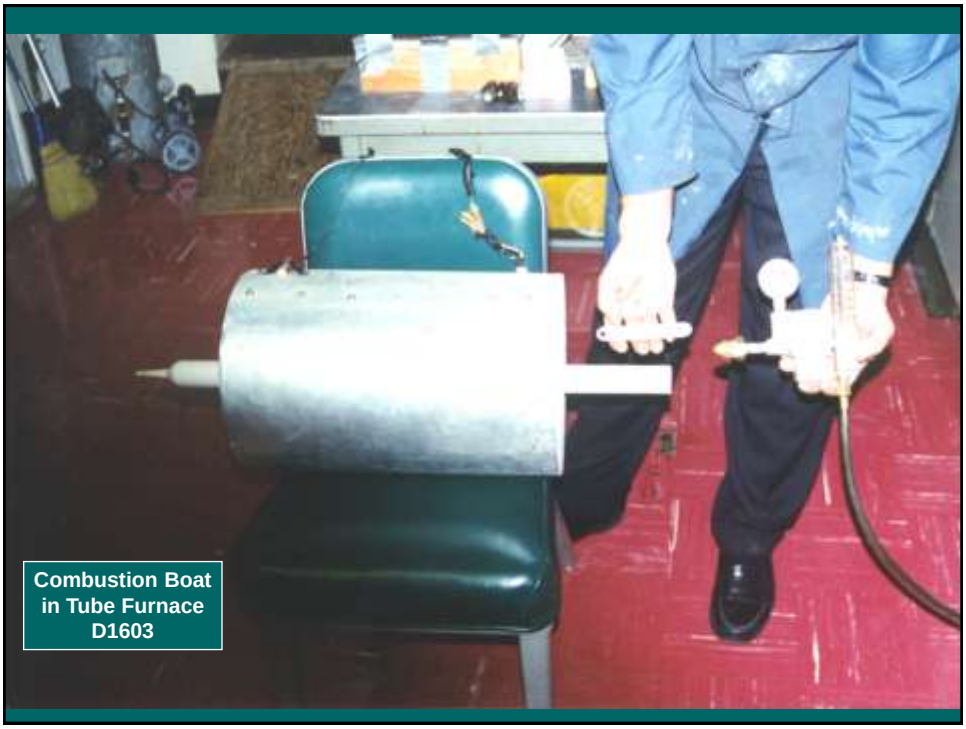


FIG. 1 Bending Jig for Coated Fabrics

9. 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 22,000 kg (45,000 lb) ~ 50 rolls


Combustion Boat
in Tube Furnace
D1603


Muffle Furnace
D4218

10. Oven Aging

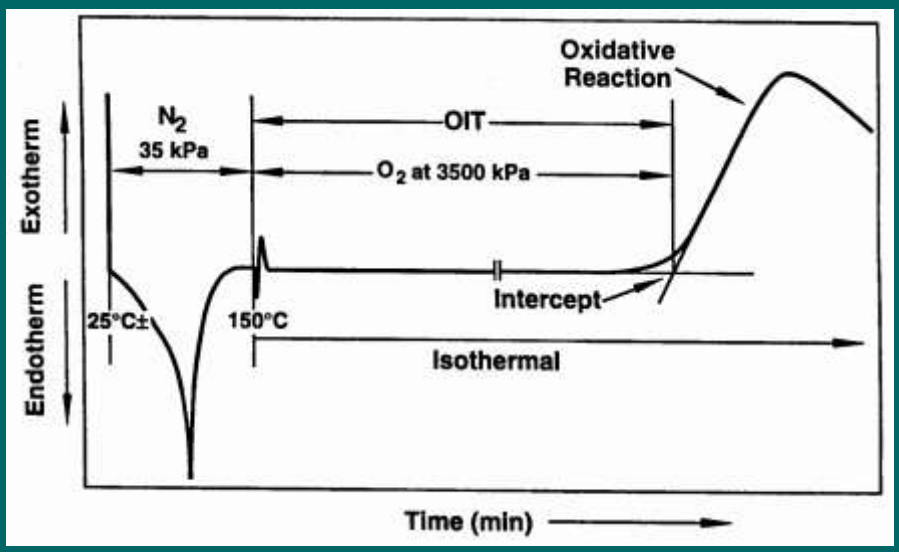
- assessment of thermal stability of antioxidants (AOs)
- follows ASTM D5721
- forced air oven at 85°C
- Std.-OIT is not recommended
- HP-OIT ≥ 60% ret. after 90 days (black)
- HP-OIT ≥ 50% ret. after 90 days (other colors)
- frequency is per formulation

D5721 Forced Air Oven

Oxidative Induction Time

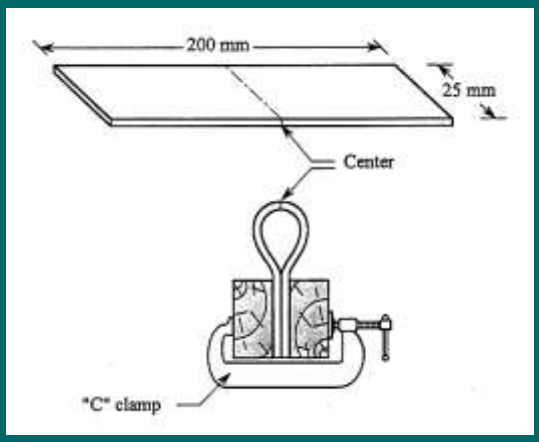
- OIT is an indirect measure of the amount of antioxidants
- HP-OIT, per ASTM D5885, is specified
- small specimen ~ 2 mg
- pressure at 3500 kPa (500 lb/in.^{2})
- temperature at 150°C in N_2; 1-min. dwell; switch to 0_2; record time; see following

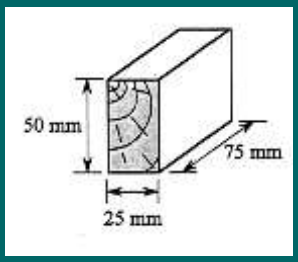
HIP-OIT (ASTM D5885)



In Addition to OIT Criteria

- incubated specimen cannot crack
- follows GRI GM16 test method
- 180 deg. bending within a holder
- visual observation for cracks at 7X magnification' "go" or "no-go" test





Test Specimen as Removed from Weathering Device, Bent 180 deg. and Clamped Between Two Wooden Blocks and One of the Clamping Blocks

11. Ultraviolet Resistance

- assessment of UV stability of the AOs and CB (there should be synergy)
- uses a laboratory weatherometer
- follows GRI GM11 (~ ASTM G154)
- called “ultraviolet fluorescent device”
- 20 hr. UV cycle at 75°C, then 4 hr. condensation at 60°C
- HP-OIT ≥ 80% ret. after 1600 hrs. (black)
- HP-OIT ≥ 60% ret. after 1600 hrs. (other colors)
- also, no cracking after incubation per GRI GM16
- frequency is per formulation

GRI-GM11
Ultraviolet
Fluorescent
Weathering Device

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 ~ 200 yrs.
- GM18 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 GM18 spec is for 5-years (it promises to be 100's)
- GM18 is silent on any type of installation warranty (this is the major concern)

Concluding Comments

- specification addresses 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

fPP & fPP-R – SI Units
fPP & fPP-R – English Units

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

U. S. Standard Units

Table 1(a) – Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes

Property	Test Method ASTM or GRI	fPP 30 mils	fPP 40 mils	fPP 60 mil	fPP-R 36 mils	fPP-R 45 mils	fPP-R 60 mil	Testing Frequency (minimum)
Mass per Unit Area – lb/ft² (min. ave.)	D5261	0.12	0.16	0.20	0.15	0.18	0.24	15,000 lb
Thickness – mils (min. ave.)	D5199	30	40	60	36	45	60	per roll
• lowest individual specimen – mils, nominal – 10%		27	36	54	32	40	54	
Tensile Strength								
• dumbbell[1] – lb/in. (min. ave.)	D6693-IV	60	72	86	-	-	-	15,000 lb
• grab[1] – lb (min. ave.)	D7004	-	-	-	200	250	300	15,000 lb
Tensile Elongation								
• dumbbell[1,2] - % (min. ave.)	D6693-IV	700	700	700	-	-	-	15,000 lb
• grab[1] - % (min. ave.)	D751-A	-	-	-	22	22	22	15,000 lb
Multiaxial Elongation - %	D5617	120	120	120	-	-	-	formulation
Tear Resistance								
• nonreinforced[1] – lb (min. ave.)	D1004	10	12	18	-	-	-	15,000 lb
• reinforced[1] – lb (min. ave.)	D5884	-	-	-	55	55	55	15,000 lb
Puncture Resistance – lb (min. ave.)	D4833	25	30	40	75	85	100	15,000 lb
Fly Adhesion – lb (min. ave.)	D6636	-	-	-	15	15	15	15,000 lb
Low Temperature Flexibility - °F	D2136[4]	-40	-40	-40	-40	-40	-40	formulation
Carbon Black Content[3] - %	D4218	2-3	2-3	2-3	2-3	2-3	2-3	45,000 lb
Ultraviolet Light Resistance[5,6]	D7238 @ 70°C							per formulation
(a) % strength retained after 20,000 light hrs	D6693-IV		≥ 50			≥ 50		
- or -								
(b) % elongation retained after 20,000 light hrs	D6693-IV		≥ 50			≥ 50		
- and -								
(c) Surface Cracking Observation after 20,000 light hrs	GM16		none			none		
(d) Surface Chalking (or Powdering) after 20,000 light hrs	GM23		minor			minor		

(1) Test methods modified to 20 in. /min. for nonreinforced and 12 in. /min. for reinforced
(2) Calculation based on a 2.0 in. gage length
(3) Using 1/8 in. mandrel for 4-hours.
(4) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content
(5) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 70°C followed by 4 hr. condensation at 60°C
(6) See Section 5.2 for fPP-R geomembranes

SI (METRIC) UNITS

Table 1(b) – Flexible Polypropylene Nonreinforced (fPP) and Reinforced (fPP-R) Geomembranes

Property	Test Method ASTM or GRI	fPP 0.76 mm	fPP 1.02 mm	fPP 1.52 mm	fPP-R 0.91 mm	fPP-R 1.14 mm	fPP-R 1.52 mm	Testing Frequency (minimum)
Mass per Unit Area – kg/m² (min. ave.)	D5261	0.59	0.78	0.98	0.73	0.88	1.17	7500 kg
Thickness – mils (min. ave.)	D5199	0.76	1.02	1.52	0.91	1.14	1.52	per roll
• lowest individual specimen – mils, (nominal – 10%)		0.68	.92	1.37	0.82	1.03	1.37	
Tensile Strength								
• dumbbell[1] – kN/m (min. ave.)	D6693-IV	11	13	17	-	-	-	7500 kg
• grab[1] – N (min. ave.)	D7004	-	-	-	890	1110	1340	7500 kg
Tensile Elongation								
• dumbbell[1,2] - % (min. ave.)	D6693-IV	700	700	700	-	-	-	7500 kg
• grab[1] - % (min. ave.)	D751-A	-	-	-	22	22	22	7500 kg
Multiaxial Elongation - %	D5617	120	120	120	-	-	-	formulation
Tear Resistance								
• nonreinforced[1] – N (min. ave.)	D1004	45	53	80	-	-	-	7500 kg
• reinforced[1] – N (min. ave.)	D5884	-	-	-	245	245	245	7500 kg
Puncture Resistance – N (min. ave.)	D4833	110	130	180	330	380	440	7500 kg
Fly Adhesion – N (min. ave.)	D6636	-	-	-	65	65	65	7500 kg
Low Temperature Flexibility - °C	D2136[4]	-40	-40	-40	-40	-40	-40	formulation
Carbon Black Content[3] - %	D4218	2-3	2-3	2-3	2-3	2-3	2-3	22,000 kg
Ultraviolet Light Resistance[5,6]	D7238 @ 70°C							per formulation
(a) % strength retained after 20,000 light hrs	D6693-IV		≥ 50			≥ 50		
- or -								
(b) % elongation retained after 20,000 light hrs	D6693-IV		≥ 50			≥ 50		
- and -								
(c) Surface Cracking Observation after 20,000 light hrs	GM16		none			none		
(d) Surface Chalking (or Powdering) after 20,000 light hrs	GM23		minor			minor		

(1) Test methods modified to 500 mm/min. for nonreinforced and 12 in. /min. for reinforced
(2) Calculation based on a 50 mm gage length
(3) Using 32 mm mandrel for 4-hours.
(4) Applicable only to black geomembranes. Also D1603 is an acceptable method to determine carbon black content
(5) The conditions of the UV Fluorescent exposure method should be 20 hr. UV cycle at 70°C followed by 4 hr. condensation at 60°C
(6) See Section 5.2 for fPP-R geomembranes