



Material Specification for New PVC Geomembranes^{1,2,3,4,5*}

(*Specification Notes are shown in Appendix A)

Effective Date: September 1, 2019

Certified Properties ^{6,7}	ASTM	PVC 10	PVC 20	PVC 30	PVC 40	PVC 50	PVC 60
Average Thickness mil [mm] ^{6,7,8,9}	D-5199 - Procedure B	10 ± 0.5 mil [0.25 ± 0.013 mm]	20 ± 1 mil [0.51 ± 0.03 mm]	30 ± 1.5 mil [0.76 ± 0.04 mm]	40 ± 2 mil [1.02 ± 0.05 mm]	50 ± 2.5 mil [1.27 ± 0.06 mm]	60 ± 3 mil [1.52 ± 0.08 mm]
Tensile Properties ^{6,7,8}	D-882 - Minimum (MD & TD)	24 lbs/inch 4.2 kN/m	48 lbs/inch 8.4 kN/m	73 lbs/inch 12.8 kN/m	97 lbs/inch 17.0 kN/m	116 lbs/inch 20.3 kN/m	137 lbs/inch 24.0 kN/m
Tensile Force at Break							
Elongation at Break		250%	360%	380%	430%	430%	450%
Tensile Force at 100% Elongation		10 lbs/inch 1.8 kN/m	20 lbs/inch 3.6 kN/m	30 lbs/inch 5.4 kN/m	40 lbs/inch 7.2 kN/m	50 lbs/inch 9.0 kN/m	60 lbs/inch 10.8 kN/m
Average Modulus at Break		2,400 lbs/in ² 16,800 kN/m ²	2,400 lbs/in ² 16,470 kN/m ²	2,400 lbs/in ² 16,470 kN/m ²	2,400 lbs/in ² 16,470 kN/m ²	2,400 lbs/in ² 16,470 kN/m ²	2,400 lbs/in ² 16,470 kN/m ²
Average Modulus at 100% Elongation		1,000 lbs/in ² 6,895 kN/m ²	1,000 lbs/in ² 6,895 kN/m ²	1,000 lbs/in ² 6,895 kN/m ²	1,000 lbs/in ² 6,895 kN/m ²	1,000 lbs/in ² 6,895 kN/m ²	1,000 lbs/in ² 6,895 kN/m ²
Tear Strength ^{6,7,8}	D-1004 - (MD & TD) Min	2.5 lbs 11 N	6.0 lbs 27 N	8.0 lbs 35 N	10.0 lbs 44 N	13.0 lbs 58 N	15.0 lbs 67 N
Dimensional Stability ^{6,7,10}	D-1204 - Maximum Change (MD & TD)	4%	4%	3%	3%	3%	3%
Low Temperature Impact Test ^{6,7,11,12}	D-1790 - More than 50% of specimens pass	-10° F -23° C	-15° F -26° C	-20° F -29° C	-20° F -29° C	-20° F -29° C	-20° F -29° C
Camber or layflat of manufactured roll, maximum allowable deviation between two (2) readings ^{6,7,8, 23}	FGI Circumference Test – see Appendix C	Maximum Circumference Difference along roll width < 25 mm (1.0 in.) & Maximum Bowing Difference < 11 mm (0.43 in.)					

Index Properties ^{7,13}	ASTM	PVC 10	PVC 20	PVC 30	PVC 40	PVC 50	PVC 60
Specific Gravity ^{7,13}	D-792 - Typical	1.2 g/cc	1.2 g/cc	1.2 g/cc	1.2 g/cc	1.2 g/cc	1.2 g/cc
Water Extraction Percent Loss (maximum) ^{7,13}	D-1239 - Maximum Loss	0.25%	0.25%	0.25%	0.30%	0.30%	0.30%
Weighted Average Blended Phthalate Based Plasticizer Molecular Weight ^{7,13,14, 15, 16, 20}	D-2124 - Minimum	400 grams/mol	400 grams/mol	400 grams/mol	400 grams/mol	400 grams/mol	400 grams/mol
Volatile Percent Loss ^{7,13}	D-1203 - Maximum	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Soil Burial ^{7,13,17, 22} Tensile Force at Break (95%), Elongation at Break (80%), and Tensile Force at 100% Elongation (80%)	G160 - Minimum Values	22.8 lbs/inch 4.0 kN/m 200 8.2 lbs/inch 1.4 kN/m	45.6 lbs/inch 8.0 kN/m 288 16.0 lbs/inch 2.9 kN/m	69.4 lbs/inch 12.2 kN/m 304 24.0 lbs/inch 4.3 kN/m	92.2 lbs/inch 16.2 kN/m 344 32.0 lbs/in 5.8 kN/m	110.2 lbs/inch 19.3 kN/m 344 40.0 lbs/in 7.2 kN/m	130.2 lbs/inch 22.8 kN/m 360 48.0 lbs/in 8.6 kN/m
Hydrostatic Resistance ^{7,13}	D-751 - Min	42 psi 290 kPa	68 psi 470 kPa	100 psi 690 kPa	120 psi 830 kPa	150 psi 1030 kPa	180 psi 1240 kPa
Color Deviation within a manufactured lot ^{7,13,18, 21}	E1164- and E308	Delta E less than 2.0	Delta E less than 2.0	Delta E less than 2.0	Delta E less than 2.0	Delta E less than 2.0	Delta E less than 2.0
Film Gloss, maximum gloss at 60 degrees angle for calendered and embossed sides ^{7,13}	D2457 - Maximum	50 (calendered side) / 15 (embossed side)	50 (calendered side) / 15 (embossed side)	50 (calendered side) / 15 (embossed side)	50 (calendered side) / 15 (embossed side)	50 (calendered side) / 15 (embossed side)	50 (calendered side) / 15 (embossed side)
Shore Hardness ^{7,13,19}	D2240 – Durometer A	Delta ± 3	Delta ± 3	Delta ± 3	Delta ± 3	Delta ± 3	Delta ± 3
Seam Strengths ⁸	ASTM	PVC 10	PVC 20	PVC 30	PVC 40	PVC 50	PVC 60
Seam Shear Strength ⁸	D-7408 - Min	20.0 lbs/in 3.5 kN/m	38.4 lbs/in 6.7 kN/m	58.4 lbs/in 10.0 kN/m	77.6 lbs/in 14.0 kN/m	92.8 lbs/in 16.0 kN/m	109.6 lbs/in 20.0 kN/m
Seam Peel Strength at 2 in./min ⁸	D-7408 - Min	10.0 lbs/in 1.8 kN/m	12.5 lbs/in 2.2 kN/m	15.0 lbs/in 2.6 kN/m	15.0 lbs/in 2.6 kN/m	15.0 lbs/in 2.6 kN/m	15.0 lbs/in 2.6 kN/m
Seam Peel Strength at 20 in./min ⁸	D-7408 - Min	10.0 lbs/in 1.8 kN/m	15.0 lbs/in 2.2 kN/m	18.0 lbs/in 3.1 kN/m	18.0 lbs/in 3.1 kN/m	18.0 lbs/in 3.1 kN/m	18.0 lbs/in 3.1 kN/m

***Notes:**

1. This FGI Material Specification for New PVC Geomembranes replaces the FGI PVC Specification revision dated January 1, 2017 (FGI 1117).
2. A new PVC Geomembrane can contain reworked material. Rework material is defined as: material from like product internal to the manufacturing process but not after field/external usage. The manufacturer must retain the formulation of the geomembrane including the amount of reworked material included in the formulation just in case the customer requests this information.
3. Rework material does not include any PVC geomembrane that has been utilized outside of the manufacturing process for any application.
4. Rework material is defined in ASTM D883 and is considered to be scrap from the manufacturer's process.
5. It is recommended that PVC geomembranes not be handled or installed at cold temperatures below 40°F/5°C. If a PVC geomembrane will/must be installed at temperatures below 40°F/5°C, the installer must submit a cold weather work plan for approval by the geomembrane manufacturer and/or fabricator.
6. Certified properties are tested by lot as specified in Appendix A (see below) of FGI PVC Specification revision dated 1 September 2019.
7. Modifications or further details of tests are described in Appendix B (see below) of the FGI PVC Specification revision dated 1 September 2019.
8. Metric values are converted from US values and are rounded to the available significant digits.
9. Thickness under D5199 will not vary more than $\pm 5\%$. Best practices require an online scanner.
10. Dimensional stability test specimens should be exposed to 100°C for 15 minutes before measuring the exposed specimen.
11. Group considered the cold temperature bending test D2136 but selected the cold cracked test D1790 because it is more severe for assessing cold temperature behavior.
12. For warm and arid climates (sheet temperatures greater than or equal to 50°C or 120°F and rainfall less than 250 mm or 10 inches annually) passing temperatures for the Low Temperature Impact Test are -17°C for PVC 20 and -20°C for all other thicknesses. For areas that experience temperature less than -20°C (typical environment), the PVC geomembrane should pass the Impact Test at -29°C for thicknesses of 30, 40, 50, and 60 mils. If the product destination is not known, the PVC geomembrane should pass the Impact Test at -29°C for thicknesses of 30, 40, 50, and 60 mils.
13. Index properties are tested once per formulation as specified in Appendix A (see below) of the FGI PVC Specification revision dated 1 September 2019.
14. These requirements for average plasticizer molecular weight pertain to formulations that utilize Phthalate plasticizers.
15. This method does not determine one of the main co-plasticizers used in PVC flexible films, epoxidized soy bean oil. The important point is the very high molecular weight this plasticizer has, so it can increase the value of the average.
16. For arid climates (sheet temperatures greater than or equal to 50°C or 120°F and rainfall less than 250 mm or 10 inches annually), use a weighted average plasticizer molecular weight with a minimum value of 410 grams/mol.
17. The soil burial test specimen does not have to undergo UV conditioning or exposure before performing this test.
18. This color specification should be shared between the manufacturer and fabricator/customer to achieve desired color uniformity or as specified by the customer.
19. Manufacturer should specify the Shore Hardness for the geomembrane manufacturing lot and the test results using D2240 should be ± 3 from the manufacturer's specified value.
20. If the geomembrane application is potable water, please use the National Sanitation Foundation (NSF) NSF-61 material certification or similar certification.
21. The Color Deviation requirements of this specification should be met unless specified differently by the customer.

22. Soil Burial minimum values for: (1) Tensile Force at Break corresponds to 95% of the non-buried Tensile Force at Break, (2) Elongation at Break corresponds to 80% of the non-buried Tensile Force at Break, and (3) Tensile Force at 100% Elongation corresponds to 80% of the non-buried Tensile Force at Break.
23. This camber or layflat specification of a manufactured roll should be specified by the customer, e.g., number of points measured, or meet the Maximum Circumference and Maximum Bowing Differences recommended in this specification.

APPENDIX A - FGI 8119-PVC Geomembranes MANUFACTURING TESTING FREQUENCIES

Certified Properties

Certified test properties are tested based on a quantity of material produced. Certified properties are tested once per lot, or once every 40,000 lbs of material (18,000 kg), whichever is more frequent. The certification properties include thickness, tensile break strength, elongation at break, modulus at 100% strain, tear resistance, dimensional stability, camber or layflat (see following note about frequency), and low temperature impact. Thickness is to be tested once per roll unless automatic thickness measuring equipment is installed on the production equipment. Certified test reports (Mill Certificates) for the tested properties are to be provided with every order on request. Camber or layflat should be checked at least every 2,500 yards (2,288 meters), every two (2) hours of manufacturing, or whichever is more frequent.

Index Properties

Index tests are performed when preparing and approving a geomembrane formulation. The tests are performed on the final production formulation of a geomembrane. The index properties include specific gravity, water extraction, volatile loss, hydrostatic resistance, average plasticizer molecular weight, color, gloss, hardness, and soil burial resistance. A certified statement of the test results for the formulation is to be made available to the customer on request.

APPENDIX B - FGI 8119-PVC Geomembranes TESTING CLARIFICATIONS AND DETAILS

General:

- When both US and metric values are shown the value for acceptance is the US value. Metric values are conversions and may contain rounding errors.

ASTM D5199: Measuring the Nominal Thickness of Geosynthetics

- US units of thousandths of an inch (0.001 inches = 1 mil)
- Metric unit of millimeters of thickness (mm)
- In addition to thickness measurements on samples as required by ASTM D5199, during manufacturing thickness should be measured in the machine direction every 100 ft (30 m) and continuously in the transverse direction by some means.

ASTM D882: Tensile Properties of Thin Plastic Sheeting

- Use Method A
- ASTM D882 method may be used for PVC film up to 60 mil (1.5mm) thick
- Units are in pounds of force per inch of width (lbs/in) for tensile force at break and tensile force at 100 % of elongation.
- For modulus at break and modulus at 100 % of elongation, units are lb/in²
- Metric units are in kiloNewtons per meter of width (kN/m), or Newtons per millimeter of width (N/mm) which are equivalent units for tensile force at break and at 100% of elongation.

ASTM D1004 : Initial Tear Resistance of Plastic Film and Sheeting

- Units are in pounds of force to initiate tear in the specially die-cut specimen (lbs) or in Newtons of force (N)

ASTM D1790: Low Temperature Brittleness of Plastic Sheeting by Impact

- More than 50% of specimens must pass at specified temperature

ASTM G160: Evaluating Microbial Susceptibility of Nonmetallic Materials by Soil Burial

- Bury sample in prepared soil for 30 days
- Perform test on actual liner sheet samples
- Measure maximum change in properties as shown in specification

ASTM D1204: Linear Dimensional Changes of Thermoplastic Film at Elevated Temp.

- Test specimens at 100°C for 15 minutes
- Measure percent change in two lineal dimensions (length & width)

ASTM D1203: Volatile Loss from Plastics Using Activated Carbon Methods

- Use method A

ASTM D1239: Resistance of Plastic Films to Extraction by Chemicals

- Test specimens in 50°C (122°F) water for twenty-four hours
- Measure percent change in weight

ASTM D751: Test Methods for Coated Fabrics

- For Hydrostatic Burst use Section 33, Procedure A, "Pressure Application by Mullen Type Hydrostatic Tester"
- Units of pressure in pounds per square inch (psi) or kiloPascals (kPa)

ASTM D7408: Standard Specification for Non-Reinforced PVC (Polyvinyl Chloride) Geomembrane Seams

- Seams Produced Using Chemical, Adhesive, Solvent and Thermal Fusion Methods
- Use 25.4 mm wide (1") specimens.
- Seam Shear Strength Testing:
Use grip separation of 51 mm (2 in) plus the seam width
Crosshead speed of 510 mm/min (20 in/min)
- Seam Peel Strength Testing:
Position grips 13 mm (1/2") on either side of seam
Crosshead speed of 51 mm/min (2 in/min)

ASTM E308: Standard Practice for Computing the Colors of Objects by Using the CIE System

- Evaluating color deviation within a manufactured lot.

ASTM E1164: Standard Practice for Obtaining Spectrometric Data for Object-Color Evaluation

- Evaluating color deviation within a manufactured lot.

ASTM D2457: Standard Test Method for Specular Gloss of Plastic Films and Solid Plastics

- Evaluating geomembrane gloss within a manufactured lot.

ASTM D2240: Standard Test Method for Rubber Property – Durometer Hardness

- Evaluating geomembrane hardness and feel or hand within a manufactured lot.

APPENDIX C - FGI 8119-PVC Geomembranes FGI CIRCUMFERENCE TEST

Test Specimen and Testing Frequency:

- The completed roll itself is measured.
- In general, the measurements are made in metric values.
- When both US and metric values are shown the value for acceptance is the US value. US values are conversions and may contain rounding errors.
- Manufacturer should perform the Circumference Test every 2,500 yards (2,288 meters), every two (2) hours of manufacturing, or whichever is more frequent.

Equipment:

- Flexible but non-elongating Tailor's measuring tape (see photos **Figures 1 to 4** below show typical measuring tapes) in US or metric units. (For example, see https://www.amazon.com/eBoot-Measure-Sewing-Tailor-Ginger/dp/B06XS877YJ/ref=sr_1_2_sspa?ie=UTF8&qid=1542303512&sr=8-2-spons&keywords=tailors+tape+measure&psc=1&smid=APHB2NWNKDSBL).

Test Method:

- Circumference: Circumference measurement at any given point on the roll
- Circumference difference: Difference between maximum and minimum circumference measurements
- Bowing difference: Difference between circumference measurements at opposite ends of the roll with 1" (25.4 mm) on each edge.
- Facing roll, start at one end and wrap circle tape around roll, with the centimeter/millimeter side (not inches side) showing (see **Figure 1**).
- Pull circle tape firmly around roll, until free end is flush with start of circle tape and record the measurement in metric units. Please see correct measurement methods (**Figures 1 and 2**) and incorrect measurement methods (**Figures 3 and 4**).
- Repeat this procedure across the width of the roll at the specified number of points along the roll (see Inspection Checkpoints).



Figure 1: Correct Measurement



Figure 2: Correct Measurement



Figure 3: Incorrect Measurement because tape is twisted.



Figure 4: Incorrect Measurement because tape is not parallel to roll edge.

Inspection Checkpoints:

- Circumference inspections typically consist of either 2, 3, 5, or 7 checks or measurement points at a given roll width along the roll length depending on the width of the film. For geomembranes, seven (7) checks or measurements must be made across the roll width at a particular location. If fewer measurements are made at a given roll width, they should use the following locations:
- 2-place check: Check at each end.
- 3-place check: Check at beginning, middle, and end of roll width.
- 5-place check: Check at beginning, (within one inch (25.4 mm) of roll edge) approximately midway between beginning and middle, at middle, at approximately midway between middle and roll end, and at end or edge of roll.
- 7-place check: Check at beginning, (within one inch (25.4 mm) of edge of roll) at two approximately evenly spaced points between beginning and middle, at middle, at two approximately evenly spaced points between middle and end, and at end or edge of roll (see **Figure 5**).

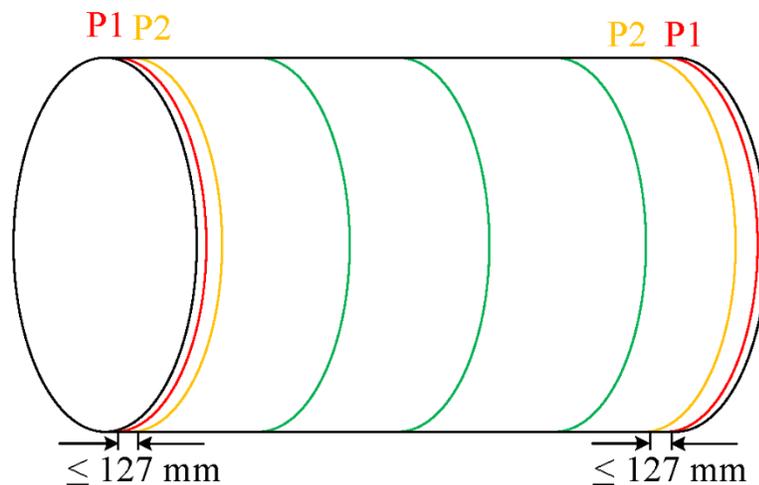


Figure 5: Location of 7-Place Check Measurements including the first (P1) and second (P2) measurement locations at edges of the roll.

Suggested Maximum Difference Between Any Two Readings:

- For all products, the first two and last two readings must not be more than 127 mm apart at the roll edges. For example, the first and last measurements must be as close to the edge as possible on all rolls but not more than 127 mm apart (see **Figure 5**).
- Remember, target low edges on all products.
- Make first measurement place at roll edge (P1) and a second measurement less than 127 mm away towards the center of the roll for the second measurement place (P2) (see **Figure 5**). The difference between these two circumferences (P1 and P2) must be between -3 mm and +1.0 mm as shown below in equation form:

$$-3 \text{ mm} \leq (P1 - P2) \leq +1.0 \text{ mm}.$$
- Ideally, the difference between these two circumferences (P1 and P2) should be 0 mm.

Reporting Requirements:

- Report the actual circumference measurements and the specified circumference difference measurement(s) (circle and bowing) to the nearest millimeter.
- Manufacturer should submit the Maximum Circumference Difference along roll width and whether or not it is less than 25 mm (1.0 in.), i.e., Passes or Fails, for each roll shipped as required above.
- Manufacturer should submit the Maximum Bowing Difference, i.e., Edge to edge deviation of a completed roll, and whether or not it is less than 11 mm (0.43 in.), i.e., Passes or Fails, for each roll shipped as required above.

The FGI PVC Specification (1 September 2019) was developed with the cooperation of FGI member companies to meet the stringent requirements of today's geosynthetic applications. To assure this level of quality, be sure to specify that your PVC geomembrane is produced and fabricated by a FGI member.

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