POLY-FLEX®
GEOMEMBRANE

REFERENCE MANUAL

POLY-FLEX®
POLYETHYLENE GEOMEMBRANES

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POLY-FLEX®
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POLY-FLEX® HDPE & LLDPE LINER SPECIFICATIONS

1. GENERAL REQUIREMENTS

1.1 Scope

The following describes parameters for the manufacture, supply, and installation of Poly-Flex® polyethylene geomembranes. All procedures, operations, and methods shall be in accordance with the engineer's specifications, plans, and drawings.

1.2 Qualifications of Contractor Work Activities

1.2.1 Manufacturing

The manufacturer shall have at least five (5) years continuous experience in manufacturing polyethylene geomembrane and/or experience totaling 10,000,000 square feet of manufactured polyethylene geomembrane.

1.2.2 Installation

The installation contractor shall be a dealer trained to install geomembrane.

Installation shall be performed under the constant direction of a field installation supervisor who shall remain on site and be responsible, throughout the liner installation, for liner layout, seaming, testing, repairs, and all other activities by the installer. The field installation supervisor shall have installed or supervised the installation of a minimum of 2,000,000 square feet of polyethylene geomembrane. Seaming shall be performed under the direction of a master seamer (who may also be the field installation supervisor) who has seamed a minimum of 2,000,000 square feet of polyethylene geomembrane, using the same type of seaming apparatus specified for this project. The field installation supervisor and/or master seamer shall be present whenever seaming is performed.

1.3 Submittals

1.3.1 Manufacturer

The manufacturer shall provide the following information:

A. Submittals with Bid Documents

1. List of material properties.
2. Manufacturing quality control program.

B. Submittals After Contract Award, Prior to Liner Installation

1. Copy of quality control certificates issued by the resin supplier.
2. Copy of quality control certificates for the geomembranes in conformance with Section 2.4.3.

1.3.2 Installation Contractor

The installer shall provide the following written information:

A. Submittals With Bid Documents

A list of completed facilities, totaling a minimum of 2,000,000 square feet, for which the installer has installed polyethylene geomembrane. For each installation, the following information shall be provided:

a. Name and purpose of facility, location, and date of installation.

b. Name of owner, design engineer, manufacturer, and name and telephone number of contact at the facility who can discuss the project.

c. Thickness and quantity of the installed geomembrane.

B. Submittals by Successful Bidder Prior to Commencement of Installation

1. Proposed installation panel layout.
2. Resume(s) of the field installation supervisor and master seamer.

1.4 Meeting

A daily meeting shall be held at the work area just prior to commencement of the work to discuss work activities. The earthwork contractor, the liner installer, and the inspector shall be present.

1.5 Warranty

A written warranty shall be obtained from the manufacturer (for material) and the installation contractor (for workmanship). These documents shall warrant both the quality of the material and workmanship for a specified duration of time.

2. MATERIAL SPECIFICATIONS

2.1 Materials

1. The geomembrane shall be High-Density Polyethylene (HDPE) or Linear Low Density Polyethylene (LLDPE).
2. Gasket material shall be neoprene, closed cell medium, 1/4-inch thick, 2 inches wide with adhesive on one side, or other compatible gasket materials as required.
3. Metal battens or banding and hardware shall be stainless steel.
4. Sealant shall be General Electric Silicone, RTV 103, or equivalent.

2.2 Geomembrane Raw Materials

The geomembrane shall be manufactured of polyethylene resins produced in the United States and shall be compounded and manufactured specifically for the intended purpose. The resin manufacturer shall certify each lot for the following properties:

The natural polyethylene resin without the carbon black shall meet the following requirements:

Property	Test Method	HDPE Requirements	LLDPE Requirements
Density, g/cc	ASTM D 1505, ASTM D 4883, or ASTM D 792	0.932 - 0.940	0.915 - 0.926
Melt Index, g/10 min.	ASTM D 1238	<1.0	<1.0

2.3 Rolls

The geomembrane shall be a minimum 23 ft seamless width, as manufactured by Poly-America, L.P. (2000 W. Marshall Dr., Grand Prairie, TX 75051, 888-765-9359). Carbon black shall be added to the resin if the resin is not compounded for ultra-violet resistance.

The surface of the smooth geomembrane shall not have striations, roughness, pinholes, or bubbles.

The geomembrane shall be supplied in rolls. Labels on each roll shall identify the thickness of the material, the length and width of the roll, lot and roll numbers, and name of manufacturer.

The geomembrane rolls shall meet the following specifications:

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Property	Test Method	Minimum Average Values 30 mil	40 mil	60 mil	80 mil	100 mil
Thickness, mils	ASTM D 5199					
minimum average		30	40	60	80	100
lowest individual reading		27	36	54	72	90
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940	0.940
Tensile Properties[1]	ASTM D 6693					
1. Yield Strength, lb/in		63	84	126	168	210
2. Break Strength, lb/in		114	152	228	304	380
3. Yield Elongation, %		12	12	12	12	12
4. Break Elongation, %		700	700	700	700	700
Tear Resistance, lb	ASTM D 1004	21	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	54	72	108	144	180
Stress Crack Resistance[2], hrs	ASTM D 5397 (App.)	300	300	300	300	300
Carbon Black Content[3], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596			--Note 4--		
Oxidative Induction Time (OIT)						
Standard OIT, minutes	ASTM D 3895	100	100	100	100	100
Oven Aging at 85°C	ASTM D 5721					
High Pressure OIT - % retained after 90 days	ASTM D 5885	80	80	80	80	80
UV Resistance[5]	ASTM D 7238					
High Pressure OIT[6] - % retained after 1600 hrs	ASTM D 5885	50	50	50	50	50
Roll Dimensions						
1. Width (feet):		23	23	23	23	23
2. Length (feet)		1000	750	500	375	300
3. Area (square feet):		23,000	17,250	11,500	8,625	6,900
4. Gross weight (pounds, approx.)		3,470	3,470	3,470	3,470	3,470

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 gauge length of 1.3 inches; Break elongation is calculated using a gauge length of 2.0 inches.
2 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
5 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
6 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Minimum Average Values

Property	Test Method	0.75 mm	1.00 mm	1.50 mm	2.00 mm	2.50 mm
Thickness, microns	ASTM D 5199					
minimum average		750	1,000	1,500	2,000	2,500
lowest individual reading		675	900	1,350	1,800	2,250
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940	0.940
Tensile Properties[1]	ASTM D 6693					
1. Yield Strength, kN/m		11	15	22	29	37
2. Break Strength, kN/m		20	27	40	53	67
3. Yield Elongation, %		12	12	12	12	12
4. Break Elongation, %		700	700	700	700	700
Tear Resistance, N	ASTM D 1004	93	125	187	249	311
Puncture Resistance, N	ASTM D 4833	240	320	480	640	800
Stress Crack Resistance[2], hrs	ASTM D 5397 (App.)	300	300	300	300	300
Carbon Black Content[3], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596			--Note 4--		
Oxidative Induction Time (OIT)						
Standard OIT, minutes	ASTM D 3895	100	100	100	100	100
Oven Aging at 85°C	ASTM D 5721					
High Pressure OIT - % retained after 90 days	ASTM D 5885	80	80	80	80	80
UV Resistance[5]	ASTM D 7238					
High Pressure OIT[6] - % retained after 1600 hrs	ASTM D 5885	50	50	50	50	50
Roll Dimensions						
1. Width (meters):		7	7	7	7	7
2. Length (meters)		304.9	228.7	152.4	114.3	91.5
3. Area (square meters):		2,137	1,603	1,068	801	641
4. Gross weight (kilograms, approx.)		1,574	1,574	1,574	1,574	1,574

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 gauge length of 33 mm; Break elongation is calculated using a gauge length of 50 mm.
2 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
5 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
6 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Property	Test Method	Minimum Average Values 40 mil	60 mil	80 mil	100 mil
Thickness, mils	ASTM D 5994				
minimum average		38	57	76	95
lowest individual of 8 of 10 readings		36	54	72	90
lowest individual of 10 readings		34	51	68	85
Asperity Height[1], mils	ASTM D 7466	10	10	10	10
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940
Tensile Properties[2]	ASTM D 6693				
1. Yield Strength, lb/in		84	126	168	210
2. Break Strength, lb/in		60	90	120	150
3. Yield Elongation, %		12	12	12	12
4. Break Elongation, %		100	100	100	100
Tear Resistance, lb	ASTM D 1004	28	42	56	70
Puncture Resistance, lb	ASTM D 4833	60	90	120	150
Stress Crack Resistance[3], hrs	ASTM D 5397 (App.)	300	300	300	300
Carbon Black Content[4], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 5--			
Oxidative Induction Time (OIT) Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
High Pressure OIT - % retained after 90 days	ASTM D 5885	80	80	80	80
UV Resistance[6]	ASTM D 7238				
High Pressure OIT[7] - % retained after 1600 hrs	ASTM D 5885	50	50	50	50
Roll Dimensions					
1. Width (feet):		23	23	23	23
2. Length (feet)		750	500	375	300
3. Area (square feet):		17,250	11,500	8,625	6,900
4. Gross weight (pounds, approx.)		3,500	3,500	3,470	3,470

1 Of 10 readings; 8 must be ≥ 7 mils and lowest individual reading must be ≥ 5 mils.
2 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gauge length of 1.3 inches; Break elongation is calculated using a gauge length of 2.0 inches.
3 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
4 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
5 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
6 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
7 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Property	Test Method	Minimum Average Values 1.00 mm	1.50 mm	2.00 mm	2.50 mm
Thickness, microns	ASTM D 5994				
minimum average		950	1,425	1,900	2,375
lowest individual of 8 of 10 readings		900	1,350	1,800	2,250
lowest individual of 10 readings		850	1,275	1,700	2,125
Asperity Height[1], microns	ASTM D 7466	250	250	250	250
Sheet Density, g/cc	ASTM D 1505/D 792	0.940	0.940	0.940	0.940
Tensile Properties[2]	ASTM D 6693				
1. Yield Strength, kN/m		15	22	29	37
2. Break Strength, kN/m		11	16	21	26
3. Yield Elongation, %		12	12	12	12
4. Break Elongation, %		100	100	100	100
Tear Resistance, N	ASTM D 1004	125	187	249	311
Puncture Resistance, N	ASTM D 4833	267	400	534	667
Stress Crack Resistance[3], hrs	ASTM D 5397 (App.)	300	300	300	300
Carbon Black Content[4], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 5--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
High Pressure OIT - % retained after 90 days	ASTM D 5885	80	80	80	80
UV Resistance[6]	ASTM D 7238				
High Pressure OIT[7] - % retained after 1600 hrs	ASTM D 5885	50	50	50	50
Roll Dimensions					
1. Width (meters):		7	7	7	7
2. Length (meters):		228.7	152.4	114.3	91.5
3. Area (square meters):		1,603	1,068	801	641
4. Gross weight (kilograms, approx):		1,588	1,588	1,574	1,574

1 Of 10 readings; 8 must be ≥ 180 microns and lowest individual reading must be ≥ 130 microns.
2 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gauge length of 33 mm; Break elongation is calculated using a gauge length of 50 mm.
3 The yield stress used to calculate the applied load for the SP-NCTL test should be the mean value via MQC testing.
4 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
5 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
6 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
7 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Property	Test Method	Minimum Average Values 30 Mil	40 Mil	60 Mil	80 Mil
Thickness, mils	ASTM D 5199				
minimum average		30	40	60	80
lowest individual reading		27	36	54	72
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939	0.939
Tensile Properties[1]	ASTM D 6693				
1. Break Strength, lb/in		114	152	228	304
2. Break Elongation, %		800	800	800	800
2% Modulus, lb/in^2 (max.)	ASTM D 5323	60,000	60,000	60,000	60,000
Tear Resistance, lb	ASTM D 1004	16	22	33	44
Puncture Resistance, lb	ASTM D 4833	42	56	84	112
Axi-Symetric Break Strain, %	ASTM D 5617	30	30	30	30
Carbon Black Content[2], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596		--Note 3--		
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
High Pressure OIT - % retained after 90 days	ASTM D 5885	60	60	60	60
UV Resistance[4]	ASTM D 7238				
High Pressure OIT[5] - % retained after 1600 hrs	ASTM D 5885	35	35	35	35
Roll Dimensions					
1. Width (feet):		23	23	23	23
2. Length (feet):		1,000	750	500	375
3. Area (square feet):		23,000	17,250	11,500	8,625
4. Gross weight (pounds, approx.):		3,435	3,435	3,435	3,435

1 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches.
2 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
3 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
4 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
5 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Property	Test Method	Minimum Average Values 0.75 mm	1.00 mm	1.50 mm	2.00 mm
Thickness, microns	ASTM D 5199				
minimum average		750	1,000	1,500	2,000
lowest individual reading		675	900	1,350	1,800
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939	0.939
Tensile Properties[1]	ASTM D 6693				
1. Break Strength, kN/m		20	27	40	53
2. Break Elongation, %		800	800	800	800
2% Modulus, MPa (max.)	ASTM D 5323	414	414	414	414
Tear Resistance, N	ASTM D 1004	70	100	150	200
Puncture Resistance, N	ASTM D 4833	190	250	370	500
Axi-Symetric Break Strain, %	ASTM D 5617	30	30	30	30
Carbon Black Content[2], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596	--Note 3--			
Oxidative Induction Time (OIT)					
Standard OIT, minutes	ASTM D 3895	100	100	100	100
Oven Aging at 85°C	ASTM D 5721				
High Pressure OIT - % retained after 90 days	ASTM D 5885	60	60	60	60
UV Resistance[4]	ASTM D 7238				
High Pressure OIT[5] - % retained after 1600 hrs	ASTM D 5885	35	35	35	35
Roll Dimensions					
1. Width (meters):		7	7	7	7
2. Length (meters):		304.9	228.7	152.4	114.3
3. Area (square meters):		2,137	1,603	1,068	801
4. Gross weight (kilograms, approx.):		1,558	1,558	1,558	1,558

1 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 50 mm.
2 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
3 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
4 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
5 UV resistance is based on percent retained value regardless of the original HP-OIT value.

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Property	Test Method	Minimum Average Values 40 Mil	60 Mil	80 Mil
Thickness, mils	ASTM D 5994			
minimum average		38	57	76
lowest individual of 8 of 10 readings		36	54	72
lowest individual of 10 readings		34	51	68
Asperity Height[1], mils	ASTM D 7466	10	10	10
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939
Tensile Properties[2]	ASTM D 6693			
1. Break Strength, lb/in		60	90	120
2. Break Elongation, %		250	250	250
2% Modulus, lb/in^2 (max.)	ASTM D 5323	60,000	60,000	60,000
Tear Resistance, lb	ASTM D 1004	22	33	44
Puncture Resistance, lb	ASTM D 4833	44	66	88
Axi-Symetric Break Strain, %	ASTM D 5617	30	30	30
Carbon Black Content[3], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596		--Note 4--	
Oxidative Induction Time (OIT) Standard OIT, minutes	ASTM D 3895	100	100	100
Oven Aging at 85°C	ASTM D 5721			
High Pressure OIT - % retained after 90 days	ASTM D 5885	60	60	60
UV Resistance[5]	ASTM D 7238			
High Pressure OIT[6] - % retained after 1600 hrs	ASTM D 5885	35	35	35
Roll Dimensions				
1. Width (feet):		23	23	23
2. Length (feet):		750	500	375
3. Area (square feet):		17,250	11,500	8,625
4. Gross weight (pounds, approx.):		3,465	3,465	3,435

1 Of 10 readings; 8 must be ≥ 7 mils and lowest individual reading must be ≥ 5 mils.
2 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 2.0 inches.
3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
5 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
6 UV resistance is based on percent retained value regardless of the original HP-OIT value.

These data are provided for informational purposes only and are not intended as a warranty or guarantee. Poly-America, L.P. assumes no responsibility in connection with the use of these data. Suitablility for a particular use shall be determined by and is the sole responsibility of the end user. These values are subject to change without notice. REV. 03/14

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Property	Test Method	Minimum Average Values 1.00 mm	1.50 mm	2.00 mm
Thickness, microns	ASTM D 5994			
minimum average		950	1,425	1,900
lowest individual of 8 of 10 readings		900	1,350	1,800
lowest individual of 10 readings		850	1,275	1,700
Asperity Height[1], microns	ASTM D 7466	250	250	250
Sheet Density, g/cc (max.)	ASTM D 1505/D 792	0.939	0.939	0.939
Tensile Properties[2]	ASTM D 6693			
1. Break Strength, kN/m		11	16	21
2. Break Elongation, %		250	250	250
2% Modulus, MPa (max.)	ASTM D 5323	414	414	414
Tear Resistance, N	ASTM D 1004	100	150	200
Puncture Resistance, N	ASTM D 4833	200	300	400
Axi-Symetric Break Strain, %	ASTM D 5617	30	30	30
Carbon Black Content[3], %	ASTM D 1603	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Carbon Black Dispersion	ASTM D 5596		--Note 4--	
Oxidative Induction Time (OIT)				
Standard OIT, minutes	ASTM D 3895	100	100	100
Oven Aging at 85°C	ASTM D 5721			
High Pressure OIT - % retained after 90 days	ASTM D 5885	60	60	60
UV Resistance[5]	ASTM D 7238			
High Pressure OIT[6] - % retained after 1600 hrs	ASTM D 5885	35	35	35
Roll Dimensions				
1. Width (meters):		7	7	7
2. Length (meters):		228.7	152.4	114.3
3. Area (square meters):		1,603	1,068	801
4. Gross weight (kilograms, approx.):		1,572	1,572	1,558

1 Of 10 readings; 8 must be ≥ 180 microns and lowest individual reading must be ≥ 130 microns.
2 Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction. Break elongation is calculated using a gauge length of 50 mm.
3 Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
4 Carbon black dispersion for 10 different views: Nine in Categories 1 and 2 with one allowed in Category 3.
5 The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
6 UV resistance is based on percent retained value regardless of the original HP-OIT value.

2.4 Quality Control Specifications

2.4.1 Raw Materials

A. Resin

All resins for use in geomembrane must pass a candidate pre-approval process before being eligible for use. Each incoming railcar shall be sampled with the following testing performed and compared to the manufacturer's specifications:

1. Density: ASTM D 1505.
2. Melt Index: ASTM D 1238.
3. Oxidative Induction Time (OIT): ASTM D 3895.

B. Additives

All incoming materials are to be tested and approved prior to use with the following testing performed and compared to the manufacturer's specifications:

1. Carbon Black Content: ASTM D 1603.
2. Oxidative Induction Time (OIT): ASTM D 3895.

2.4.2 Finished Product: During Production

A. Inspection

Performed on each roll during manufacturing.

1. Appearance

Sheet surface appearance shall be monitored for flaws.

2. Thickness

A full width sample shall be cut from the end of each roll for thickness measurement.

B. Out-of-Spec. Material

Any roll not meeting the specification for any of the above inspections shall be separated from other rolls and placed on hold.

C. Roll Identification

Four tags per roll shall be used.

1. Inside the core.
2. On the core plug.
3. On the roll surface.
4. On the production roll sample.

2.4.3 Manufacturer's Quality Control & Quality Assurance Testing

A. Sampling

Full width samples shall be taken as retains from the end of each roll to the manufacturer's laboratory.

B. Testing

The geomembrane quality control testing shall meet the following frequency requirements:

Property	Test Method	Testing Frequency (min.)
Thickness (smooth sheet) (textured sheet)	ASTM D 5199 ASTM D 5994	per roll
Asperity Height (textured sheet only) Alternate the measurement side for double-sided textured sheet.	ASTM D 7466	every second roll
Sheet Density	ASTM D 1505/D 792	200,000 lb (90,000 kg)
Tensile Properties 1. Yield Strength (HDPE only) 2. Break Strength 3. Yield Elongation (HDPE only) 4. Break Elongation	ASTM D 6693	20,000 lb (9,000 kg)
2% Modulus (LLDPE only)	ASTM D 5323	per each formulation
Tear Resistance	ASTM D 1004	45,000 lb (20,000 kg)
Puncture Resistance	ASTM D 4833	45,000 lb (20,000 kg)
Axi-Symetric Break Strain (LLDPE only)	ASTM D 5617	per each formulation
Stress Crack Resistance (HDPE only)	ASTM D 5397 (App.)	per GRI GM10
Carbon Black Content	ASTM D 1603	20,000 lb (9,000 kg)
Carbon Black Dispersion	ASTM D 5596	45,000 lb (20,000 kg)
Oxidative Induction Time (OIT) Standard OIT	ASTM D 3895	200,000 lb (90,000 kg)
Oven Aging at 85°C High Pressure OIT	ASTM D 5721 ASTM D 5885	per each formulation
UV Resistance High Pressure OIT	ASTM D 7238 ASTM D 5885	per each formulation

C. **Reporting**

Results from the testing shall be reviewed by the quality control manager. The test data shall then be transferred to the product data file for roll certification. Material that does not meet specifications shall be identified and placed on hold.

3. GEOMEMBRANE INSTALLATION

3.1 Materials Logistics

3.1.1 Transportation and On-site Storage

The geomembrane rolls shall be shipped by flatbed trailer to the job site. The geomembrane shall be stored so as to be protected from puncture, dirt, grease, moisture, and excessive heat. Damaged material shall be stored separately for repair or replacement. The rolls shall be stored on a prepared smooth surface (not wooden pallets) and should not be stacked more than two rolls high.

3.2 Earthwork

3.2.1 General

The owner or his representative (soil quality assurance inspector) shall inspect the subgrade preparation. Prior to liner installation the subgrade shall be compacted in accordance with the project specifications. Weak or compressible areas which cannot be satisfactorily compacted should be removed and replaced with properly compacted fill. All surfaces to be lined shall be smooth and free of all foreign and organic material, sharp objects, or debris of any kind. The subgrade shall provide a firm, unyielding foundation with no sharp changes or abrupt breaks in grade. Standing water or excessive moisture shall not be allowed.

The installer, on a daily basis, shall approve the surface on which the geomembrane will be installed. After the supporting soil surface has been approved, it shall be the installer's responsibility to indicate to the inspector any changes to its condition that may require repair work.

3.2.2 Anchor Trench

The anchor trench shall be excavated to the line, grade, and width shown on the project construction drawings, prior to liner system placement. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the geomembrane.

3.3 Method of Placement

The rolls shall be deployed using a spreader bar assembly attached to a loader bucket or by other methods approved by the project engineer.

The installer shall be responsible for the following:

1. Equipment or tools shall not damage the geomembrane during handling, transportation, or deployment.
2. Personnel working on the geomembrane shall not smoke or wear shoes that may damage the geomembrane.

3. The method used to unroll the panels shall not cause scratches or crimps in the geomembrane and shall not damage the supporting soil.
4. Adequate loading (e.g., sand bags or similar items that will not damage the geomembrane) shall be placed to prevent uplift by wind (in case of high winds, continuous loading is recommended along edges of panels to minimize risk of wind flow under the panels).

3.3.1 Weather Conditions

Geomembrane deployment shall proceed between ambient temperatures of 32° F and 104° F. Placement can proceed below 32° F only after it has been verified by the inspector that the material can be seamed according to the specification. Geomembrane placement shall not be done during any precipitation, in the presence of excessive moisture (e.g., fog, rain, dew) or in the presence of excessive winds, as determined by the installation supervisor.

3.4 Field Seaming

Approved seaming processes are fusion and extrusion welding. On side slopes, seams shall be oriented in the general direction of maximum slope, i.e., oriented down, not across the slope. In corners and odd-shaped geometric locations, the number of field seams shall be minimized.

No base T-seam shall be closer than 5 feet from the toe of the slope. Seams shall be aligned with the least possible number of wrinkles and "fishmouths." If a fishmouth or wrinkle is found, it shall be relieved and cap-stripped.

3.4.1 Seam Overlap

Geomembrane panels must have a finished minimum overlap of 4 inches for fusion welding and 6 inches for extrusion welding.

Cleaning solvents may not be used unless the product is approved by the liner manufacturer.

3.4.2 Test Seams

Field test seams shall be conducted on the liner to verify that seaming conditions are satisfactory. Test seams shall be conducted at the beginning of each seaming period, and at least once every 4 hours, for each seaming apparatus and personnel used that day.

All test seams shall be made in contact with the subgrade. Welding rod used for extrusion welding shall be manufactured from the same type of resin as the geomembrane. The test seam samples shall be 10 feet long for fusion welding and 3 feet long for extrusion welding with the seam centered lengthwise. Three specimens shall be cut from each end of the test seams by the inspector. The inspector shall use a tensiometer to test 3 specimens for shear and 3 specimens for peel. Each specimen shall be one inch wide with a grip separation of 4 inches plus the width of the seam. The seam shall be centered between the clamps.

3.4.3 Assessment of Seam Test Results

Seam testing shall be performed in accordance with ASTM D 6392 and meet the requirements of GRI GM 19.

3.4.4 Non-Destructive Seam Testing

The installer shall non-destructively test all field seams over their full length.

A. Vacuum Box Testing

1. Seam testing shall be performed in accordance with ASTM D 5641.
2. All areas where animated soap bubbles appear shall be marked, repaired, and then retested.

B. Air Pressure Testing (For Double Fusion Seams Only)

1. Seam testing shall be performed in accordance with ASTM D5820.
2. Energize the air pump to a pressure between 25 and 30 psi, allow 2 minutes for the injected air to come to equilibrium in the channel, and sustain pressure for approximately 5 minutes.
3. If loss of pressure exceeds 4 psi, or pressure does not stabilize, locate faulty area, repair, and retest.

The following procedures shall apply to locations where seams cannot be non-destructively tested:

1. If the seam is accessible to testing equipment prior to final installation, the seam shall be non-destructively tested prior to final installation.
2. If the seam cannot be tested prior to final installation, the seams shall be spark tested according to the spark tester manufacturer's procedures.

3.4.5 Destructive Seam Testing

Destructive seam testing should be minimized to preserve the integrity of the liner. The installer shall provide the inspector with one destructive test sample per project specifications (usually once per 500 feet of seam length) from a location specified by the inspector.

A. Sampling Procedure

In order to obtain test results prior to completion of liner installation, samples shall be cut by the installer as the seaming progresses. The installer shall also record the date, location, and a pass or fail description. All holes in the geomembrane resulting from obtaining the seam samples shall be immediately patched and vacuum tested.

B. Size and Disposition of Samples

The samples shall be 12 inches wide by 36 inches long with the seam centered lengthwise. The sample shall be cut into three equal-length pieces, one to be given to the inspector, one to be given to the owner, and one to the installer.

C. Field Laboratory Testing

Seam testing shall be performed in accordance with ASTM D 6392 and meet the requirements of GRI GM 19.

D. Independent Laboratory Testing

The owner, at his discretion and expense, may send seam samples to a laboratory for testing. The test method and procedures to be used by the independent laboratory shall be the same as used in field testing.

E. Procedures for Destructive Test Failure

The following procedures shall apply whenever a sample fails the field destructive test:

1. The installer shall cap strip the seam between the failed location and any passed test locations.
2. The installer can retrace the welding path to an intermediate location (usually 10 feet from the location of the failed test), and take a sample for an additional field test. If this test passes, then the seam shall be cap stripped between that location and the original failed location. If the test fails, then the process is repeated.
3. Over the length of seam failure, the installer shall either cut out the old seam, reposition the panel and reseam, or add a cap strip.

3.4.6 Repairs

All seams and non-seam areas of the geomembrane shall be inspected by the inspector. The surface of the geomembrane shall be clean at the time of inspection.

A. Evaluation

Each suspect location in seam and non-seam areas shall be non-destructively tested as appropriate in the presence of the inspector. Each location that fails the non-destructive testing shall be marked by the inspector and repaired accordingly.

B. Repair Procedures

1. Defective seams shall be cap stripped or replaced.
2. Small holes shall be repaired by extrusion welding a bead of extrudate over the hole. If the hole is larger than 1/4 inch, it shall be patched.
3. Tears shall be repaired by patching. If the tear is on a slope or an area susceptible to stress and has a sharp end it must be rounded prior to patching.
4. Large cuts shall be repaired by patches.
5. Patches shall be completed by extrusion welding. The weld area shall be ground no more than 10 minutes prior to welding. No more than 10% of the thickness shall be removed by grinding. Welding shall commence where the grinding started and must overlap the previous seam by at least 2 inches. Reseaming over an existing seam without regrinding shall not be permitted. The welding shall restart by grinding the existing seam and rewelding a new seam.
6. Patches shall be round or oval in shape, made of the same geomembrane, and extend a minimum of 6 inches beyond the edge of defects.

C. Verification of Repairs

Each repair shall be non-destructively tested. Repairs that pass the non-destructive test shall be taken as an indication of an adequate repair. Failed tests indicate that the repair shall be repeated and retested until passing test results are achieved.

The inspector shall keep daily documentation of all non-destructive and destructive testing. This documentation shall identify all seams that initially failed the test and include evidence that these seams were repaired and successfully retested.

3.5 Cover Material and Backfilling of Anchor Trench

The geomembrane shall be covered as soon as possible. The covering operation shall not damage the geomembrane. The cover soil material shall be free of foreign and organic material, sharp objects, or debris of any kind, which could potentially damage the geomembrane. No construction equipment or machinery shall operate directly on the geomembrane. The use of lightweight machinery (i.e., generators, etc.) with low ground pressure is allowed.

The anchor trench shall be backfilled by the earthwork contractor. Trench backfill material shall be placed and compacted in accordance with the project specifications.

Care shall be taken when backfilling the trenches to prevent any damage to the geomembrane. If damage occurs, it shall be repaired prior to backfilling.

3.6 Geomembrane Acceptance

The installer shall retain all ownership and responsibility for the geomembrane until accepted by the owner.

Final acceptance is when all of the following conditions are met:

1. Installation is finished.
2. Verification of the adequacy of all field seams and repairs, including associated testing, is complete.

INHERENT PROPERTIES OF POLYETHYLENE LINERS

The properties listed in the table below are primarily inherent to the resin type used to produce the liner or are directly proportional to the thickness of the liner and less dependent on the manufacturing method. Therefore, these properties will not change from roll to roll or even lot to lot. Hence, they should not be included as part of routine quality control testing. The exception to this is Oxidative Induction Time. This test is a measurement of the amount of anti-oxidant added to the resin to produce the finished sheet. This test can function both as a performance test and a quality control test. As a quality control test it is desirable to run the test at high temperatures to keep the test duration short. This test is routinely run at the time of manufacture. As a performance test it is desirable to run the test at lower temperatures. Testing at lower temperatures cannot be done for quality control purposes.

The information given below is based on nominal values. Individual test results may vary from these values depending upon the reproducibility of the test.

NOMINAL PROPERTIES

TEST DESCRIPTION	TEST METHOD	UNITS	HDPE	LLDPE
Modulus of Elasticity	ASTM D 6693	lb/in^2	110,000	45,000
Secant Modulus	ASTM D 5323	lb/in^2	60,000	45,000
Volatile Loss	ASTM D 1203	%	0.1	0.1
Dimensional Stability	ASTM D 1204	%	+/- 0.5	+/- 1.0
Water Absorption (24 hr @ 23 °C)	ASTM D 570	% change	0.1	0.1
Coefficient of Linear Thermal Expansion	ASTM D 696	(cm/cm • °c)	1.2 x 10-4	1.4 x 10-4
Moisture Vapor Transmission Rate (100 °F and 100% relative humidity)	ASTM E 96	$g/m^2 \cdot day$		
		100 mil	0.17	—
		80 mil	0.20	0.25
		60 mil	0.26	0.33
		40 mil	0.39	0.45
		30 mil	0.50	0.57
Low Temperature Brittleness	ASTM D 746	°F	<-112	<-112
Oxidative Induction Time	ASTM D 3895	minutes @ 200 °C	100	100
Multi-Axial Tension	ASTM D 5617	stress, lb/in^2	2200	1200
		strain, %	18	40+

POLY-FLEX® POLYETHYLENE EMBED CHANNEL SPECIFICATION

POLYETHYLENE EMBED CHANNEL SPECIFICATION

POLY-FLEX® POLYETHYLENE GEOMEMBRANES

GENERAL

1.1 Scope

The following describes parameters for the manufacture, supply, and installation of Poly-Flex® High Density Polyethylene Embed Channel (PEC). All procedures, operations, and methods shall be in strict accordance with the engineer's specifications and drawings.

1.2 References

ASTM International

1.3 Submittals

1. The manufacturer shall maintain test records of resins used to manufacture the PEC.
2. The contractor shall submit shop drawings showing the exact location and installation procedures.
3. At the engineer's request, sample(s) of PEC shall be submitted.

1.4 Manufacturer's Quality Control Testing

All resins for use in PEC must pass Poly-America, L.P.'s raw material specifications before being eligible for use. Each lot shall be sampled and tested in the Poly-America laboratory. The tests shall include density and melt index. All additives and concentrates must pass Poly-America specifications.

PRODUCT

2.1 Product

The PEC shall be manufactured by Poly-America, L.P. The raw material shall be made of polyethylene resins manufactured in the United States. Carbon black shall be added to the resin if the resin is not precompounded for ultra-violet resistance. The final product shall meet the following values:

Density:	ASTM D1505	≥ 0.940 g/cc
Melt Index:	ASTM D1238	≤ 1.0 g/10 minutes
Carbon Black Content:	ASTM D1603	2% - 3%
Tensile Strength at Yield:	ASTM D6693	2,100 lb/in^2
Dimensions:	As shown on the drawing on page 24.	
Weight:	0.45 lb/ft	
Length:	5 ft and 10 ft	

2.2 Shipment and Storage

PEC shall be shipped in a manner so as not to be damaged by packaging or handling and shall be stored in a clean environment.

INSTALLATION

PEC can be nailed to wooden forms or pushed or vibrated into poured concrete. A 3-inch clearance is recommended from concrete edges or corners.

3.1 Installation in Concrete Forms

PEC shall be installed inside the concrete forms in accordance with the shop drawings prior to pouring concrete. Place PEC in the designated locations with the surface of PEC in contact with the form. PEC shall be secured to the wooden forms by means of nails driven from the inside of PEC into the forms (see Step 1 drawing). All exposed nails shall be clipped at the surface of PEC after removal of the forms (see Step 2 drawing).

3.2 Fabrication

PEC can be prefabricated into frames and vibrated into freshly poured concrete. Small air vent holes shall be drilled in approximately 3-foot intervals in the surface of PEC prior to its placement into fresh concrete.

Welded connections are made by extrusion welding the back side of the 3.5-inch surface and the outside of the legs. Backup HDPE plates are sometimes used behind the surface to be welded to reinforce the connection. A very flat extrusion weld bead is then placed on the 3.5-inch surface. PEC can also be butt welded similar to HDPE pipe welding techniques (See Figure 1). The two pieces (A & B) to be welded are laid on a flat surface. Each piece is held in contact with the “welding mirror” (C) for approximately 45 seconds until a melt bead (D) forms at the mirror; the mirror is removed (E) and the pieces are pushed together (F) fusing the molten plastic. This process gives a full perimeter weld of the PEC. Care must be exercised to assure alignment of the channels after the weld. This method can also be used for miter joints.

It is necessary to prevent gaps or repair gaps caused by thermal contraction or improper placement of the PEC. The liner-to-PEC connection will not be water tight unless the channels are properly joined at their ends.

3.3 Seaming

All seaming shall be done in accordance with standard extrusion seaming procedures, as outlined in this manual, and by experienced technicians who are qualified to seam geomembranes.

The following steps shall be followed prior to welding Poly-Flex® liners to the PEC:

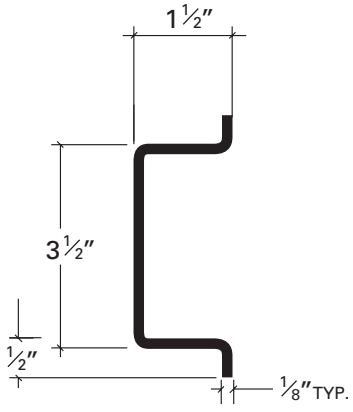
1. Remove cement paste, form oils, curing compound or other contaminants from the surface of PEC. The 3.5-inch wide surface shall be clean and dry. The welding surfaces of the PEC can be taped prior to its installation. The tape is removed after the concrete is hardened to expose the clean surfaces of PEC for welding.
2. Use a hot air gun to tack liner to PEC in a straight line in the center of the PEC surface.
3. A grinder with an 80-grit disc shall be used to remove the surface contamination and oxidation from the welding surface area prior to the extrusion welding. Place the extrudate on the center line (see Step 3 drawing). All air vent or nail holes shall also be ground and covered with the extrudate.

All seams shall be non-destructively tested, whenever possible, by using a vacuum box apparatus or spark testing if the PEC connection is designed to be waterproof.

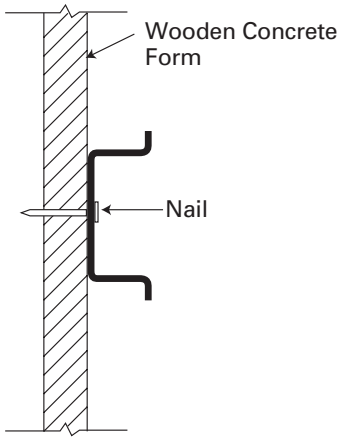
Since destructive seam testing is not possible, it is very important that seaming be done by qualified technicians.

POLYETHYLENE EMBED CHANNEL SPECIFICATION

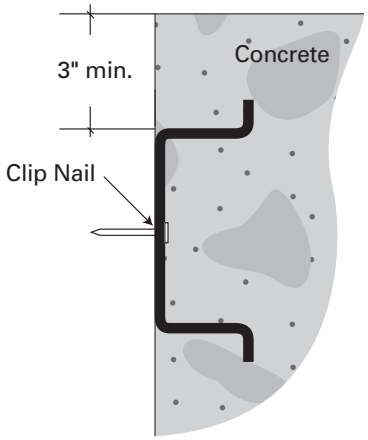
POLY-FLEX®
POLYETHYLENE GEOMEMBRANES



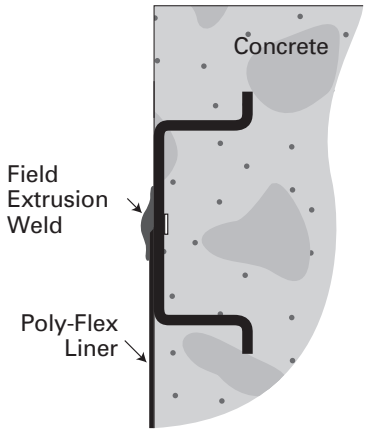
POLYETHYLENE EMBED CHANNEL (PEC)



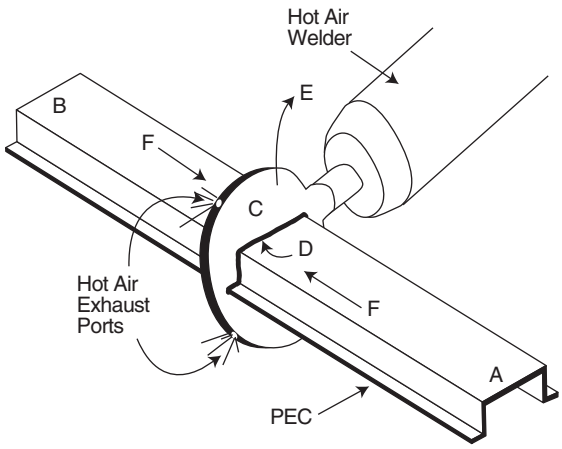
STEP 1. ATTACH PEC TO WOODEN FORM



STEP 2. PEC IN CONCRETE



STEP 3. WELD LINER TO PEC



"Welding Mirror" is a PTFE-coated Leister accessory for butt welding polyethylene and polypropylene profiles.

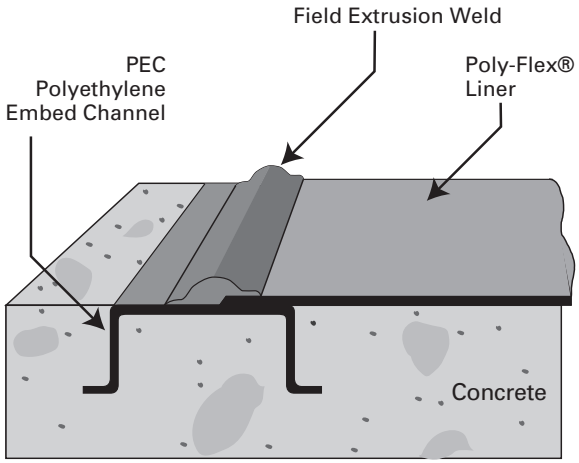


FIGURE 1

CHEMICAL RESISTANCE INFORMATION

CHEMICAL COMPATIBILITY OF POLY-FLEX® LINERS

Chemical compatibility or resistance, as applied to geomembranes, is a relative term. Actual compatibility would mean that one material dissolves in the other, such as alcohol in water or grease in gasoline. An example of incompatibility would be oil and water. In liners it is undesirable to have the chemicals dissolve in the liner, hence the term compatibility is the reverse of what is normally meant in the chemical industry. In the strictest sense and from a laboratory perspective, chemical compatibility, as the term applies to this industry, would imply that the chemical has no effect on the liner. From an engineering perspective, chemical compatibility means that a liner survives the exposure to a given chemical even though the chemical could have some effect on the performance of the liner, but not enough to cause failure. One must understand and define chemical compatibility for a specific project.

Generally polyethylene is affected by chemicals in one of three ways:

1. No effect—This means that the chemical in question and the polyethylene do not interact. The polyethylene does not gain (lose) weight or swell, and the physical properties are not significantly altered.
2. Oxidizes (cross linking)—Chemicals classed as oxidizing agents cause the polyethylene molecules to cross link and cause irreversible changes to the physical properties of the liner, i.e., they make the liner brittle.
3. Plasticizes—Chemicals in this classification are soluble in the polyethylene structure. They do not change the structure of the polyethylene itself but act as a plasticizer. In doing so, the liner experiences weight gain of 3-15%, may swell by up to 10%, and has measurable changes in physical properties (e.g. the tensile strength at yield may decrease by up to 20%). Even under these conditions the liner maintains its integrity and is not breached by liquids, provided the liner has not been subjected to any stress. These effects are reversible once the chemicals are removed and the liner has time to dry.

Aside from the effect that chemicals have on a liner is the issue of vapor permeation through the liner. Vapor permeation is molecular diffusion of chemicals through the liner. Vapor transmission for a given chemical is dependent primarily on liner type, contact time, chemical solubility, temperature, thickness, and concentration gradient, but not on hydraulic head or pressure. Transmission through the liner can occur in as little as 1-2 days. Normally, a small amount of chemical is transmitted.

As stated above, chemical compatibility is a relative term. For example, the use of HDPE as a primary containment of chlorinated hydrocarbons at a concentration of 100% may not be recommended, but it may be acceptable at 0.1% concentration for a limited time period or may be acceptable for secondary containment. Factors that go into assessment of chemical compatibility are type of chemical(s), concentration, temperature, and the type of application. No hard and fast rules are available to make decisions on chemical compatibility. Even the EPA 9090 test is just a method to generate data so that an opinion on chemical compatibility can be more reliably reached.

A simplified table on chemical resistance is provided to act as a screening process for chemical containment applications.

POLY-FLEX
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CHEMICAL RESISTANCE INFORMATION

CHEMICAL CLASS	CHEMICAL EFFECT	PRIMARY CONTAINMENT (LONG TERM CONTACT) HDPE	PRIMARY CONTAINMENT (LONG TERM CONTACT) LLDPE	SECONDARY CONTAINMENT (SHORT TERM CONTACT) HDPE	SECONDARY CONTAINMENT (SHORT TERM CONTACT) LLDPE
CARBOXYLIC ACID	1				
- Unsubstituted (e.g. Acetic acid)		B	C	A	C
- Substituted (e.g. Lactic acid)		A	B	A	A
- Aromatic (e.g. Benzoic Acid)		A	B	A	A
ALDEHYDES	3				
- Aliphatic (e.g. Acetaldehyde)		B	C	B	C
- Hetrocyclic (e.g. Furfural)		C	C	B	C
AMINE	3				
- Primary (e.g. Ethylamine)		B	C	B	C
- Secondary (e.g. Diethylamine)		C	C	B	C
- Aromatic (e.g. Aniline)		B	C	B	C
CYANIDES (e.g. Sodium Cyanide)	1	A	A	A	A
ESTER (e.g. Ethyl acetate)	3	B	C	B	C
ETHER (e.g. Ethyl ether)		C	C	B	C
HYDROCARBONS	3				
- Aliphatic (e.g. Hexane)		C	C	B	C
- Aromatic (e.g. Benzene)		C	C	B	C
- Mixed (e.g. Crude oil)		C	C	B	C
HALOGENATED HYDROCARBONS	3				
- Aliphatic (e.g. Dichloroethane) +A4		C	C	B	C
- Aromatic (e.g. Chlorobenzene)		C	C	B	C
ALCOHOLS	1				
- Aliphatic (e.g. Ethyl alcohol)		A	A	A	A
- Aromatic (e.g. Phenol)		A	C	A	B
INORGANIC ACID					
- Non-oxidizers (e.g. Hydrochloric acid)	1	A	A	A	A
- Oxidizers (e.g. Nitric Acid)	2	C	C	B	C
INORGANIC BASES (e.g. Sodium hydroxide)	1	A	A	A	A
SALTS (e.g. Calcium chloride)	1	A	A	A	A
METALS (e.g. Cadmium)	1	A	A	A	A
KETONES (e.g. Methyl ethyl ketone)	3	C	C	B	C
OXIDIZERS (e.g. Hydrogen peroxide)	2	C	C	C	C

Chemical Effect (see discussion on Chemical Resistance)

1. No Effect—Most chemicals of this class have no or minor effect.
2. Oxidizer—Chemicals of this class will cause irreversible degradation.
3. Plasticizer—Chemicals of this class will cause a reversible change in physical properties.

Chart Rating

A. Most chemicals of this class have little or no effect on the liner.
Recommended regardless of concentration or temperature (below 150° F).

B. Chemicals of this class will affect the liner to various degrees.
Recommendations are based on the specific chemical, concentration, and temperature.
Consult the design engineer.

C. Chemicals of this class at high concentrations will have a significant effect on the physical properties of the liner.
Generally not recommended but may be acceptable at low concentrations and with special design considerations.
Consult the design engineer.

The data in this table are provided for informational purposes only and are not intended as a warranty or guarantee. Poly-America, L.P. assumes no responsibility in connection with the use of these data. Consult with the design engineer for specific chemical resistance information and liner selection.

GEOMEMBRANE MANUFACTURING QUALITY CONTROL & QUALITY ASSURANCE

1. DEFINITIONS

Manufacturing Quality Control (MQC) is a planned system of routine inspections that is used to directly monitor and control the quality of a material.

Manufacturing Quality Assurance (MQA) is independent of the MQC and includes inspections, verifications, audits, and evaluations of materials and workmanship necessary to determine and document the quality of a material.

2. MANUFACTURING QUALITY CONTROL AND QUALITY ASSURANCE PROGRAM

2.1 Raw Material

Poly-America L.P.'s quality control and quality assurance for HDPE and LLDPE geomembrane manufacturing starts with the testing of the raw materials. The resin manufacturers provide documentation confirming that the raw materials comply with Poly-America specifications.

Resin manufacturers report the following properties with each resin shipment:

Density	This property is a measure of unit weight and is an indicator of the degree of crystallinity. It can be related to the material's chemical resistance, rigidity, permeability, tensile strength, and deformation characteristics.
Melt Index	This property is an indication of the molecular weight and rheological properties of the polymer and can be related to the processability.
Carbon Black Content (pre-compounded only)	The carbon black content is an important property to ensure protection against ultraviolet radiation. The raw materials may be pre-compounded with the carbon black. However, if resins are not pre-compounded, Poly-America≥ will supplement them with the appropriate quantity of carbon black before manufacturing liner.

2.1.1 Geomembrane Material Railcar Acceptance

All resins, additives, and concentrates used in Poly-Flex® geomembranes must have their physical integrity validated before they can be released into the production material stream. All incoming railcars are sampled; incoming materials not delivered by railcar are statistically sampled. Upon verification of the resin compliance with the specifications, the resin is pumped from the railcar into the silos dedicated to the production of the geomembrane.

1. Resin samples are taken from each of the four payload compartments in an incoming railcar.
2. Resin samples are sent to the laboratory. Using state of the art equipment, highly trained Quality Assurance personnel test the resin to ensure that it meets the specifications for producing Poly-Flex® geomembranes. The following tests are performed and compared against Poly-America specifications:

Property	Resins	Additives & Concentrates
Density (ASTM D 1505)	•	
Melt Index (ASTM D 1238)	•	
Carbon Black Content (ASTM D 1603)		•
Oxidative Induction Time (ASTM D 3895)	•	•

3. After meeting production specifications, the resin is pumped from its railcar into a silo dedicated to that material.
4. Off-spec material is returned to the vendor.

Applicable Test Methods

ASTM International

ASTM D 792	Specific gravity (relative density) and density of plastics by displacement
ASTM D 1004	Initial tear resistance of plastic sheeting
ASTM D 1238	Flow rates of thermoplastics by extrusion plastometers
ASTM D 1505	Density of plastics by the Density-Gradient technique
ASTM D 1603	Carbon black in olefin plastics
ASTM D 1898	Sampling of plastics
ASTM D 3895	Test method for oxidative induction time of polyolefins by thermal analysis
ASTM D 4833	Index Puncture Resistance of geotextiles, geomembranes and related products
ASTM D 5199	Test method for measuring nominal thickness of geotextiles and geomembrane
ASTM D 5323	Determination of 2% secant modulus for polyethylene geomembranes
ASTM D 5397	Procedure to perform a single point notched constant tensile load - Appendix (SP-NCTL) test
ASTM D 5596	Test method for microscopic evaluation of the dispersion of carbon black in polyolefin geosynthetics
ASTM D 5617	Multi-axial tension test for geosynthetics
ASTM D 5721	Practice for air-oven aging of polyolefin geomembranes
ASTM D 5885	Test method for oxidative induction time of polyolefin geosynthetics by high pressure differential scanning calorimetry
ASTM D 5994	Test method for measuring the core thickness of textured geomembranes
ASTM D 6392	Determining the integrity of nonreinforced geomembrane seams produced using thermofusing methods
ASTM D 6693	Determining tensile properties of nonreinforced polyethylene and nonreinforced flexible polypropylene geomembranes
ASTM D 7238	Effect of exposure of unreinforced polyolefin geomembrane using fluorescent UV condensation apparatus
ASTM D 7466	Measuring the asperity height of textured geomembrane

Geosynthetic Research Institute (GRI) Standards

GM 10	Specification for the stress crack resistance of geomembrane sheet
GM 19	Seam strength and related properties of thermally bonded polyolefin geomembranes

Addendum to Test Procedures

The following are modifications or clarifications to test procedures:

1. Specifications are based on the average of Machine Direction (MD) and Cross Direction (XMD) values.
2. Specimens shall be taken uniformly across the width of the sheet as stated in ASTM D 1898.

3. MANUFACTURING

3.1 Blown Sheet Process

Polyethylene resin is pumped directly from storage silos or from totes on the floor to hoppers above the extruder.

Hoppers feed resin into the extruder. The resin is heated to the melting point in the extruder barrel. It is conveyed through the barrel by the rotation of a specially designed screw which, in conjunction with heating elements along the barrel, provides consistency to produce a molten polymer stream.

The molten material is forced through a screen pack, which acts as a final filter for impurities or contaminants, and up through a die. It extrudes from the circular die as a film tube ("bubble"), pulled vertically by a set of nip rollers located at the top of a cooling tower. An IBC (Internal Bubble Cooling) unit, part of the extruder, maintains consistent bubble diameter. Material gauge is monitored and maintained by a computer system which controls the operation of the extruder.

At the top of the tower the bubble passes through a collapsing frame and is pulled through the nip rollers. The material is directed back toward the ground, and continues cooling as it approaches a winding machine. Before being taken up by the winder, the tube is split and spread to its deployable width. The winder rolls the finished geomembrane onto a specially made heavy-duty core.

3.2 Process Quality Control

Poly-Flex® geomembranes are manufactured via the blown film process. This is a continuous process. The key element to successfully producing a high-quality liner is to maintain consistency in both the raw material and the process. As described above, raw material consistency is established in the laboratory when the resin is initially received. Consistency during processing is assured by an on-line quality control monitor. This representative of the quality department has been specially trained to monitor the process and the liners during the manufacturing process.

The extrusion process starts with the verification of the formulation. This is done at the beginning of each order or blend change by the extrusion manager and then is continuously monitored by the on-line quality control representative.

The process conditions during manufacturing have been optimized for each resin formulation. These conditions are kept in a log book that is available to the line operator. These process conditions must be maintained throughout the production run. Any variation of process parameters from the set point range recorded on the process log book are immediately reported to the production supervisor by the on-line quality control represen-

tative. If the variation exceeds the control range, the quality control representative places the material being produced on hold. Materials are placed on hold until the process is brought under control.

The on-line quality monitor can also place material on hold if the material has any visual defect (holes, water spots, or scratches) or dimensional abnormalities (width, length, or thickness).

All materials placed on hold will be further inspected and tested. If the material passes specification and is approved by the quality control manager and/or production manager, the material will then be released into stock. If the material fails to pass specification or does not get approval of either the quality control manager or production manager then the material will be reclassified or scrapped. In either case it cannot be sold as a prime Poly-Flex® geomembrane.

Poly-Flex® geomembranes are continuously monitored for pinholes during the manufacturing process by spark testing equipment. The spark tester unit is a perpetual monitor of any holes that could surface in the sheet. The spark tester monitors the entire layflat width of the sheet as it is being manufactured. The detector operates from a 120 V AC power supply. The 120 volts are transformed to a higher voltage that ranges from 0-24 kilovolts. The electrode is made up of a long semiconductor blanket that is positioned to lay over the sheet as it passes over a steel roller prior to final winding. A grounding conductor is connected to the roller with a return line to the controller. If a hole passes under the electrically charged blanket, the voltage will arc to the steel roller and the detection system will sense the voltage drop, thus triggering an audible alarm and shutting down the winder. Twice per shift, the quality control technician tests the spark tester by introducing a 1/32" pinhole in the sheet. This hole is at the end of a roll after the scheduled footage has been achieved. The winder continues to run until the hole is detected. Once the hole is detected, the alarm sounds and the winder shuts down. The quality control technician restarts the winder and cuts out the entire layflat area of the pinhole.

After a roll of material has been produced it is labeled and a retain is cut for laboratory evaluation.

3.3 Roll Labeling

Three labels are affixed to each roll, as described below:

1. One label on the inside of the core.
2. One label on the core plug.
3. One label on the roll surface.

An additional label is attached to the laboratory sample.

3.4 Storage, Staging, and Shipping of Geomembrane Rolls

Finished rolls (verified and labeled) are moved to the storage area using a specially designed cart and remain in storage until a purchase order is received. Rolls selected for shipment are moved to a staging area, where they are held for a truck. Before loading the order for shipment, all documentation is checked against the information on the roll labels. Rolls are lifted and moved using a loading arm equipped with rigging and hooks. Fork-lifting machinery are never to be used to lift or move geomembrane rolls.

3.5 Laboratory Quality Control & Quality Assurance

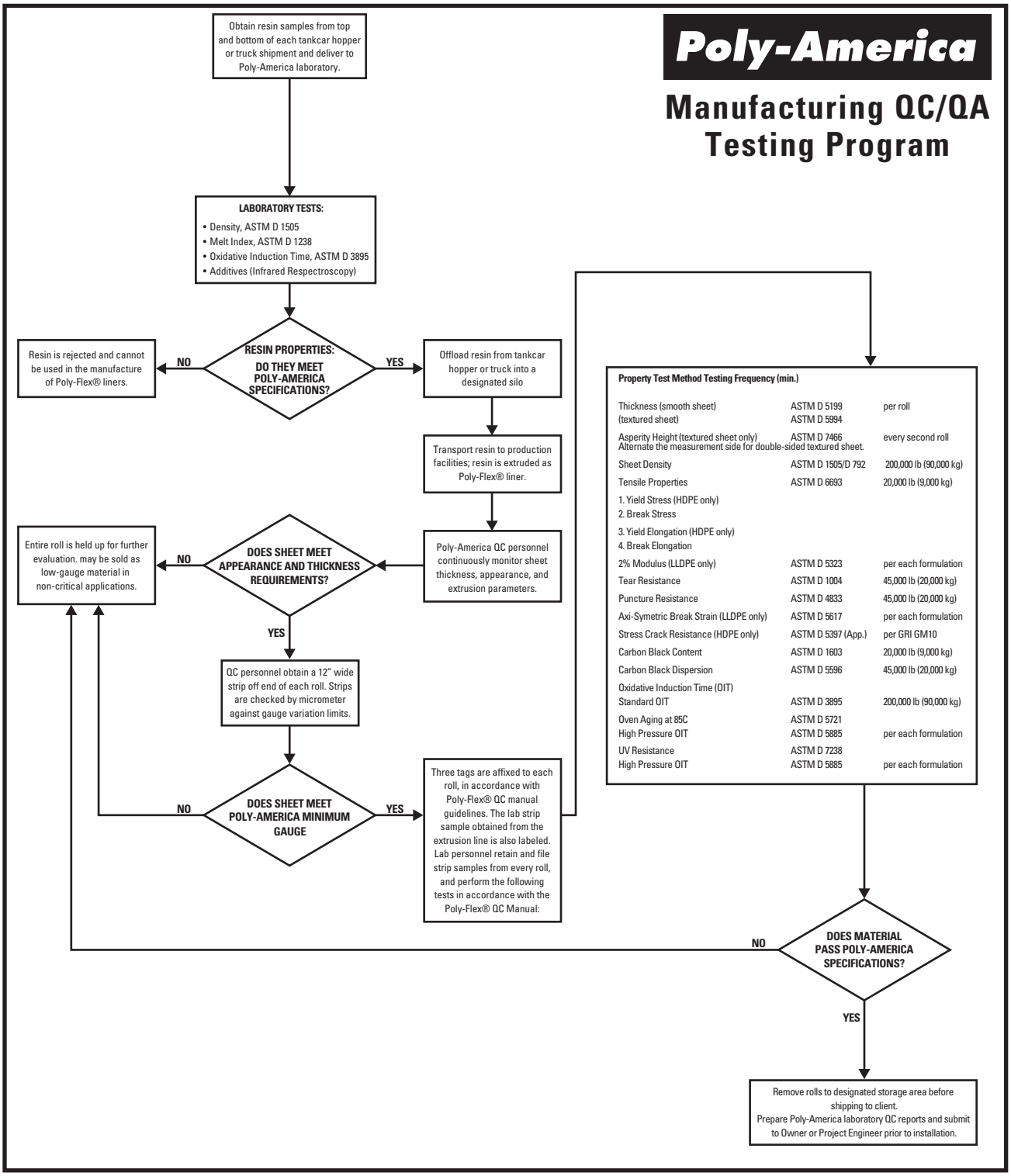
A retain from each roll is provided for the laboratory. Testing is conducted on the retains as indicated below.

Property	Test Method	Testing Frequency (min.)
Thickness (smooth sheet) (textured sheet)	ASTM D 5199 ASTM D 5994	per roll
Asperity Height (textured sheet only) Alternate the measurement side for double-sided textured sheet.	ASTM D 7466	every second roll
Sheet Density	ASTM D 1505/D 792	200,000 lb (90,000 kg)
Tensile Properties 1. Yield Strength (HDPE only) 2. Break Strength 3. Yield Elongation (HDPE only) 4. Break Elongation	ASTM D 6693	20,000 lb (9,000 kg)
2% Modulus (LLDPE only)	ASTM D 5323	per each formulation
Tear Resistance	ASTM D 1004	45,000 lb (20,000 kg)
Puncture Resistance	ASTM D 4833	45,000 lb (20,000 kg)
Axi-Symetric Break Strain (LLDPE only)	ASTM D 5617	per each formulation
Stress Crack Resistance (HDPE only)	ASTM D 5397 (App.)	per GRI GM10
Carbon Black Content	ASTM D 1603	20,000 lb (9,000 kg)
Carbon Black Dispersion	ASTM D 5596	45,000 lb (20,000 kg)
Oxidative Induction Time (OIT) Standard OIT	ASTM D 3895	200,000 lb (90,000 kg)
Oven Aging at 85°C High Pressure OIT	ASTM D 5721 ASTM D 5885	per each formulation
UV Resistance High Pressure OIT	ASTM D 7238 ASTM D 5885	per each formulation

After the testing has been completed, the data are reviewed by the quality control manager. If any rolls do not meet specifications, additional testing is conducted on that roll. If the roll still does not meet specifications the production manager is notified and the roll is placed on hold.

After the data have been reviewed they are entered into a product file which is used for roll certification.

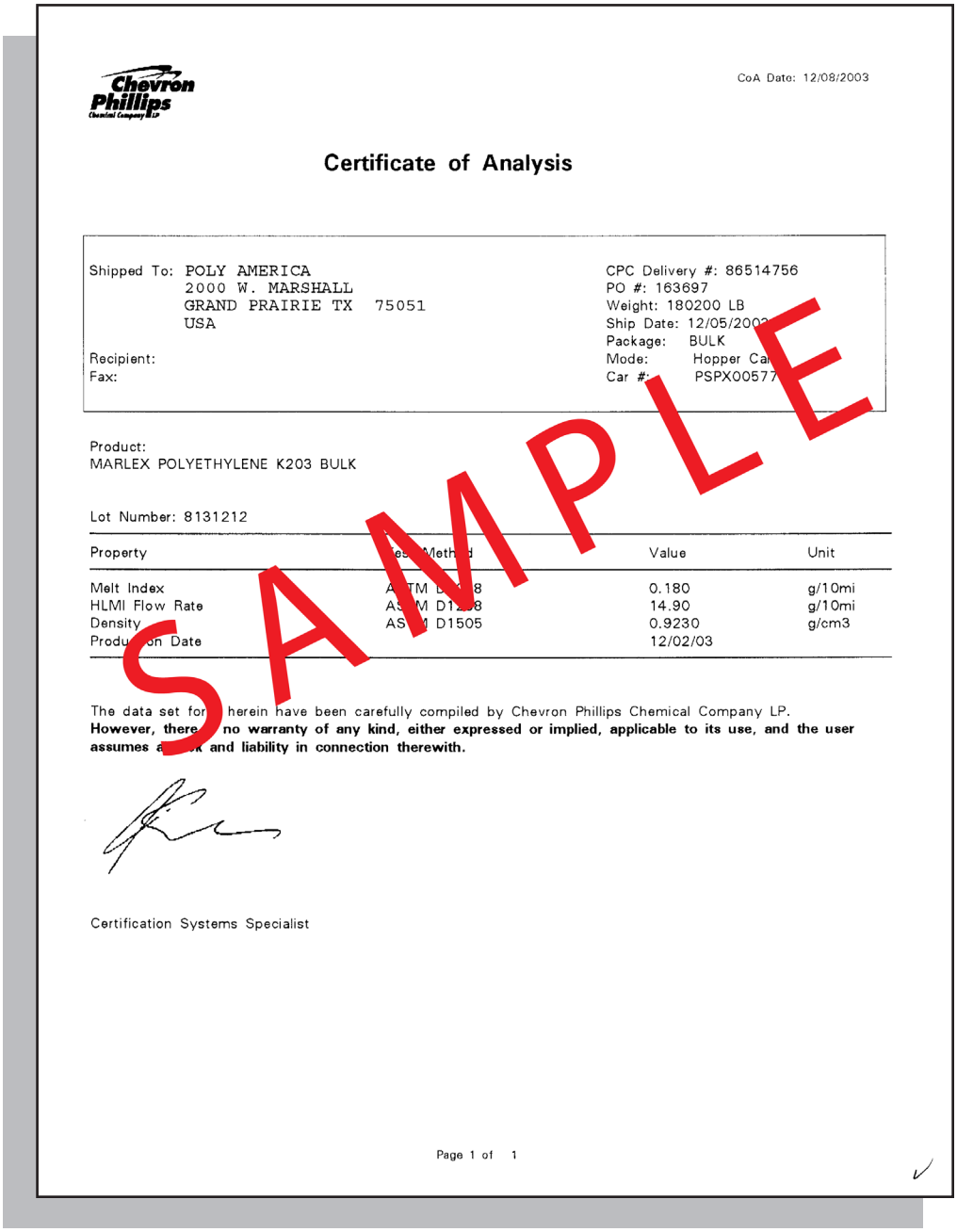
4. MANUFACTURING QUALITY CONTROL PROGRAM FLOW CHART



5. PAPER FLOW FORMS

5.1 Product Quality Report

This report documents the raw material manufacturer's test results for the physical properties of the incoming resin. Each incoming shipment to Poly-America is accompanied by such a report. A copy of this report is sent to the engineer/client with the finished product.



Chevron Phillips Chemical Company LP

CoA Date: 12/08/2003

Certificate of Analysis

Shipped To: POLY AMERICA
2000 W. MARSHALL
GRAND PRAIRIE TX 75051
USA

Recipient:
Fax:

CPC Delivery #: 86514756
PO #: 163697
Weight: 180200 LB
Ship Date: 12/05/2003
Package: BULK
Mode: Hopper Car
Car #: PSPX00577

Product:
MARLEX POLYETHYLENE K203 BULK

Lot Number: 8131212

Property	Test Method	Value	Unit
Melt Index	ASTM D1238	0.180	g/10mi
HLMI Flow Rate	ASTM D1238	14.90	g/10mi
Density	ASTM D1505	0.9230	g/cm3
Production Date		12/02/03	

SAMPLE

The data set forth herein have been carefully compiled by Chevron Phillips Chemical Company LP. **However, there is no warranty of any kind, either expressed or implied, applicable to its use, and the user assumes all risk and liability in connection therewith.**

Certification Systems Specialist

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5.2 Quality Control Report

This report is sent to the engineer/client as Poly-America, L.P.'s standard quality control report. It documents the property values of the specific rolls shipped to a project.

CERTIFICATION SHEET

DATE: _____

POLY-AMERICA, L.P.
2000 W. Marshall Drive
Grand Prairie, Texas 75051

PROJECT NO: _____ ORDER NO: _____

TRIP NO: _____ CERTIFIED BY: _____

TEST DESCRIPTION		THICKNESS	CARBON BLACK	TEAR	PUNCTURE	TENSILE □ □ /ELD	ELON □ □ /ELD	TENSILE □ BREAK	ELON □ □ BREAK	CAR □ BLK □ DISPERSION	DENSIT □	NCTL
ASTM METHOD		D5199	D1603	D1004	D4833	D6693	D6693	D6693	D6693	D5596	D1505	D5397
(modifications)		min/avg										Appendix
UNITS		mils	%	lb	lb	lb/in	%	lb/in	%		g/cc	hours
SPECIFICATION												
ROLL NUMBER	BLEND											

5.3 Hold Tag

During production, any roll found to be defective is tagged and immediately removed. The roll is not released for shipment, but it will be studied to determine the cause of the defect.

HOLD

FOR QUALITY DEPARTMENT EVALUATION.
DO NOT SEND THIS MATERIAL TO WAREHOUSE.

DATE _____ SHIFT _____

TIME _____ FILM LINE _____

QA INSP _____ ROLL NO. _____

PRODUCT CODE _____

REASON PRODUCT BEING HELD _____

_____

_____

_____

QUALITY DEPARTMENT ASSESSMENT

DATE _____

AUTHORIZATION _____

_____ RELEASE

_____ SCRAP

INSTRUCTIONS _____

_____

_____

_____

_____

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