

CONSTRUCTION SPECIFICATION

VA-797. FLEXIBLE MEMBRANE LINER

1. **SCOPE**

This work will consist of the furnishing and installation of a flexible membrane liner.

2. **MATERIALS**

All liner material furnished will have a nominal thickness as specified. The liner will be manufactured to be suitable for use in the specified exposed or buried conditions. The liner will be uniform in color, thickness, and surface texture. The liner will be resistant to fungal or bacterial attack and free of cuts, abrasions, holes, blisters, contaminates, and other imperfections.

a. **Smooth HDPE Liner**

The smooth HDPE liner will be formulated from virgin polymer material and will meet the properties listed in the table below.

Property	Test Methods	Requirements*		
		-----nominal thickness-----		
		30 mil	40 mil	60 mil
Density, g/cc	ASTM D1505	0.940	0.940	0.940
Tensile Properties	ASTM D6693 (type IV at 2 in/min)			
yield stress, lb/in		63	84	126
break stress, lb/in		114	152	228
yield elongation, %		12	12	12
break elongation, %		700	700	700
Tear resistance, lb	ASTM D1004	21	28	42
Puncture resistance, lb	ASTM D4833	54	72	108
Carbon black content, %	ASTM D1603	2-3	2-3	2-3
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2	Cat 1-2
Seam properties	ASTM D6392			
shear strength, lb/in		60	80	120
peel strength, lb/in**		39/FTB	52/FTB	78/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

b. Textured HDPE Liner

The textured HDPE liner will be formulated from virgin polymer material and will meet the properties listed in the table below.

Property	Test Methods	Requirements*		
		-----nominal thickness-----		
		30 mil	40 mil	60 mil
Density, g/cc	ASTM D1505	0.940	0.940	0.940
Tensile Properties	ASTM D6693 (type IV at 2 in/min)			
yield stress, lb/in		63	84	126
break stress, lb/in		45	60	90
yield elongation, %		12	12	12
break elongation, %		100	100	100
Tear resistance, lb	ASTM D1004	21	28	42
Puncture resistance, lb	ASTM D4833	45	60	90
Carbon black content, %	ASTM D1603	2-3	2-3	2-3
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2	Cat 1-2
Seam properties	ASTM D6392			
shear strength, lb/in		60	80	120
peel strength, lb/in**		39/FTB	52/FTB	78/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

c. Smooth LLDPE Liner

The smooth LLDPE liner will be formulated from virgin polymer material and will meet the properties listed in the table below.

Property	Test Methods	Requirements*		
		-----nominal thickness-----		
		30 mil	40 mil	60 mil
Density, g/cc	ASTM D1505	0.915	0.915	0.915
Tensile Properties	ASTM D6693 (type IV at 2 in/min)			
break stress, lb/in		114	150	228
break elongation, %		800	800	800
Tear resistance, lb	ASTM D1004	16	22	33
Puncture resistance, lb	ASTM D4833	42	56	84
Carbon black content, %	ASTM D1603	2-3	2-3	2-3
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2	Cat 1-2
Seam properties	ASTM D6392			
shear strength, lb/in		44	58	90
peel strength, lb/in**		37/FTB	50/FTB	75/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

d. Textured LLDPE Liner

The textured LLDPE liner will be formulated from virgin polymer material and will meet the properties listed in the table below.

Property	Test Methods	Requirements*		
		-----nominal thickness-----		
		30 mil	40 mil	60 mil
Density, g/cc	ASTM D1505	0.915	0.915	0.915
Tensile Properties	ASTM D6693 (type IV at 2 in/min)			
break stress, lb/in		60	80	120
break elongation, %		350	350	350
Tear resistance, lb	ASTM D1004	17	22	33
Puncture resistance, lb	ASTM D4833	33	44	66
Carbon black content, %	ASTM D1603	2-3	2-3	2-3
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2	Cat 1-2
Seam properties	ASTM D6392			
shear strength, lb/in		40	53	79
peel strength, lb/in**		33/FTB	44/FTB	66/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

e. Non-reinforced EPDM Liner

The non-reinforced EPDM liner will be formulated from virgin compounding materials and will meet the properties listed in the table below. Regrind, reworked, or trim materials will be from the same manufacturer and the same formulation as the liner. Recycled materials will not be allowed.

Property	Test Methods	Requirements*	
		-----nominal thickness-----	
		45 mil	60 mil
Specific gravity	ASTM D792	1.1	1.1
Tensile Properties	ASTM D882 (type IV at 20 in/min)		
break stress, lb/in		50	50
break elongation, %		400	400
Tear resistance, lb	ASTM D1004	9	11
Puncture resistance, lb	ASTM D4833	35	60
Low temperature brittleness, °F	ASTM D1790	<-45	<-45
Seam properties	ASTM D413/D4437		
shear strength, lb/in**	(NSF modified	35	35
peel strength, lb/in***	20 in/min strain rate)	14	14

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** At 200 percent strain.

*** Cohesive bond mode.

f. Reinforced EPDM Liner

The reinforced EPDM liner will be formulated from virgin compounding materials and will meet the properties listed in the table below. Re grind, reworked, or trim materials will be from the same manufacturer and the same formulation as the liner. Recycled materials will not be allowed.

Property	Test Methods	Requirements* nominal thickness 45 mil
Specific gravity	ASTM D792	1.1
Tensile Properties	ASTM D751 Method A	125
Tear resistance, lb	ASTM D5884 Method B	130
Puncture resistance, lb	FTMS 101C Method 2031	45
Ply adhesion, lb/in	ASTM D413 Machine method	7
Low temperature brittleness, °F	ASTM D1790	<-45
Seam properties		
shear strength, lb/in**	ASTM D751	35
peel strength, lb/in***	ASTM D413	14

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** At 200 percent strain.

*** Cohesive bond mode.

g. PVC Liner

The PVC liner will be manufactured from virgin polymers and other compounding materials and will meet the properties listed in the table below. Regrind, reworked, or trim materials will be from the same manufacturer and the same formulation as the liner. No more than 10 percent regrind, reworked, or trim materials will be used to manufacture the liner. Recycled materials will not be allowed. The PVC compound will consist of 50 to 70 percent PVC resin, by weight. Liquid plasticizers will be mixed until completely absorbed by the resin powder. Other additives will be thoroughly mixed into the resin.

Property	Test Methods	Requirements*	
		-----nominal thickness-----	
		30 mil	40 mil
Specific gravity	ASTM D792	1.2	1.2
Tensile Properties	ASTM D882 (MD and XD)		
break stress, lb/in		73	97
elongation at break, %		350	400
Tear resistance, lb	ASTM D1004	8.5	10.5
Low temperature brittleness, °C	ASTM D1790	<-29	<-29
Dimensional stability, % (max.)	ASTM D1204	3	3
Hydrostatic resistance, lb/in ²	ASTM D751 Method A	100	120
Seam properties	ASTM D6392/D6214/D4437**		
shear strength, lb/in		58	77
peel strength, lb/in		15	15

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

MD-Machine direction

XD-Cross-machine direction.

** ASTM D6392 shall be used for thermally welded seams, D6214 for chemically welded seams, and D4437 for all other types.

h. Unreinforced PP Liner

The unreinforced PP liner will be manufactured from virgin polymer material and will meet the properties listed in the table below.

Property	Test Methods	Requirements*		
		-----nominal thickness-----		
		30 mil	40 mil	60 mil
Specific gravity	ASTM D792	0.90	0.90	0.90
Tensile Properties	ASTM D638 (type IV at 20 in/min)			
break stress, lb/in		60	72	130
break elongation, %		600	600	600
Tear resistance, lb	ASTM D1004	9	11	16
Puncture resistance, lb	ASTM D4833	28	35	65
Carbon black content, %	ASTM D1603	2-4	2-4	2-4
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2	Cat 1-2
Low temperature brittleness, °C	ASTM D1790	<-40	<-40	<-40
Seam properties	ASTM D6392/D6214/D4437***			
shear strength, lb/in		35	45	55
peel strength, lb/in***		20/FTB	30/FTB	40/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** ASTM D6392 shall be used for thermally welded seams, D6214 for chemically welded seams, and D4437 for all other types.

*** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

i. Reinforced PP Liner

The reinforced PP liner will be manufactured from virgin polymer material and will meet the properties listed in the table below. A reinforced PP liner will consist of one ply of reinforcing polyester (scrim) between two sheets of PP. The polyester scrim will be an open weave that permits strike-through of the PP.

Property	Test Methods	Requirements*	
		-----nominal thickness-----	
		36 mil	45 mil
Specific gravity	ASTM D792	0.90	0.90
Tensile Properties	ASTM D751 Method A	225	225
Tear resistance, lb	ASTM D5884 Method B	55	75
Puncture resistance, lb	FTMS 101C Method 2031	200	250
Ply adhesion, lb/in	ASTM D413 Machine Method	20	20
Carbon black content, %	ASTM D1603	2-4	2-4
Carbon black dispersion	ASTM D5596	Cat 1-2	Cat 1-2
Low temperature brittleness, °C	ASTM D2136	<-40	<-40
Seam properties			
shear strength, lb/in	ASTM D751	160	200
peel strength, lb/in**	ASTM D413	20/FTB	20/FTB

* All values, unless specified otherwise, are minimum average roll values as reported for the test method.

** Film tear bond: A failure of one of the bonded sheets by tearing prior to complete separation in the bonded area.

3. SHIPPING AND STORAGE

Liner material will be delivered, handled, and stored according to the manufacturer's recommendations. Liner material will be stored and protected from puncture, dirt, grease, excessive heat, exposure to ultraviolet radiation, or other damage.

Damaged liner material will be repaired or replaced. Liner material that cannot be satisfactorily repaired to comply with the requirements of section 2 of this specification will be removed from the job site.

4. SUBGRADE PREPARATION

Subgrade soils will be compacted to provide a smooth, firm, and unyielding foundation. All subgrade surfaces will be free of organic material, rocks larger than 3/8 inch, angular rocks, or other sharp objects. Surface deformations will not exceed 1 inch. Standing water, mud, and snow will be removed prior to liner placements.

The liner will not be placed until the subgrade has been approved by the NRCS or SWCD representative.

5. ANCHOR TRENCH

The anchor trench will be constructed in accordance with the construction drawings. The trench corners will be slightly rounded to prevent sharp bends in the liner.

If sloughing of the trench occurs, the sloughed soils will be removed and necessary repairs will be made to provide a smooth trench wall. Standing water, mud, and snow will be removed prior to liner placement and trench backfill.

Soil material used for backfilling the trench will meet the requirements specified in section 4 of this specification. The trench will be backfilled in two equal lifts and compacted by rolling with rubber-tired equipment or manually directed compaction equipment.

6. LINER PLACEMENT

The liner will be installed with a minimum of handling by using a spreader bar assembly attached to a front-end loader, track-hoe bucket, or by other methods recommended by the liner manufacturer. The liner will be placed parallel to the direction of maximum slope. During installation, the liner will be secured with sandbags to protect it from wind uplift forces. The liner will be seamed and secured by the end of each workday.

Construction equipment will not be allowed to operate directly on the liner except for rubber-tired all terrain vehicles that produce ground pressure less than 5 pounds per square inch.

The liner will be placed in accordance with the manufacturer's recommendations and will not be placed during foggy conditions, precipitation events, or in the presence of excessive winds.

The liner will be loosely laid over the subgrade with sufficient slack to accommodate thermal expansion and contraction. Each panel will be laid out and positioned to minimize the number and length of liner seams and in accordance with the manufacturer's recommendations. The methods used to place panels will minimize wrinkles especially along field seams. Wrinkles will not exceed 6 inches in height or "fold over" during soil cover placement or other load application. When specified on the construction drawings or recommended by the manufacturer, a geosynthetic rub sheet will be used under the liner when dragging or moving the panels.

Liner panels will have a minimum seam overlap of 4 inches for hot wedge welding, hot air welding, chemical fusion welding, adhesive seams, inseam tape, and cover strip seams. A minimum seam overlap of 3 inches will be used for extrusion-welded seams. Upslope panels will overlap downslope panels to produce a shingle effect for drainage.

7. SEAMING METHODS

a. HDPE, LLDPE, PP

The primary method of seaming will be hot wedge fusion welding. Fillet extrusion welding will be used for repairs, T-seams, and detail work. Hot air fusion or chemical fusion welding may be used for PP.

b. PVC

Seams will be joined using hot wedge fusion welding, hot air fusion welding, chemical fusion welding, or an adhesive.

c. EPDM

Seams will be joined using double-faced in-seam tape or a cover strip recommended by the manufacturer.

8. SEAMING PROCEDURES

Seaming will extend to the outside edge of the liner to be placed in the anchor trenches. Seaming will not be conducted in the presence of moisture, dust, dirt, standing water, or soft subgrade. Seaming procedures will be in accordance with the liner manufacturer's recommendations.

a. Hot Wedge Welding

Hot wedge welding will be accomplished by a double-wedge fusion welder that produces a double track weld. Welding equipment and accessories will be in accordance with the liner manufacturer's recommendations. The welder will be calibrated at least once per day and at the beginning of each seaming period.

b. Fillet Extrusion Welding

Extrusion welding equipment and accessories will be in accordance with the liner manufacturer's recommendations. The extrusion welder will be calibrated at least once per day and at the beginning of each seaming period. To ensure proper bonding of the extrusion weld, edges of the patch material and the adjacent liner will be properly abraded by a light grinding. This operation will be done no more than 15 minutes before the welding operation. The abrasion process will remove no more than 10 percent of the material thickness.

c. Chemical Fusion Welding

The chemical fusion agent will be applied to both panels by a squeeze bottle or paintbrush. The width of application will be a minimum of 2 inches. Pressure will be applied to the seam in accordance with the liner manufacturer's recommendations to provide adequate contact between the panels. Excess agent extruded from the seam will be immediately removed.

d. Adhesive

Adhesive will be approved by the manufacturer and consist of material with a life expectancy similar to that of the liner material. The adhesive will be applied to both panels by a paintbrush or other approved method. The adhesive will cover the entire seam overlap. Pressure will be applied to the seam in accordance with the liner manufacturer's recommendations to provide adequate contact between the panels. Excess adhesive extruded from the seam will be immediately removed. Sealant will be as recommended by the liner manufacturer. Silicone sealant will not be used with PVC liner materials.

e. Inseam Tape

A primer will be applied to both panels by a scrub pad or other approved method recommended by the manufacturer. The primer will cover the entire seam overlap. As soon as the primer has flashed, install the tape on the bottom sheet, remove tape backing, lap the top sheet over the tape, and roll with sufficient pressure to provide adequate contact between the panels.

f. Cover Strip

A primer will be applied to both panels by a scrub pad or other approved method recommended by the manufacturer. The top sheet will be lapped over the bottom sheet and rolled to provide contact between the panels. Additional primer will be applied to cover the entire seam overlap. As soon as the primer has flashed, install the cover strip and roll it with sufficient pressure to provide adequate contact between the cover strip and the panels.

9. SEAM TESTING

Field seams will be nondestructively tested over their full length. Seam testing will be performed as the work progresses.

a. Nondestructive Seam Testing

Air pressure tests will be performed in accordance with ASTM D5820 on all double-track fusion seams. The air pressure test equipment and procedures will conform to this specification and the liner manufacturer's recommendations. Pressurize the air channel to 25 to 30 pounds per square inch for HDPE, LLDPE, and PP liners, 15 to 25 pounds per square inch for 30 mil PVC liners, and 20 to 30 pounds per square inch for 40 mil PVC liners.

Monitor any pressure drops for 5 minutes. A loss of pressure in excess of 4 pounds per square inch for HDPE, LLDPE, and PP liners, 5 pounds per square inch for 30 mil PVC liners, 4 pounds per square inch for 40 mil PVC liners, or a continuous loss of pressure is an indication of a leak. The location of all defective seams will be marked and repaired.

Vacuum box tests will be performed in accordance with ASTM D5641 on all seams and repairs made by extrusion welds and may be used on PP chemical fusion welds. Vacuum box tests will not be used on PVC liner seams. The location of all defective seams will be marked and repaired.

Air lance tests will be performed in accordance with ASTM D4437 on single-track fusion welds, chemical fusion welds, and on adhesive PVC seams and EPDM seams, and may be used on PP chemical fusion seams. The location of all defective seams will be marked and repaired per the requirements of section 10 of this specification.

b. Destructive Seam Testing

If required by the construction drawings, seam samples will be cut at no more than one sample per 500 feet of weld for destructive seam testing. All destructive seam samples will be tested in shear and peel modes in accordance with ASTM D6392 to verify seams meet the requirements in section 2 of this specification.

10. REPAIRS

All defective liner areas and failed seams will be repaired and retested.

a. Tears, Punctures, and Material Defects

All tears, punctures, and material defects in the liner will be repaired by installing a patch over the defective area. Surfaces of the liner to be patched will be cleaned before the repair. All patches will be of the same liner material and extend a minimum of 6 inches beyond the edges of the defect area. All patches will have rounded corners and will be seamed to the liner. Holes that are less than 0.25 inch in diameter on HDPE, LLDPE, and PP liners will be repaired by a bead of extrudent.

b. Seam Repair

Failed seams will be repaired by installing a cap strip over the entire length of failed seam. The cap strip will be of the same liner material and will extend beyond the failed seam a minimum of 6 inches in all directions. Alternatively, the upper flap may be extrusion welded to the liner along the entire length of the failed seam.

11. APPURTENANCES

The liner will be mechanically attached to pipe, concrete, or steel structures as shown on the construction drawings and according to liner the manufacturer's recommendations. All appurtenances will have the same properties as the liner material unless otherwise specified.

a. Pipe Boots

Factory fabricated pipe boots will be used as specified on the construction drawings. Pipe boots fabricated in the field will be from the same material as the liner. The boots will be welded and clamped to pipes of the same material as the liner. They will be clamped to other types of pipe as shown in the construction drawings, or as recommended by the manufacturer, to provide a leak-free attachment.

b. Gasket Material

Unless otherwise approved by the liner manufacturer, gasket material will be neoprene, closed-cell medium, 0.25 inch thick, with adhesive on one side.

c. Metal Battens

Metal battens will be 0.25 inch thick by 2 inch wide stainless steel. Metal battens will be installed according to the construction drawings and the liner manufacturer's recommendations. The battens will be bolted to concrete by stainless steelbolts on 6-inch intervals to create a leak-free connection under submerged conditions. Bolt spacing may be increased to 12 inches for connections above the fluid level. Clamps will be 0.5 inch wide stainless steel.

d. Embedded Channels

Embedded channels will be installed according to the construction drawings and the liner manufacturer's recommendations. The embedded channel will be prefabricated to the dimensions shown on the construction drawings. All sections of the channel will be continuously welded to subsequent sections before installation in the concrete forms. All corners will be miter cut and welded on all sides.

12. COVER SOIL

Cover soil and placement method will be in accordance with the construction drawings and will conform to the liner manufacturer's recommendations. Cover soils will meet the same requirements as specified for subgrade soils in section 4 of this specification. Cover soil placement will be performed by a loader or bulldozer with ground pressure of less than 8 pounds per square inch. Cover soil will not be dropped onto the liner from a height of more than 3 feet. Following construction of an access ramp, the soil will be placed from the bottom of the slope upward. Construction equipment or machinery will not operate directly on the liner. Cover soil will be placed during the coolest part of the day if possible.

13. PLACEMENT OF CONCRETE

Concrete placement for ramps and other appurtenances will be in accordance with the construction drawings. All reinforcing steel will be placed on flat-footed plastic rebar chairs. All rebar splices will be fully tied. On slopes, concrete will be placed from the bottom of the slope to the top. Metal shovels and rodding will not be used to consolidate or place the concrete. Concrete forms will be held in place by methods that avoid damaging the liner. All concrete will be in accordance with Construction Specification VA-731, Concrete Construction.