



SPECIFICATIONS

MONOLITHIC THERMOPLASTIC LINER SYSTEM FOR CONCRETE MANHOLES AND WET WELLS

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I. SCOPE OF WORK

- A. This specification shall govern for the furnishing of all work necessary to accomplish and complete the installation of monolithic thermoplastic liners for concrete manholes and wet wells.
- B. The liner system shall be **non-structural, third-party certified for wastewater infrastructure use, designed to provide a gastight and watertight homogenous barrier that protects concrete manholes and wet wells from corrosion, abrasion, inflow and infiltration.**
- C. The Liner System shall be modular and include the following main components:
- 1) Fiberglass Reinforced Plastic (FRP) concrete protective liners for manhole and wet well base section, and all appurtenances, **including but not limited to integral flow control systems (sliding gate plates and integrally molded slots), as specified in Contract Documents.**
 - 2) Polypropylene (PP) or high-density polyethylene (HDPE) concrete protective riser liner sections, including all appurtenances;
 - 3) Cone top configuration: FRP concrete cone liner section with integral FRP convertible collar and FRP telescopic access tube for round manway opening;

OR

Flat top configuration: PP or HDPE concrete protective liner, with integral FRP convertible collar and FRP telescopic access tube for round manway opening or lined rectangular opening for rectangular hatch opening;

- D. The Liner System shall be fabricated in an ISO 9001 certified facility and **manufactured by Predl Systems North America Inc, Burnaby, BC.**

II. GOVERNING STANDARDS

Manholes shall conform to the following design criteria:

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|----|------------|---|
| A. | ASTM D395: | Standard Test Methods for Rubber Property – Compression Set |
| B. | ASTM D412: | Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension |
| C. | ASTM D471: | Standard Test Method for Rubber Property – Effect of Liquids |
| D. | ASTM D543: | Standard Practices for Evaluating the Resistance of Plastics to Chemical Reagents |
| E. | ASTM D573: | Standard Test Method for Rubber – Deterioration in an Air Oven |
| F. | ASTM D624: | Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers |
| G. | ASTM D638: | Standard Test Method for Tensile Properties of Plastics |
| H. | ASTM D695: | Test Methods for Compressive Properties of Rigid Plastics |

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|----|----------------------------|---|
| I. | ASTM D790: | Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and electrical Insulating Materials |
| J. | ASTM D792: | Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement |
| K. | ASTM D1149: | Standard Test Methods for Rubber Deterioration – Cracking in an Ozone Controlled Environment |
| L. | ASTM D1238 | Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer |
| M. | ASTM D2137: | Standard Test Methods for Rubber Property - Brittleness Point of Flexible Polymers and Coated Fabrics |
| N. | ASTM D2240: | Standard Test Method for Rubber Property – Durometer Hardness |
| O. | ASTM D2584: | Test Method for Ignition Loss of Cured Reinforced Resins |
| P. | ASTM D4060: | Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser |
| Q. | DIN 53752 | Testing of Plastics – Determination of the Coefficient of Linear Thermal Expansion |
| R. | Greenbook 2009 (or later): | Standard Specifications for Public Works Construction, Chemical Resistance Test (Pickle Jar Test) |

III. GENERAL DESCRIPTION

A. Configuration:

The Liner System shall be modular and include the following main components:

1. **FRP Baseline:** The prefabricated Baseline shall be constructed from one-piece homogenous composite and/or thermoplastic with minimum thickness of 3 mm (1/8") and shall have nominal inside diameter corresponding to precast concrete base section as shown on Contract Documents.

Manhole Baseline shall include:

- a) Full flow channels with side walls to the crown of the pipe(s) or above;
- b) A non-skid pattern on inner bench surfaces;
- c) Integral slots to accommodate sliding gates for flow control purposes, as specified in Contract Documents;
- d) Gasketed, flexible and watertight, bell type, pipe connections for specific pipe types to receive the collection pipes at the exact angles and slopes as specified on Contract Documents.

Bells shall be monolithically attached to the manhole Baseline channels, be integral to the Baseline and have a water stop on the outside and a pipe stop on the inside that matches the diameter and wall thickness of the collection pipe and ensure that the flow line from the pipe stop to the inside channels are smooth and without obstruction. Bells shall conform to the outside and inside curvature of the manhole walls.

The standard vertical side wall (skirt) height above the bench shall be 2" - 3". Optional extended vertical side wall (skirt) height above the bench shall be 10" - 12". Other skirt heights, as agreed upon between the purchaser and the manufacturer, are covered by this specification.

Any optional slot meant to receive flow control gates shall be constructed in a one-step process at the time of FRP Baseline molding, resulting in a one-piece homogeneous liner.

Wet well Baseline shall include:

- a) Custom molded to Contract Document specifications, with exact sump, chamfer and skirt configuration;
- b) Stainless steel threaded inserts with pump-specific mounting pattern;

When installing a Baseline as part of a fully lined structure, with polypropylene (PP) or high density polyethylene (HDPE) wall liners, the Baseline shall have a smooth 3mm thick transition strip of corresponding liner material embedded into the FRP around the top lip at the time of manufacture to provide a transition and welding surface between the FRP Baseline and the adjoining PP or HDPE concrete protective wall liner.

2. **PP or HDPE Wall Liners:** All PP or HDPE liner sheets shall be extruded with a large number of anchoring studs, a minimum of 39 per SF (420/m²), manufactured during the extrusion process in one piece with the sheet so there is no welding and no mechanical finishing work to attach the studs to the sheet. Minimum distance between studs shall be no less than 2.1275". Stud height shall be no less than 13mm or 9/16".

Flat PP and HDPE sheets shall be heat welded to conform to the inside surface of the precast concrete structure. Penetrations through the wall liner can be accommodated with pipe sleeves or pipe bells. Pipe sleeves and Bells shall be monolithically attached to the Wall Liner. Bells shall have a water stop on the outside and a pipe stop on the inside that matches the diameter and wall thickness of the collection pipe and ensure that the flow line from the pipe stop to the inside channels are smooth and without obstruction. Pipe Sleeves and Bells shall conform to the outside and inside curvature of manhole or wet well walls.

Polypropylene ladder rungs with integral polypropylene rung inserts shall be installed if required in Contract Documents.

3. **FRP Cone Liner** (cone top configuration only) : The prefabricated FRP Cone liner shall be constructed from one piece homogenous composite and/or thermoplastic with minimum thickness of 3 mm (1/8") and shall conform to the inside of the precast concrete cone top section as shown on Contract Documents. The FRP Cone Liner component shall provide concrete protection from corrosion, abrasion, inflow and infiltration for the cone top section and shall feature an integral FRP Access Collar and Gasket at the manway opening, to receive an FRP Telescoping Access Tube.

When installing the Cone Liner as part of a fully lined structure, with polypropylene (PP) or high density polyethylene (HDPE) wall liners, the Cone Liner shall have a smooth 3mm thick transition strip of corresponding liner material embedded into the FRP around the top lip at the time of manufacture to provide a transition and welding surface between the FRP Baseline and the adjoining PP or HDPE concrete protective wall liner.

FRP Cone Liners are either concentric or eccentric, as specified in Contract Documents. Polypropylene ladder rungs with integral polypropylene rung inserts shall be installed if required in Contract Documents.

4. **PP or HDPE Flat Top Liner** (flat top slab configuration only): All PP or HDPE liner sheets shall be extruded with a large number of anchoring studs, a minimum of 39 per SF (420/m²), manufactured during the extrusion process in one piece with the sheet so there is no welding and no mechanical finishing work to attach the studs to the sheet. Minimum distance between studs shall be no less than 2.1275". Stud height shall be no less than 13mm or 9/16". For round manway openings, PP or HDPE flat top liners shall feature an integral FRP Access Collar and Gasket at the manway opening, to receive an FRP Telescoping Access Tube. For square hatch openings, the flat top liners shall feature a lined rectangular opening capable of accommodating a rectangular hatch as specified in Contract Documents.

5. **Telescoping Access Tube** (round manway opening only): The FRP Telescoping Access Tube shall provide concrete protection from corrosion, abrasion, inflow and infiltration for the manway entry section, between the casting at the finished grade and top of the manhole top section. The Telescoping Access Tube shall accommodate grading adjustments up to 12" of height.
6. **Flow Control Gates** shall provide flow control within the manhole base section, as specified in Control Documents. Flow control gates shall be constructed from a one-piece corrosion and abrasion resistant polypropylene plate. Multi-piece configurations shall optionally made available to accommodate weight and access limitations. A Flow Control Gate shall be present at all time during regular operation of the manhole and secured in place using corrosion resistant mechanical devices.

Basic Flow Control Gate configuration shall include a fully closed gate (no opening) and a fully open gate (opening corresponding to the flow channel internal diameter). Flow Control Gates with custom openings (v-notch, rectangular weirs, etc.) as agreed upon between the purchaser and the manufacturer, are covered by this specification.

Flow Control Gates shall feature handles to ease insertion, removal and general handling.

B. Thermoplastic Heat Welding

All fabrication and welding must be done by Predl Certified welders/fabricators in accordance with the published directives and procedures of the manufacturer. When the welding is completed and tested, the finished concrete product will be protected by a homogenous monolithic Thermoplastic Liner System that will provide excellent resistance to microbial attack, abrasion, and chemicals normally found in municipal waste water or storm water and will not pull off the wall in the event that infiltration occurs.

The following welding techniques are acceptable:

1. Extrusion Welding: Used to seal all seams inside structure, primary welding method.
2. Butt Welding: Used to fuse flat sheets together.
3. Hot Air Welding: Used as a tack weld or only in triple pass method where extrusion welding is not possible.

Testing and supervision of the fabrication, installation and welding shall only be performed by Predl trained and certified personnel and must be checked when completed by visually checking and by Spark Testing all welded joints. Spark Testing shall be performed in accordance with the equipment manufacturer's recommendations. After Spark Testing the finished liner, using a Black Magic Marker, the fabricator will sign and date wall liner and will photograph or video the welds and the signature and send copies of the photographs/video to the owner. Upon request, the Certified fabricator/welder will provide written verification of current certification.

- C. **Dimensions:** All liners shall have the same nominal inside diameters as the host structures, as specified in Contract Documents. Tolerance on the inside diameter shall be +/- 1%. Tolerance on over liner height as shall be the greater of +/-1% or +/-1/8". Allowable tolerance for invert elevation shall be 0.125" and 2% for pipe slope.

Default PP or HDPE liner thickness is 3 mm, 2 mm and 5 mm thicknesses are optional, as required in the Contract Documents.

Flow Control Gate dimensions shall be such that when fully inserted into its receiving slot a substantially watertight connection is obtained between the FRP Baseline flow channel and the gate and the top of the gate is substantially level with the FRP Baseline benching. Receiving slots shall be extend at least 1" into the flow channels. Default Flow Control Gate thickness is 40 mm but custom thicknesses shall be accommodated, as required in the Contract Documents.

C. Marking and Identification

Baseliner shall be marked with the following information:

- 1) Manufacturer's identification
- 2) Nominal diameter
- 3) Manhole identification
- 4) Detailed invert configuration
- 5) Installation assist marks molded into the Baseliner

All other liners shall be marked with the following information:

- 1) Manufacturer's identification
- 2) Nominal diameter
- 3) Manhole identification

IV. MATERIALS

- A. **FRP Liners (Baseliner and FRP Cone Liner):** The resins used shall be unsaturated, supplier certified, commercial grade polyester resins. Mixing lots of resin from different manufacturers or "odd-lotting" of resins shall not be permitted. Quality-assurance records on the resin shall be maintained.

The reinforcing materials shall be commercial grade "E-CR" type glass, specially formulated for corrosive environments, in the form of mat, chopped roving, continuous roving, roving fabric or a combination of the above, having a coupling agent that will provide a suitable bond between the glass reinforcement and resin. Fiberglass and/or polypropylene ribs and/or structural members may be utilized to meet the design criteria.

No inert fillers shall be used. Additives, such as thixotropic agents, catalysts, promoters, etc., may be added as required by the specific manufacturing process to be used to meet the requirements of this standard.

The laminate shall consist of multiple layers of glass matting and resin. The surface exposed to the sewer/chemical environment shall be resin rich and shall have no exposed fibers.

- B. **PP or HDPE Liners (Wall Liners, Flat Top Liners, Penetration Sleeves, etc.):** The material used in the liner, welding strips and other accessories shall be a combination of PP or HDPE resin, pigments and plasticizers, specially compounded to remain flexible. PP and HDPE resin shall constitute not less than 99 percent by weight of the resin used in the formulation. Liner material shall be AGRU Sure-Grip HDPE or PP. Thermoplastic welding filament shall be AGRU supplied, compatible with the liner material.
- C. **Bells:** Bell shall be manufactured from the same unsaturated, supplier certified, commercial grade polyester resins as the main FRP Baseliner body. If available, polypropylene injection molded Bells are also allowed.
- D. **Gaskets:** Resilient materials for connectors and filler rings shall be manufactured from natural or synthetic rubber and shall conform to the material requirements prescribed in this specification. If a splice is used in the manufacture of the seal, its strength shall be such that the seal shall with-stand a 180° bend with no visible separation.
- E. **Flow Control Gates:** The material used in Flow Control Gates shall be a combination of PP resin, pigments and plasticizers. PP resin shall constitute not less than 99 percent by weight of the resin used in the formulation.

- F. **Mechanical devices:** Expansion rings, tension bands, and take-up devices used for mechanically compressing the resilient portion of the connector against the pipe or manhole shall be made from a material or materials in combination that will ensure durability, strength, resistance to corrosion, and have properties that will ensure continued resistance to leakage.

All metallic mechanical devices and bolt assemblies used to mechanically deform resilient materials shall be constructed of corrosion resistant materials meeting the physical properties and chemical composition requirements of ASTM A493 and A666, Type 302 through Type 316.

- G. **Third party accessories:** Third party accessories integral to the baseliner (valves, gates, etc.) shall be governed by the respective manufacturers' materials specifications.

V. MANUFACTURE

- A. Manufacturer shall have 25 years of FRP and 10 years of HDPE/PP concrete protective liner manufacturing experience and shall have fabricated and delivered at least 20,000 concrete protective liners for wastewater applications

VI. REQUIREMENTS

- A. **FRP Exterior Surface:** The exterior surface shall be finished with embedded aggregates and FRP bonding bridges to allow for adequate bonding with the surrounding concrete once cast. The exterior surface shall be free of blisters larger than 0.5" in diameter, delamination and fiber show, except in the vicinity of FRP bonding bridges where fiber show is acceptable. **Gel-coat or paint or other coatings are not allowed.**
- B. **FRP Interior Surface:** The interior surfaces shall be resin rich with no exposed fibers. Interior flow surfaces shall be smooth for improved corrosion resistance and reduced sludge build-up. The surface shall be free of crazing, delamination, blisters larger than 0.25" in diameter, and wrinkles of 0.125" or greater in depth. **Gel-coat shall be permitted on interior surfaces, no paint or other coatings are allowed.**
- C. **Repairs:** Any liner repair is required to meet all requirements of this specification. All repair must all be preapproved by the manufacturer.
- D. **Chemical Resistance:** Liners must demonstrate having sufficient corrosion resistance by passing the "Greenbook" 2009 edition (or later), Standard Specifications for Public Works Construction, Chemical Resistance Test (Pickle Jar Test), per third-party accredited laboratory test results.
- E. **Physical Properties:**

All FRP liner material shall have the following physical properties when tested at 77 °F ± 5 degrees:

Property	Standard	Units	Initial	(Par. VI.F.)
Density	ASTM D792	g/cm ³	1.02	
Thickness	--	Mm	3 min.	--
Tensile Strength	ASTM D638	psi	7,000 min.	6,500 min.
Hardness (Shore "A")	ASTM D2240		95-97	89-97
Weight change	--	--	--	0.05% max.
Flexural Strength	ASTM D790	lbf	124 avg.	--
Compressive Strength	ASTM D695	psi	13,000	--
Ignition Loss	ASTM D2584	%	52 avg.	--
Taber abrasion test (weight loss)	ASTM D4060	%	0.075	--

Tensile specimens shall be prepared and tested in accordance with ASTM D412 using Die B. Weight change specimens shall be 1 IN by 3 IN samples.

All PP liner material shall have the following physical properties when tested at 77 °F ± 5 degrees:

Property	Standard	Units	Initial	(Par. VI.F)
Density	ASTM D792	g/cm ³	0.91	--
Thickness	--	mm	3	--
Melt Flow Index (230/5)	ASTM D1238	g/10min	1.25	--
Liner coefficient of thermal expansion	DIN 53752	K ⁻¹ x10 ⁻⁴	1.6	--
Tensile Strength	ASTM D638	psi	10000 min.	9000
Elongation at max load	ASTM D638	--	140%	128%
Elongation at break	ASTM D638	--	250% min.	250% min.
Hardness (Shore "A")	ASTM D2240		90-95	85-95
Weight change		--	--	0.05% max.
Taber abrasion test (weight loss)	ASTM D4060	--	0.1%	--
Pullout resistance (per anchor)	Greenbook 210-2.3.4	lbf	>300	--

Tensile specimens shall be prepared and tested in accordance with ASTM D412 using Die B. Weight change specimens shall be 1 IN by 3 IN samples.

All HDPE liner material shall have the following physical properties when tested at 77 °F ± 5 degrees:

Property	Standard	Units	Initial	(Par. VI.F)
Density	ASTM D792	g/cm ³	0.94	--
Thickness	--	mm	3	--
Melt Flow Index (190/2.16)	ASTM D1238	g/10min	<=0.1	--
Liner coefficient of thermal expansion	DIN 53752	K ⁻¹ x10 ⁻⁴	1.2	--
Tensile Strength	ASTM D638	psi	>2200 min.	>2200 min
Elongation at break	ASTM D638	--	300% min.	300% min
Hardness (Shore "D")	ASTM D2240		54	54-64
Weight change		--	--	0.065% max.
Pullout resistance (per anchor)	Greenbook 210-2.3.4	lbf	>300	

Tensile specimens shall be prepared and tested in accordance with ASTM D412 using Die B. Weight change specimens shall be 1 IN by 3 IN samples.

All composite FRP-PP and FRP-HDPE liner material shall have the following physical properties when tested at 77 °F ± 5 degrees:

Property	Standard	Units	Initial	(Par. VI.F)
Tensile Strength	ASTM D638	psi	>3000 min.	--

Tensile specimens shall be prepared and tested in accordance with ASTM D412 using Die B. Weight change specimens shall be 1 IN by 3 IN samples.

All PP Flow Control Gates shall have the following physical properties:

Property	Standard	Units	Requirement
Density	ASTM D792	g/cm ³	0.94
Tensile Strength	ASTM D412	psi	6,500 min.
Liner coefficient of thermal expansion	DIN 53752	K ⁻¹ x10 ⁻⁴	1.6

All gaskets shall have the following physical properties:

Property	Standard	Units	Requirement
Chemical resistance: 1N sulfuric acid 1N hydrochloric acid	ASTM D543 (at 24°C for 48 hr.)	% %	No weight loss No weight loss
Tensile Strength	ASTM D412	psi	1,200 min.
Elongation at Break	ASTM D412	%	350 min.
Hardness (Shore A)	ASTM D2240	--	±5 from the connector manufacturer's specified hardness
Accelerated oven aging	ASTM D573 (at 70°C for 7 days)	%	Max 15% decrease in tensile strength; Max 20% decrease in elongation
Compression set	ASTM D 395, Method B (at 70°C for 22 hr.)	%	Max 25% decrease of original deflection
Water absorption	ASTM D471 (at 70°C for 48hr.)	%	Increase of max 10% of original weight (19 by 25mm specimen)
Ozone Resistance	ASTM D1149	--	Rating 0
Low temperature brittle point	ASTM D2137	--	No fracture at -40°C
Tear resistance	ASTM D624, Die B	kN/m	34

Upon request, the manufacturer shall provide written certification that liners and gaskets used meets or exceeds the requirement of this specification.

F. Chemical resistance

After conditioning to constant weight at 110 °F, liner specimens shall be exposed to the following solutions for a period of 112 days at 77 °F ± 5 degrees, as prescribed in Standard Specifications for Public Works Construction, section 211-2 (Pickle Jar Test).

At 28-day intervals, tensile specimens and weight change specimens shall be removed from each of the chemical solutions and tested. If any specimen fails to meet the 112-day requirement before completion of the 112-day exposure, the material will be subject to rejection.

Chemical Solution	Concentration
Sulfuric acid	20%*
Sodium hydroxide	5%
Ammonium hydroxide	5%*
Nitric acid	1%*
Ferric chloride	1%
Sodium hypochlorite	1%
Soap	0.1%
Detergent (linear alkyl benzyl sulfonate or LAS)	0.1%
Bacteriological	BOD not less than 700 ppm

* Volumetric percentages of concentrated C.P. grade reagents.

VII. TEST METHODS

All test methods shall be performed per corresponding ASTM standard and per "Greenbook" 2009 edition (or later), Standard Specifications for Public Works Construction, Chemical Resistance Test (Pickle Jar Test).

VIII. QUALITY ASSURANCE/QUALITY CONTROL

- A. **Examination:** Each liner shall be examined for dimensional requirements and workmanship.
- B. **Composition Control:** Controls on glass and resin content shall be maintained for all manufacturing processes and for each portion of FRP liner fabrication. Records shall be maintained for these control checks. Proper glass content may be shown by glass usage checks or glass and resin application rate checks.
- C. **Certified facility:** Liners shall be designed and manufactured in an ISO 9001 and ISO 14001 certified manufacturing facility.

IX. HANDLING AND STORAGE

- A. FRP liners must not be dropped. When stored for extended periods (more than a few days) liners shall be stored on a flat surface, upside down to minimize deformation.
- B. Liners (FRP and PP or HDPE) shall be not be impacted.
- C. Liners (FRP and PP or HDPE) shall not be exposed to direct sunlight for extended periods.
- D. Flow Control Gates shall be stored on a flat surface and shall not be exposed to direct sunlight for extended periods.

X. CASTING & INSTALLATION

- A. **Casting:** FRP and PP/HDPE liners are non-structural components. Liners must be monolithically cast within precast concrete sections using a wet cast method. The FRP Cone Top Liner and the FRP Baseline's benching "shelf", channels and bells must be fully supported during the concrete pouring process against the vertical and horizontal forces created by the concrete during casting.

The poured precast components must not be moved until adequate hydration has occurred.

Lifting devices must not penetrate any surface of the liner. No liner may have holes or openings which will permit the intrusion of liquids or gases through the liner wall and into the concrete.

- B. **Installation:** The lined manhole installation should strictly follow the manufacturers' recommended installation procedures to ensure long-term corrosion resistant service. Outer joints of the precast concrete sections shall be gasketed or sealed as directed by the utility and/or precast concrete manufacturer.
- C. **Welding:** Adjacent liners in a fully stacked precast structure must be heat welded, by manufacturer certified welders, to form a monolithic liner system to achieve the intended gastight and watertight homogenous barrier that protects finished concrete manholes and wet wells from corrosion, abrasion, inflow and infiltration.