ST. TAMMANY PARISH

MICHAEL B. COOPER
PARISH PRESIDENT

February 2, 2026

Please find the following addendum to the below-mentioned QUOTE.

Addendum No.: 1

Quote#: 26-6-1

Project Name: 619 Plantation Blvd Pipe Liner

Quote Due Date: Thursday, February 12, 2026

GENERAL INFORMATION:

1. Please be advised that the Thermoform Structure PVC liner has been formally recognized as an approved equal alternative lining technology to the CIPP liner specified. Technical Info and Guide attached.

QUESTIONS & ANSWERS:

Question 1. On behalf of our installation team I am requesting a review of Thermoform Structure PVC liner as an alternative lining technology to the CIPP specified.

Thermoform PVC liner is a factory manufactured, structural, styrene free PVC liner system. Thermoform is manufactured in Birmingham and meets all BABA requirements. Unlike CIPP liners which are cured in the field and dependant upon the quality and completeness of the cure to determine their material properties, Thermoform is factory manufactured. Wall Thickness is based on the design calculation and set at extrusion, materials properties are determined by our resin companound and do not change throughout production or installation.

Answer 1. Please refer to General Information #1.

Question 2. What is the current condition of the invert of the existing pipe?

Answer 2. The Contractor is responsible for evaluating the condition of the project site.

Question 3. Are there any photos or videos available for review?

Answer 3. There are no photos or videos available.

ATTACHMENTS:

1. Compressed Thermoform PVC Liner - Technical Info and Guide Feb 2024.pdf

End of Addendum # 1

Thermoform PVC Pipe Liner

Technical Information & Guide

What is Thermoform PVC Pipe Liner?

Thermoform

Table of Contents

Standard Specification for Thermoform PVC Alloy Liner

Standard specification for Thermoform™ PVC alloy pipe liner for rehabilitation of existing sewer and conduits

1. Scope

1.1 This specification covers requirements and test methods for materials, dimensions, workmanship, flattening resistance, impact resistance, pipe stiffness, extrusion quality, and a form of marking for Thermoform™ folded PVC Alloy pipe liner for existing sewer and culvert rehabilitation.

1.2 Pipe produced to this specification is for use in non-pressure sewer and culvert rehabilitation where the folded PVC pipe is inserted into and then expanded to conform to the wall of the original pipe forming a new structural pipe-within-a-pipe. See Standard Practice for Installation of Thermoform™ PVC Alloy for Rehabilitation of Existing Sewer and Conduits.

1.3 This standard is based on ASTM F1871 (Standard Specification for Folded/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation.

2. Referenced Documents

2.1 ASTM Standards

D256 Test Method for Determining the Izod Pendulum Impact Resistance of Plastics

D638 Test Method for Tensile Properties of Plastics

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials **D2122**

Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

D2152 Test Method for Adequacy of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion

D2412 Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel-Plate Loading

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

F1057 Practice for Estimating the Quality of Extruded Poly (Vinyl Chloride) (PVC) Pipe by the Heat Reversion Technique

3. Significance and Use

3.1 The requirements of this specification are intended to provide folded pipe suitable for the rehabilitation of existing pipelines and conduits conveying sewage and storm water, under non-pressure conditions, through the heating, insertion, and expansion of the folded pipe.

Note

Industrial waste disposal lines should be installed only with the specific approval of the cognizant code authority since chemicals not commonly found in drains and sewers and temperatures in excess of 140°F (60°C) may be encountered.

4. Application of Materials

4.1 The nominal liner pipe sizes are applicable for a range of host pipe inside diameters.

Table 1: Recommended Range of Use

Liner Pipe O.D. (nominal) inches	Recommended Host Pipe I.D. inches	Liner Pipe wall thickness (nominal) inches	Dimension Ratio
4	3.6 - 4.1	0.114 - 0.154	35 - 26
6	5.7 - 6.1	0.171 - 0.231	35 - 26
8	7.6 - 8.2	0.229 - 0.308	35 - 26
9	8.6 - 9.2	0.257 - 0.346	35 - 26
10	9.5 - 10.2	0.286 - 0.385	35 - 26
12	11.6 - 12.6	0.343 - 0.462	35 - 26
15	14.5 - 15.4	0.300 - 0.462	50 - 32.5
18	17.6 - 18.2	0.300 - 0.514	60 - 35
21	20.6 - 21.2	0.300 - 0.500	70 - 42
24	23.5 - 24.3	0.300 - 0.500	80 - 48
27	26.2 - 27.3	0.300 - 0.350*	90 - 77
30	29.5 - 30.3	0.300 - 0.500	100 - 60
36	35.5 - 36	0.300 - 0.500	120 - 72
42	40.7 - 42.4	0.300 - 0.400*	140 - 105
48	46.6 - 48.5	0.300 - 0.400*	160 - 120

*For heavier wall, inquire with factory

5. Materials and Manufacture

5. 1 Basic Materials

The pipe shall be made from virgin PVC compound meeting the following requirements for physical properties:

5.1.1	Impact Strength (Izod):	0.65 ft-lb/in. of notch
5.1.2	Tensile strength:	4,500 psi
5.1.3	Tensile modulus:	360,000 psi
5.1.4	Flexural strength:	7,500 psi
5.1.5	Flexural modulus:	360,000 psi

6. Other Requirements

6.1 Pipe Flattening

There shall be no evidence of splitting, cracking. or breaking when the rounded pipe is tested in accordance with 10.2,

6.2 Pipe Impact Strength

The impact strength of the rounded pipe shall not be less than the values given in Table 2 when tested in accordance with 10.3,

Table 2: Minimum Impact Strength

Pipe size (inches)	Impact Strength (ft-lbf)
4	150
6-8	210
9-48	220

6.3 Pipe Stiffness

Pipe stiffness values for the rounded pipe shall comply with Table 3 when tested in accordance with 10.4.

Table 3: Minimum Pipe Stiffness		
Liner Pipe O.D. (nominal), inches	**Dimension Ratio**	**Pipe Stiffness (psi)**
4	35	31
6	35	31
8	35	31
9	35	31
10	35	31
12	35	31
15	35 - 50	47 - 13
18	35 - 60	37 - 7
21	42 - 70	22 - 5
24	48 - 80	15 - 4
27	77 - 90	10 - 3
30	60 - 100	7 - 2
36	72 - 120	5 - 1
42	105 - 140	2 - 0.8
48	120 - 160	1.2 - 0.5

6.4 Extrusion Quality

The extrusion quality of the pipe shall be evaluated by both of the following test methods:

6.4.1 Acetone Immersion

The pipe shall not flake or disintegrate when tested in accordance with 10.5.1.

6.4.2 Heat Reversion

The extrusion quality shall be evaluated by heat reversion method in accordance with 10.5.2.

6.5 Flexural Properties

Flexural modulus of elasticity values for the rounded pipe shall comply with the provisions of 5.1.5 when tested in accordance with 10.6.

7. Dimensions, Mass, and Permissible Variations

7.1 Rounded Pipe Diameter

The average outside diameter of the rounded pipe shall meet the requirements given in Table 5 with a tolerance of ±5.0 % when measured in accordance with 10.1.1.

7.2 Rounded Pipe Wall Thickness

The average wall thickness of the rounded pipe, when measured in accordance with 10.1.2, shall not be less than the values specified in Table 1.

8. Workmanship, Finish, and Appearance

8.1 The rounded and folded pipes shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, or other injurious defects. The pipe shall be as uniform as commercially practical in color, opacity, density, and other physical properties.

9. Sampling

9.1 Rounded pipe sample preparation shall involve the unfolding and expansion of a folded pipe sample within a pipe mold with an inside diameter equal to the nominal outside diameter shown in Table 1. A folded pipe sample of sufficient length (10ft maximum) to complete the testing requirements shall be inserted into the pipe mold and secured at the ends. The liner pipe shall then be heated using ambient pressure steam at a minimum temperature of 200°F. While maintaining the minimum 185°F temperature, the folded pipe shall then be rounded by applying internal steam pressure at 2-3 psi for a period of 2 min. While maintaining the' 2-3 psi internal pressure, transition to air pressure and cool the sample to 100°F or less. Remove the rounded sample from the mold for testing.

9.2 The frequency of sampling shall be as agreed upon between the purchaser and the seller. **9.3**

Initial and retest samples shall be drawn from the same production campaign.

10. Test Methods

10.1 Rounded Pipe Dimensions:

10.1.1 Pipe Diameters

Measure the outside diameter of the pipe in accordance with the applicable section of ASTM Test Method D2122. Either a tapered sleeve gage or a vernier circumferential wrap tape accurate to ±0.001 in. may be used.

10.1.2 Wall Thickness

Measure the wall thickness in accordance with the applicable sections of ASTM Test Method D2122. Make sufficient readings, a minimum of six, to ensure that the minimum thickness has been determined. Use a cylindrical anvil tubing micrometer accurate to ±0.001 in.

10.2 Pipe Flattening

Flatten three specimens of rounded pipe, 6-in. long, between parallel plates in a suitable press until the distance between the plates is 40 % of the outside diameter of the pipe. The rate of loading shall be uniform and such that the compression is completed within 2 to 5 min. Remove the load and examine the specimens for evidence of splitting, cracking, or breaking.

10.3 Impact Resistance

Determine the impact resistance of the rounded pipe in accordance with the applicable section of ASTM Test Method D2444, using a 20-lb Tup A and the flat plate Holder B. Test three specimens each 6 in. long at the impact levels given in Table 2. All shall pass. If one fails, test another six specimens; eleven passes out of twelve tested shall be acceptable.

10.4 Pipe Stiffness

Determine the pipe stiffness for rounded pipe specimens using Test Method D2412. Test three specimens, each 6 in. long. The pipe stiffness of each specimen at 5 % deflection shall equal or exceed the minimum value listed in Table 3.

10.5 Extrusion Quality:

10.5.1 Acetone Immersion

Tests shall run in accordance with Test Method D2152 on rounded pipe samples. This procedure is used for determining the extrusion quality of extruded PVC plastic pipe as indicated by reaction to immersion in anhydrous acetone. It is applicable only for distinguishing between unfused and properly fused PVC.

10.5.2 Heat Reversion

Tests shall be run in accordance with Practice F1057 on rounded pipe samples. The rounded pipe shall not exhibit any of the effects listed in the suggested Interpretation of Results in Practice F1057.

10.6 Flexural Properties

Tests shall be run on rounded pipe samples in accordance with ASTM Test Method D790. Test specimens shall be cut in the longitudinal direction and oriented on the test machine with the interior surface of the rounded sample against the loading supports.

11. Certification

11.1 When specified in the purchase order or contract, a manufacturer's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished. Each certification so furnished shall be signed by an authorized agent of the manufacturer.

12. Product Marking

12.1 Pipe in compliance with this specification shall be clearly marked at intervals of 5 ft or less as follows:

12.1.1 Manufacturer's name or trademark and code,

12.1.2 Nominal outside diameter,

12.1.3 The legend "DR XX Folded PVC Pipe,"

12.1.4 Production date code

13. Packaging

13.1 The full length and wall thickness of the folded PVC pipe is heated and coiled onto a reel in a continuous length for storage and shipping. The minimum diameter of the reel drum or core shall meet the manufacturer's specifications.

Standard Practice for Installation of Thermoform

Standard practice for installation of Thermoform™ folded PVC alloy pipe liner into existing sewers and conduits

1. Scope

1.1 This practice describes the procedures for the rehabilitation of sewer lines and conduits by the insertion of the Thermoform™ PVC Alloy Liner, which is heated, pressurized, and expanded against the interior surface of an existing pipe with steam pressure. The finished liner will be continuous and conform to the existing conduit. This rehabilitation process can be used in a variety of gravity applications, such as sanitary sewers, storm sewers, and process piping.

1.2 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.3 This standard is based on ASTM F1867 (Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation

2. Referenced Documents

2.1 ASTM Standards

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

F1417 Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air

F1867 Standard Practice for the Installation of Folded/Formed Poly (Vinyl Chloride) PVC Type A for Existing Sewer and Conduit Rehabilitation

3. Terminology

3.1 Definitions

3.1.1 Dimples (dimpling)

Where a side connection meets the existing pipe, and there is not existing pipe support for the PVC pipe during expansion causing a point of thermoplastic pipe expansion slightly beyond the existing pipe wall. This formation of an external departure from the formed pipe wall is termed dimpling.

3.1.2 Folded pipe

PVC pipe that has been manufactured in a folded shape for use in existing pipeline rehabilitation.

3.1.3 Formed pipe

Folded pipe that has been inserted into an existing sewer or conduit and expanded with heat and pressure to conform to and take the shape of the existing pipe.

3.1.4 Insertion point

An existing manhole, existing access shaft, or an excavated pit that serves as the point of entrance for the folded pipe into the existing pipe.

3.1.5 Rounded field sample

A rounded field sample is formed when the folded pipe has been inserted into a mold pipe and expanded with heat and pressure to conform to the mold pipe.

3.1.6 Termination point

An existing manhole, existing access shaft, or an excavated pit that serves as the point of exit of the folded pipe from the existing pipe.

4. Significance and Use

4.1 This standard is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of non-pressure sewers and conduits.

5. Materials

5.1 The folded pipe material shall be in accordance with Thermoform™ Manufacturing Specification.

5.2 The folded pipe shall be spooled in a continuous length for storage and shipping to the job site. Handling and storing shall be in accordance with the manufacturer's published recommendations.

6. Installation Recommendations

6.1 Cleaning and Inspection:

6.1.1 Prior to entering access areas such as manholes, and performing inspection or cleaning operations, an evaluation of the atmosphere to determine the presence of toxic or flammable vapors or lack of oxygen must be undertaken in accordance with local, state, or federal safety regulations.

6.1.2 Cleaning of Pipeline

Internal debris shall be removed from the existing pipeline. The pipeline should be cleaned with hydraulically-powered equipment, high-velocity jet cleaners, or mechanically-powered equipment in accordance with NASSCO Recommended Specifications for Sewer Collection System Rehabilitation.

6.1.3 Inspection of Pipelines

Inspection of pipelines shall be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed circuit television. The interior of the pipeline shall be inspected carefully to determine the location of any conditions that may prevent proper installation of the folded pipe, such as protruding service taps, collapsed or crushed pipe, out-of-roundness, significant line sags, and deflected joints. These conditions should be noted and corrected prior to installation.

6.1.4 Line Obstructions

The existing pipeline shall be clear of obstructions that will prevent the proper insertion and full expansion of the folded pipe such as offset joints of more than 12.5 % of inside pipe diameteror 1 in., whichever is less; service connections that protrude into the pipe more than 12.5 % of the inside pipe diameter or 1 in., whichever is less; and, other reductions in cross-sectional area of more than 10 % based on the inside diameter of the existing pipe. If inspection reveals an obstruction that cannot be removed by conventional equipment, then a point repair excavation shall be made to uncover and remove or repair the obstruction. Typically, bends along the pipe length in excess of 30° and changes in pipe size cannot be accommodated along an insertion length of the folded pipe. Such conditions require access at these points for termination and start of a new insertion.

6.2 Bypassing

If flow can not be interrupted for the necessary duration, bypassing of the flow is required around the sections of the existing pipe designated for rehabilitation. The bypass should be made by plugging the line at a point upstream of the pipe to be reconstructed and pumping the flow to a downstream point or adjacent system. The pump and bypass lines shall be of adequate capacity and size to handle any extreme flows expected during the installation period. Services within the rehabilitation area will be out of service temporarily.

6.3 Insertion:

6.3.1 The spool of folded pipe shall be positioned near the insertion point and contained in a heating chamber. A temperature of approximately 185F to 200F shall be maintained in the heating chamber for a minimum of 1 h to fully heat the length of folded pipe to be inserted. Shorter insertion lengths may be fully heated over a shorter time period.

6.3.2 A cable shall be strung through the existing conduit and attached to the folded pipe. The folded pipe shall be heated along the entire length and fed through the insertion point. The pipe is pulled, with a power winch unit and the cable, through the existing pipe into the terminating manhole. Maintain the upstream feed with the pipe reel to avoid stretching the pipe material with the winch cable. Pulling forces shall be monitored so as not to exceed the axial strain limits of the folded pipe material. Pull enough liner material to allow for insertion of a flow-through plug at the termination point.

6.3.3 After insertion is complete, cycle down the steam temperature to allow the liner to relax and reduce tensile stress on the material. During the relaxation cycle, the ends of the liner will tend to contract. It may take several heating/cooling cycles until the liner has relaxed and is no longer contracting.

6.4 Expansion:

6.4.1 To check that adequate temperatures are being achieved prior to expansion, suitable monitors to gage temperature shall be placed at the insertion and termination ends.

6.4.2 Insert flow-through plugs into ends of folded pipe. Ensure plugs are adequately restrained.

6.4.3 Through the use of heat and pressure, the folded pipe shall be expanded fully. Expansion pressures shall be sufficient to unfold the PVC pipe, press it against the wall of the existing conduit, and form dimples at service connections. Folded pipe expansion pressures typically are in the range of 0.25 to 3 psi, depending on liner size, or other site conditions.

6.5 Cool Down

The formed pipe shall be cooled to a temperature below 100°F before relieving the pressure required to hold the PVC pipe against the existing pipe wall.

6.6 After the formed pipe has cooled down, the terminating ends shall be trimmed to a minimum of 2 in. beyond the existing pipe.

6.7 Service Connections

After the formed pipe has been installed, and leakage tested, if applicable, the existing active service connections shall be reconnected. This should be done without excavation from the interior of the pipeline by means of a television camera and a remote control cutting device unless otherwise specified by the owner.

7. Inspection and Acceptance

7.1 The installation may be inspected by closed-circuit television. The formed pipe shall be continuous over the entire length of the insertion and conform to the walls of the existing pipe evidenced by visible joint definition and mirroring of existing pipe irregularities. Variations from true line and grade may be inherent because of the conditions of the existmg pipeline. No infiltration of groundwater through the formed pipe wall should be observed. All service entrances should be accounted for and be unobstructed.

7.2 Leakage Testing

If required by the owner or designated in the contract documents or purchase order, or a combination thereof, gravity pipes shall be tested for leakage. This test shall take place after the formed pipe has cooled down to ambient temperature. This test is limited to pipe lengths with no service laterals or lines with service laterals, which have not yet been reinstated. One of the following two methods shall be used.

7.2.1 An exfiltration test method involves plugging the formed pipe at both ends and filling it with water. The allowable water exfiltration for any length of pipe between termination points should not exceed 50 u.s. gal/in. of internal pipe diameter/mile/day, providing that all air has been bled from the line. The leakage quantity shall be gaged by the water level in a temporary standpipe placed in the upstream plug. During exfiltration testing, the maximum internal pipe pressure at the lowest end shall not exceed 10 ft of water or 4.3 psi and the water level inside of the standpipe shall be 2 ft higher than the top of the pipe or 2 ft higher than the groundwater level, whichever is greater. The test shall be conducted for a minimum of 1 h.

7.2.2 An air test shall be conducted in accordance with Test Method F1417. Note that the liner pipe is not pressure-rated, so use extreme caution.

7.3 Field Sampling

As designated by the owner in the contract documents or purchase order, a rounded field sample shall be prepared, by installing the folded PVC pipe into a suitable mold. The mold pipe shall be of like diameter to the existing pipe and should be a minimum of one diameter in length. The following test procedures shall be followed after the sample is expanded and cooled-down and removed from the mold pipe.

7.3.1 Rounded Field Sample Diameter

The average outside diameter of the rounded field sample shall meet the nominal diameter requirements with a tolerance of -7.0 ± 5.0 % when tested in accordance with the applicable section of Test Method D2122.

7.3.2 Rounded Field Sample Wall Thickness

The average wall thickness of the sample, when measured in accordance with the applicable sections of Test Method D2122, shall not be less than the values specified in Thermoform Manufacturing Specification.

7.3.3 Flexural Properties

The flexural modulus of elasticity shall be measured in accordance with Test Method D790, Test Method 3, Procedure A, and shall meet the requirements of the Thermoform™ Manufacturing Specification. Specimens shall be oriented on the testing machine with the interior surface of the rounded field samples against the loading supports.

Note

The evaluation of rounded field sample flexural properties is intended as an installation quality control test to verify that these properties were not negatively affected through installation processing of the PVC material.

8. Structural Design Considerations

Liner wall thickness will be determined in accordance with ASTM F1867, Appendix X1

Thermoform Chemical Resistance Chart

Thermoform™
Chemical Resistance Chart

Key	
Resistant	R
Not Resistant	N
Less resistant than "R" but still suitable	C

Source

Uni-Bell Plastic Pipe Association Handbook of PVC Pipe, PVC 1120 @ 73°F

Chemical	Resistance
Acetaldehyde	N
Acetaldehyde, aq 40%	C
Acetamide	-
Acetic acid, vapor	R
Acetic acid, glacial	R
Acetic acid, 20%	R
Acetic acid, 80%	R
Acetic anhydride	N
Acetone	N
Acetylene	C
Adipic acid	R
Alcohol, allyl	R
Alcohol, benzyl	N
Alcohol, butyl (n-butanol)	R
Alcohol, butyl (2-butanol)	R
Alcohol, ethyl	R
Alcohol, hexyl	R
Alcohol, ispropyl (2-propanol)	R
Alcohol, methyl	R
Alcohol, propyl (1-propanol)	R
Allyl chloride	N
Alums	R
Ammonia, gas	R
Ammonia, liquid	N
Ammonia, aq	R
Ammonium salts, exc. Fluoride	R
Ammonium fluoride, 25%	R
Amyl acetate	N
Amyl chloride	N
Aniline	N
Aniline chlorohydrate	N
Aniline hydrochloride	N
Aniline dyes	N
Anthraquinone	R
Anthraquinone sulfonic acid	R
Antimony trichloride	R

Chemical	Resistance
Aqua regia	C
Arsenic acid, 80%	R
Aryl-sulfonic acid	R
Barium salts	R
Beer	R
Beet sugar liquor	R
Benzaldehyde, 10%	R
Benzaldehyde, above 10%	N
Benzene (benzol)	N
Benzene sulfonic acid, 10%	R
Benzene sulfonic acid	N
Benzoic acid	R
Black liquor – paper	R
Bleach, 12.5% active chlorine	R
Bleach, 5.5% active chlorine	R
Borax	R
Boric acid	R
Boron triflouride	R
Bromic acid	R
Bromine, liquid	N
Bromine, gas, 25%	R
Bromine, aq	R
Butadiene	R
Butane	R
Butantetrol	R
Butanediol	R
Butyl acetate	N
Butyl phenol	R
Butylene	R
Butyric acid	R
Calcium salts, aq	R
Calcium hypochlorite	R
Calcium hydroxide	R
Cane sugar liquors	R

Thermoform™
Chemical Resistance Chart

Key	
Resistant	R
Not Resistant	N
Less resistant than "R" but still suitable	C

Chemical	Resistance
Carbon bisulfide	N
Carbon dioxide	R
Carbon dioxide, aq	R
Carbon monoxide	R
Carbon tetrachloride	R
Casein	R
Castor oil	R
Caustic potash (potassium hydroxide)	R
Caustic soda (sodium hydroxide)	R
Cellosolve	R
Chloroform	N
Chlorosulfonic acid	R
Chromic acid, 10%	R
Chromic acid, 30%	R
Chromic acid, 40%	R
Chromic acid, 50%	N
Citric acid	R
Coconut oil	R
Coke oven gas	R
Copper salts, aq	R
Corn oil	R
Corn syrup	R
Cottonseed oil	R
Cresol	N
Cresylic acid, 50%	R
Croton aldehyde	N
Crude oil	R
Cyclohexane	N
Cyclohexanol	N
Cyclohexanone	N
Cellosolve acetate	R
Chloramine	R
Chloric acid, 20%	R
Chlorine, gas, dry	C
Chlorine, gas, wet	N
Chlorine, liquid	N
Chlorine water	R
Chloracetic acid	R
Chlorobenzene	N
Chlorobenzyl chloride	N

Chemical	Resistance
Detergents, aq	R
Diazo salts	R
Dibutyl phthalate	N
Dibutyl sebacate	C
Dichlorobenzene	N
Dichlorotheylene	N
Diesel fuels	R
Diethyl amine	N
Dioctyl phthalate	N
Disodium phosphate	R
Diglycolic acid	R
Dioxane-1, 4	N
Dimethylamine	R
Dimethyl formamide	N
Ethers	N
Ethyl esters	N
Ethyl halides	N
Ethylene halides	N
Ethylene glycol	R
Ethylene oxide	N
Fatty acids	R
Ferric salts	R
Fluorine, dry gas	C
Fluorine, wet gas	C
Fluoboric acid, 25%	R
Fluosilicic acid	R
Formaldehyde	R
Formic acid	R
Freon – F11, F12, F113, F114	R
Freon – F21, F22	N
Fruit juices and pulps	R
Fuel oil	C
Furfural	N
Gallic acid	R
Gas, coal, manufactured	N
Gas, natural, methane	R
Gasolines	C

Thermoform™
Chemical Resistance Chart

Key	
Resistant	R
Not Resistant	N
Less resistant than "R" but still suitable	C

Chemical	Resistance
Gelatin	R
Glycerine (glycerol)	R
Glycolic acid	R
Glycols	R
Glue, animal	R
Green liquor, paper	R
Heptane	R
Hexane	R
Hydrobromic acid, 20%	R
Hydrochloric acid	R
Hydrofluoric acid, 10%	R
Hydrofluoric acid, 60%	R
Hydrofluoric acid, 100%	R
Hydrocyanic acid	R
Hydrogen	R
Hydrogen peroxide, 50%	R
Hydrogen peroxide, 90%	R
Hydrogen sulfide, aq	R
Hydrogen sulfide, dry	R
Hydroquinone	R
Hydroxylamine sulfate	R
Hydrazine	N
Hypochlorous acid	R
Iodine, in KI, 3%, aq	C
Iodine, alc	N
Iodine, aq, 10%	N
Jet fuels, JP-4 and JP-5	R
Kerosene	R
Ketones	R
Kraft paper liquor	R
Lacquer thinners	C
Lactic acid, 25%	R
Lard oil	R
Lauric acid	R
Lauryl chloride	R

Chemical	Resistance
Lauryl sulfate	R
Lead salts	R
Lime sulfur	R
Linoleic acid	R
Linseed oil	R
Liqueurs	R
Liquors	R
Lithium salts	R
Lubricating oils	R
Machine oil	R
Magnesium salts	R
Maleic acid	R
Malic acid	R
Manganese sulfate	R
Mercuric salts	R
Mercury	R
Mesityl oxide	N
Metallic soaps, aq	R
Methane	R
Methyl acetate	N
Methyl bromide	N
Methyl cellosolve	N
Methyl chloride	N
Methyl chloroform	N
Methyl cyclohexanone	N
Methyl methacrylate	R
Methyl salicylate	R
Methyl sulfate	R
Methyl sulfonic acid	R
Methylene bromide	N
Methylene chloride	N
Methylene iodide	N
Milk	R
Mineral oil	R
Mixed acids (sulfuric & nitric)	C
Mixed acids (sulfuric & phosphoric)	R
Molasses	R
Monochlorobenzene	N
Monoethanolamine	N

Thermoform™
Chemical Resistance Chart

Key	
Resistant	R
Not Resistant	N
Less resistant than "R" but still suitable	C

Chemical	Resistance
Motor oil	R
Naphtha	R
Naphthalene	N
Nickel salts	R
Nicotine	R
Nicotinic acid	R
Nitric acid, 0 to 50%	R
Nitric acid, 60%	R
Nitric acid, 70%	R
Nitric acid, 80%	C
Nitric acid, 90%	C
Nitric acid, 100%	N
Nitric acid, fuming	N
Nitrobenzene	N
Nitroglycerine	N
Nitrous acid	R
Nitrous oxide, gas	R
Nitroglycol	N
Nitropropane	C
Oils, vegetable	R
Oils and fats	R
Oleic acid	R
Oleum	N
Olive oil	C
Oxalic acid	R
Oxygen, gas	R
Ozone, gas	R
Palmitic acid, 10%	R
Palmitic acid, 70%	R
Paraffin	R
Pentane	C
Peracetic acid, 40%	R
Perchloric acid, 10%	R
Perchloric acid, 70%	R
Perchloroethylene	C
Petroleum, sour	R
Petroleum, refined	R

Chemical	Resistance
Phenol	C
Phenylcarbinol	N
Phenylhydrazine	N
Phenylhydrazine HCl	C
Phosgene, gas	R
Phosgene, liquid	N
Phosphoric acid	R
Phosphorus, yellow	R
Phosphorus, red	R
Phosphorus pentoxide	R
Phosphorus trichloride	N
Photographic chemicals, aq	R
Phthalic acid	C
Picric acid	N
Plating solutions, metal	R
Potassium salts, aq	R
Potassium permanganate, 25%	C
Potassium alkyl xanthates	R
Propane	R
Propylene dichloride	N
Propylene glycol	R
Propylene oxide	N
Pyridine	N
Pyrogallic acid	C
Rayon coagulating bath	R
Salicylic acid	R
Salicylaldehyde	C
Sea water	R
Selenic acid	R
Sewage, residential	R
Silicic acid	R
Silicone oil	R
Silver salts	R
Soaps	R
Sodium salts, aq, except	R
Sodium chlorite	R
Sodium chlorate	R
Sodium dichromate, acid	R

Thermoform™
Chemical Resistance Chart

Key	
Resistant	R
Not Resistant	N
Less resistant than "R" but still suitable	C

Chemical	Resistance
Sodium perborate	R
Stannic chloride	R
Stannous chloride	R
Starch	R
Stearic acid	R
Stoddard solvent	N
Sulfite liquor	R
Sulfur	R
Sugars, aq	R
Sulfur dioxide, dry	R
Sulfur dioxide, wet	R
Sulfur trioxide, gas, dry	R
Sulfur trioxide, wet	R
Sulfuric acid, up to 70%	R
Sulfuric acid, 70 to 90%	R
Sulfuric acid, 90 to 100%	C
Sulfurous acid	C
Tall oil	R
Tannic acid	R
Tanning liquors	R
Tartaric acid	R
Tetrachloroethane	C
Tetraethyl lead	R
Tetrahydrofuran	N
Thionyl chloride	N
Thread cutting oils	R
Terpineol	C
Titanium tetrachloride	C
Toluene	N
Tributyl citrate	R
Tributyl phosphate	N
Tricresyl phosphate	N
Trichloroacetic acid	R
Triethanolamine	R
Triethylamine	R
Trimethyl propane	R
Turpentine	R

Chemical	Resistance
Urea	R
Urine	R
Vaseline	N
Vegetable oils	R
Vinegar	R
Vinyl acetate	N
Water, distilled	R
Water, fresh	R
Water, mine	R
Water, salt	R
Water, tap	R
Whiskey	R
Wines	R
Xylene	N
Zinc salts	R

Thermoform Safety Data Sheet

1. Product and Company Information	
Common Name	Thermoform™ PVC Fold-and-Form Pipe Liner
Chemical Name	Polyvinyl Chloride (PVC)
Recommended Use	Fold-and-Form Pipe Liner for Trenchless Sanitary Sewer, Storm Drain and Highway Culvert Rehabilitation.
Supplier	DynaLiner, LLC
Address	3300 Pinson Valley Parkway, Birmingham, AL 35217
Phone	(205) 314-2498
Emergency Phone	(205) 854-4330

2. Hazards Identifications

As defined in the OSHA Hazard Communication Standard, 29 CFR 1910.1200, the products listed below are considered articles and do not require an SDS. In addition, articles are not included in the scope of the Global Harmonization System (GHS). As such, the GHS labeling elements are not included on this SDS. All components listed for this product are bound within the product. When handled as intended and under normal conditions of use, there is no evidence that any of the ingredients are released in amounts that pose a significant health risk. Although these products are not subject to the OSHA Standard or GHS labeling elements, DynaLiner, LLC would like to disclose as much health and safety information as possible to ensure that this product is handled and used properly. This SDS contains valuable information critical to the safe handling and proper use of the product. This SDS should be retained and be made available for employees and other users of this product. In addition, the recommendations for handling and use of these products should be included in worker training programs.

Note:
These products, as do most plastic products, contain chemicals which can be hazardous. These chemicals, however, are mixed and bound in the plastic and are not released except under extreme circumstances such as fire.

3. Hazardous Ingredient Identification			
Ingredient	**% Max Weight**	**PEL-OSHA (mg/m³)**	**TLV-ACGIH (mg/m³)**
Polyvinyl Chloride resin (CAS No. 9002-86-2)	≥ 80	15, 5 (respirable)	10
Proprietary ingredients	≤ 20	15, 5 (respirable)	10

4. First Aid Measures

Dust resulting from power or hand sawing this material is considered to be a low health risk by inhalation. Limits for total and respirable dust in Section 3 are applicable. Dust may be irritating to the skin, eyes, nose and upper respiratory tract. Toxic fumes and gases may be produced by combustion or high temperature decomposition. If this product is melted, this material may emit fumes and vapors that are irritating to the eyes, nose, skin and upper respiratory tract.

First Aid Measures (for exposure to products of decomposition)	
Eyes	Immediately flush eyes with potable water for at least 15 minutes. **SEEK MEDICAL ATTENTION.**
Skin	Flush skin thoroughly with soap and cool water for at least five minutes. **SEEK MEDICAL ATTENTION.**
Inhalation	Remove to fresh air. If breathing is difficult, administer oxygen. **SEEK MEDICAL ATTENTION.**

Note to physicians or First Aid Providers:

Hazardous fumes and gases that result from incomplete combustion and decomposition are hydrogen chloride, benzene, water, carbon monoxide and carbon dioxide.

5. Firefighting Measures

PVC material is self-extinguishing. It will, however, burn in the presence of other materials that support combustion.

Suitable Extinguishing Media	Dry chemical, foam, water spray or fog
Hazardous Combustion Products	Hazardous fumes and gases that result from incomplete combustion and decomposition are hydrogen chloride, benzene, water, carbon monoxide and carbon dioxide.
Recommended Fire-fighting Procedures	Wear full protective equipment and NIOSH approved self-contained breathing apparatus.
Unusual Fire & Explosion Hazards	Static sparking can occur during handling. Flammable materials should be removed from the immediate vicinity or controlled. The use of static suppressants and grounding devices is recommended.

6. Accidental Release Measures

N/A

7. Handling & Storage

N/A

8. Exposure Controls & Personal Protection

When cutting, wear safety glasses or goggles to prevent particles from being projected into eyes.

Use with adequate ventilation to meet exposure limits listed under Section 3. Where the exposure limits are or may be exceeded, use NIOSH approved respiratory protection. Select appropriate respirator (e.g., high efficiency dust mask, acid gas respirator) based on the actual or potential airborne contaminants and their concentrations present.

9. Physical & Chemical Properties			
Appearance	Solid. White.	**Vapor pressure**	N/A
Odor	N/A	**Vapor density**	N/A
Odor threshold	N/A	**pH**	N/A
Melting point/freezing point	N/A	**Relative density**	Approx. 1.4
Flash point	N/A	**Solubility**	Not soluble
Evaporation rate	N/A	**Self-ignition temperature**	849 deg. F
Flammability	Product will burn in the presence of combustible material.	**Decomposition temperature**	N/A
Upper/lower flammability or explosive limits	N/A	**Viscosity**	N/A

10. Stability & Reactivity	
Thermal Stability	Stable
Conditions to avoid (stability)	N/A
Incompatibility (material to avoid)	N/A
Hazardous decomposition or by-products	Hydrogen chloride, carbon monoxide

11. Toxicological Information

No information available.

12. Ecological Information

No information available.

13. Disposal Considerations	
Waste Disposal Method:	This product, as supplied, is not regulated as a hazardous waste by the U.S. Environmental Protection Agency (EPA) under Resource Conservation and Recovery Act (RCRA) regulations.
RCRA Hazard Class:	None

Comply with state and local regulations for disposal.

14. Transport Information	
U.S. DOT Transportation	This product is not classified as a hazardous material for transport.
Hazard Class	N/A
ID Number	N/A
Packing Group	N/A
Label Statement	N/A
Other	N/A

15. Regulatory Information	
U.S. Federal Regulations	
TSCA	N/A
CERCLA	N/A

SARA	
311/312 Hazard Categories	N/A
313 Reportable Ingredients	N/A
California Proposition 65	N/A

Other state regulations may apply. Check individual state requirements.

16. Other Information	
Additional Comments	N/A
Date of previous (M)SDS	March 15, 2015
Changes since previous (M)SDS	N/A

This information relates to the specific material designated and may not be valid for such material used in combination with any other materials or in any process. Such information is to the best of our knowledge and belief accurate and reliable as of the date compiled. However, no representation, warranty or guarantee, expressed or implied, is made as to its accuracy, reliability, or completeness. It is the user's responsibility to satisfy himself as to the suitability and completeness of such information for his particular use. We do not accept liability for any loss or damage that may occur from the use of this information.

Warrior Trenchless Solutions

MANUFACTURER'SWARRANTY

Warrior Trenchless Solutions ("Warrior") hereby warrants its PVC pipe liner product for ten (10) years from the date of manufacture, against failure as a result of defects in materials or manufacturing, and that when properly installed the product will perform in accordance with the manufacturer's specifications.
Should there be any defects in the material requiring repair and/or replacement, the Owner must notify Warrior in writing immediately upon discovery, and allow Warrior a reasonable amount of time to assess the claimed material or manufacturing defect and to make any necessary product repair or replacement. Should any defect occur during the warranty period, Warrior will repair or replace, at its option, the defective product. In no event shall Warrior be liable or responsible for labor charges or other expenses arising from or pertaining to the removal or installation of either the original or replacement product. In lieu of repair or replacement, Warrior also reserves the right to refund the amount paid by the original purchaser for the Warrior product and such refund shall fully discharge all obligations and liabilities of Warrior under this warranty.

What is not covered in this warranty. This warranty does not apply to any product that has been subjected to an accident, misuse and abuse, nor to any product that has been modified, altered, defaced, and/or had repairs made/attempt by others. Warranty does not include normal wear and tear. Under no circumstances shall Warrior be liable by virtue of this warranty or otherwise for damage to any person or property whatsoever or for any special, indirect, secondary or consequential damages of any nature, however arising, out of the use or inability to use the product because of any manufacturing defect or any claimed manufacturing defect.

THE LIMITED WARRANTY AND EXCLUSIVE REMEDY DESCRIBED ABOVE ARE EXPRESSLY IN LIEU OF ALL OTHER REMEDIES AND WARRANTIES, EXPRESSED OR IMPLIED, ON THE PART OF WARRIOR CONCERNING THE PRODUCTS, INCLUDING, WITHOUT LIMITATION, IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. WARRIOR NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON, FIRM, OR CORPORATION TO ASSUME ANY LIABILITY OR OBLIGATION ON WARRIOR'S BEHALF. WARRIOR EXPRESSLY DISCLAIMS ANY WARRANTIES, EXPRESSED OR IMPLIED, OTHER THAN THOSE EXPRESSLY SET FORTH HEREIN.

NASSCO Folded (Thermoplastic) Pipe (FP) Performance Specification Guideline

Thermoform

FOLDED (THERMOPLASTIC) PIPE (FP) INSTALLATION
(HDPE, PVC, AND PVC TYPE A)

PERFORMANCE SPECIFICATION GUIDELINE

August, 2006

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Disclaimer

These specifications were prepared by NASSCO and peer reviewed by industry professionals. These specifications are not specific to any one product and should be considered a guideline only. Conditions for use may require additions, deletions or amendments to these guidelines so as to conform to project specific site conditions. NASSCO assumes no liability as to content, use and application of these guidelines.

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PART 1 - GENERAL

A. These Specifications include the minimum requirements for the rehabilitation of sanitary sewer pipelines by the installation of Folded (Thermoplastic) Pipe (FP) within an existing, deteriorated pipe as shown on the plans included as part of these contract documents.

B. The rehabilitation of pipelines shall be done by the installation of a FP which, when installed, shall be continuous and tight-fitting throughout the entire length of the original pipe. The FP shall extend the full length of the original pipe and provide a structurally sound and water-tight new pipe within a pipe. The Contractor is responsible for proper, accurate and complete installation of the FP using the system selected by the Contractor.

C. Neither the FP system, nor its installation, shall cause adverse effects to any of the Owner's processes or facilities. The use of the product shall not result in the production of any detrimental cuttings and by-products at the wastewater treatment plant. The Contractor shall notify the Owner and identify any by-products produced as a result of the installation operations and comply with any and all local waste discharge requirements. The Contractor shall cleanup, restore existing surface conditions and structures, and repair any of the FP system determined to be defective. The Contractor shall conduct installation operations and schedule cleanup in a manner to cause the least possible obstruction and inconvenience to traffic, pedestrians, businesses, and property owners or tenants.

D. The prices submitted by the Contractor, shall include all costs of permits, labor, equipment and materials for the various bid items necessary for furnishing and installing, complete in place, the FP in accordance with these specifications. All items of work not specifically mentioned herein which are required to make the product perform as intended and deliver the final product as specified herein shall be included in the respective lump sum and unit prices bid in the Proposal.

1.1 DESCRIPTION OF WORK AND PRODUCT DELIVERY

A. These Specifications cover all work necessary to furnish and install, a Folded (Thermoplastic) Pipe. The Contractor shall provide all materials, labor, equipment, and services necessary for traffic control, bypass pumping and/or diversion of sewage flows, cleaning and television inspection of sewers to be lined, FP installation, reconnection of service connections, all quality controls, furnish samples for performance of required material tests, final television inspection, testing of lined pipe system and warranty work, all as specified herein.

B. The product furnished shall be a complete FP System including all materials, applicable equipment and installation procedures. The FP system manufacturer can

submit, a minimum of 14 calendar days in advance of the bid date, required information regarding the FP Technology to the Owner to obtain pre-approval status. Those FP systems that have been pre-approved will not be required to furnish information as required in the submittal section of these specifications unless specifically requested to do so by the Owner or if any of the FP system components have changed from those pre-approved by the Owner. All other FP systems or products will be required to meet the submittal requirements as contained herein.

C. The FP shall be continuous and from manhole to manhole or access point to access point and shall be free of all defects that will affect the long term life and normal operation of the pipeline.

D. The FP shall fit tight within the existing pipe. If leakage occurs at the manholes or the service connection interface, the Contractor shall seal these areas to stop all leakage with a method recommended by the FP system manufacturer. If leakage occurs through the wall of the pipe, due to a defect, the FP shall be repaired or removed as recommended by the FP manufacturer. Final approval of the FP installation will be based on a tight fitting, structurally sound, leak tight pipe.

E. The mainline FP shall be designed for a life of 50 years.

F. Where specified in the contract documents, the FP may be designed as a FP to rehabilitate and enhance the existing pipe and withstand all external hydrostatic loads or as a fully structural stand alone pipe-within-a-pipe. Where indicated in the contract, the installed FP shall be a structurally designed pipe within a pipe, meet or exceed all contract specified physical properties, fitting tightly within the existing pipe all within the tolerances specified. The installed structural FP shall withstand all applicable surcharge loads (soil overburden, live loads, etc.) and external hydrostatic (groundwater) pressure, if present, for each specific installation location.

G. The installed FP shall have a long term (50 year) corrosion resistance to the typical chemicals found in domestic sewage.

H. All existing and confirmed active service connections and any other service laterals to be reinstated as directed by the Owner shall be re-opened robotically or by hand in the case of man-entry size piping, to their original shape and to no less than 95% of their original capacity. All service connection cuts shall match the flow line of the existing pipe. All over-cut service connections will be properly repaired to meet the requirements of these specifications.

I. All materials furnished, as part of this contract shall be marked, as applicable, according to their respective ASTM product standards with detailed product information, stored in a manner specified by the manufacturer and tested to the requirement of this contract.

J. Testing and warranty inspections shall be as specified and executed by the Owner. Any defects found shall be repaired or replaced by the Contractor.

K. The Contractor shall furnish all samples for product testing. The Owner ensures the chain of custody and will pay for all material and product testing performed under this contract.

1.2 REFERENCES

A. The following documents form a part of this specification to the extent stated herein and shall be the latest editions thereof. These specifications reference American Society of Testing and Materials (ASTM) standard specifications. Where differences exist between codes and standards, the requirements of these specifications shall apply.

D-638 Standard Test Method for Tensile Properties of Plastics.
D-790 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
D-792 Standard Test Methods for Density and Specific Gravity of Plastics by displacement.
D-1784 Specification for Rigid Poly Vinyl Chloride (PVC) Compounds and Chlorinated Poly Vinyl Chloride (CPVC) Compounds
D-2122 Dimensions of Thermoplastic Pipe and Fittings
D-2412 Test Method for Determination of External Loading Characteristics of Pipe by Parallel-Plate Loading
D-2444 Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
D-2657 Standard Practice for Heat Fusion Joining of Polyolefin, Pipe and Fittings.
D-2990 Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics.
D-3350 Standard Specification for Polyethylene Plastic Pipe and Fittings Materials.
F-1504 Standard Specification for Folded Poly (Vinyl Chloride) (PVC) Pipe for Existing Sewer and Conduit Rehabilitation
F-1533 Standard Specification for Deformed Polyethylene (PE) FP
F-1606 Standard Practice for Rehabilitation of Existing Sewers and Conduits with Deformed Polyethylene (PE) FP
F-1867 Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation
F-1871 Standard Specification for Folded/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation
F-1947 Standard Practice for Installation of Folded Poly (Vinyl Chloride) (PVC) Pipe into Existing Sewers and Conduits

1.3 PERFORMANCE WORK STATEMENT (PWS) SUBMITTAL

A. The Contractor shall submit, to the Owner, a Performance Work Statement (PWS) at the pre-construction meeting, which clearly defines the FP product delivery in conformance with the requirements of these contract documents unless otherwise directed by the Owner. The PWS shall at a minimum contain the following:
   1 A clear definition of the product, its performance and the quality level to be furnished. Clearly indicate that the FP will conform to the project requirements as outlined in the Description of Work and as delineated in these specifications.
   2 Where the scope of work is specifically delineated in the contract documents or after the Owner has defined the specific scope of work to be performed, a detailed installation plan describing all preparation work, cleaning operations, pre-CCTV inspections, by-pass pumping plan, traffic control plan, installation procedure, method of processing, service reconnection, quality control, testing to be performed, final CCTV inspection, warrantees furnished and all else necessary and appropriate for a complete FP installation. A detailed installation schedule shall be prepared, submitted and conform to the requirements of this contract.
   3 A detailed plan for the identification of all active service connections and how the flow, from the connections, will be maintained during the lining process.
   4 A description of the FP materials to be furnished for the project. Materials shall be fully detailed in the submittals and conform to these specifications and/or shall conform to the pre-approved product submission approval.
   5 A statement of the Contractor qualifications and experience: The contractor shall have a minimum 25,000 linear feet of documented experience installing Folded Pipe technology with at least 10,000 linear feet of a size similar to that contained in this contract and a minimum of three (3) municipal references that will confirm the contractor's performance and quality on three (3) separate completed projects.
   6 As an alternate the contractor shall have on-site support of a manufacturer's field service representative having a minimum of three (3) years and 150,000 linear feet of documented experience installing Folded Pipe technology of a size similar to that contained in this contract.
   7 The lead crew personnel including the superintendent and foreman shall have a minimum of one (1) year of documented experience and a minimum of three (3) references for each individual that will confirm the individual's performance on previously completed projects.
   8 In the event that the experience of the lead superintendent and/or foreman does not meet the requirements of this contract, the manufacturer shall provide a trainer/instructor meeting these requirements for the duration of the project.
   9 As an alternate the lead crew personnel including the superintendent and foreman shall have a minimum of two (2) years of documented experience.
   10 The lead CCTV, installation and cutter operator shall have a minimum of one (1) year of verifiable experience.

11 The name and experience of each lead individual performing work on this contract shall be submitted with the PWS.
12 Engineering design calculations, shall be submitted, in accordance with the applicable ASTM specification design guidelines, for each length of FP to be installed including the thickness of each proposed section of FP. It will be acceptable for the Contractor to submit a design for the most severe line condition and apply that design to all of the line sections. These calculations shall be performed and certified by a, qualified, Engineer. All calculations shall include data that conforms to the requirements of these specifications or has been pre-approved by the Owner.
13 Proposed manufacturer's technology data shall be submitted for all FP products and all associated technologies to be furnished.
14 Submittals shall include information on the FP intended for installation and all tools and equipment required for a complete installation. The PWS shall identify which tools and equipment will be redundant on the job site in the event of equipment breakdown. All equipment, to be furnished for the project, including proposed back-up equipment, shall be clearly described. The Contractor shall outline the mitigation procedure to be implemented in the event of key equipment failure during the installation process.
15 A detailed description of the Contractor's proposed procedures for removal of any existing blockages in the pipeline that may be encountered during the cleaning process.
16 A detailed procedure for testing the water tightness of the installed FP system.
17 A detailed public notification plan shall be prepared and submitted including detailed staged notification to residences affected by the FP installation.

B. Compensation for all work required for the submittal of the PWS shall be included in the various pipelining items contained in the Proposal.

1.4 PRODUCT SUBMITTALS

A. Pipe material including:
1 Manufacturer of the FP system
2 Date of manufacture of the pipe
3 Material cell classification
4 Physical properties, including pipe stiffness, flexural modulus, flexural strength, and pipe dimensions both internal and external as applicable.
5 MSDS sheets for all materials to be furnished for the project.
6 Manufacturer's certification of conformance to the product specific ASTM standards.
7 Recycled materials, other than the manufacturer's own clean, rework material, shall not be contained in the manufactured pipe to be installed.

B. Method of pipe joining:
   1 For heat fusion joined materials, certification, verification and documentation of conformance to ASTM D-2657 as applicable or appropriate.
   2 FP system manufacturer's recommended end seal material to be used at manholes and sealing techniques to be used at service connection interface with the mainline to stop any leakage.

C. Fittings:
   1 All fittings shall be of compatible materials with the FP system.
   2 Detailed information from the fitting manufacturer must be provided indicating attachment procedures.
   3 Fittings, once installed, must be leak-tight.

D. Manufacturers' shipping, storage and handling recommendations for:
   1 FP
   2 Lubricants required for installation if applicable
   3 Fittings
   4 End seal materials

E. Compensation for all work required for the submittal of product data shall be included in the Lump Sum Price Bid in the Proposal for Mobilization.

1.5 SAFETY

A. The Contractor shall conform to all work safety requirements of pertinent regulatory agencies, and shall secure the site for the working conditions in compliance with the same. The Contractor shall erect such signs and other devices as are necessary for the safety of the work site.

B. The Contractor shall perform all of the Work in accordance with applicable OSHA standards. Emphasis shall be placed upon the requirements for entering confined spaces and with the equipment being utilized for pipe renewal.

C. The Contractor shall submit a proposed Safety Plan to the Owner, prior to beginning any work, identifying all competent persons. The plan shall include a description of a daily safety program for the job site and all emergency procedures to be implemented in the event of a safety incident. All work shall be conducted in accordance with the Contractor's submitted Safety Plan.

D. Compensation for all work required for the submittal of the Safety Plan shall be included in the price for the various pipelining items contained in the Proposal.

1.6 QUALITY CONTROL PLAN (QCP)

A. A detailed quality control plan (QCP) shall be submitted to the Owner that fully represents and conforms to the requirements of these specifications. At a minimum the QCP shall include the following:
   1 A detailed discussion of the proposed quality controls to be performed by the Contractor.
   2 Defined responsibilities, of the Contractor's personnel, for assuring that all quality requirements, for this contract, are met. These shall be assigned, by the Contractor, to specific personnel.
   3 Proposed procedures for quality control, product sampling and testing.
   4 Proposed methods for product performance controls, including method of and frequency of product sampling and testing both in delivered material and installed product form.
   5 Review of performance and product test results between the Contractor and the Owner at a regularly scheduled job meeting.
   6 Inspection forms and guidelines for quality control inspections which shall be prepared in accordance with the standards specified in this contract and submitted with the QCP.
   7 Two (2) days of inspector training, by the FP system manufacture, for the Owner's inspectors shall be provided. This training shall be at the beginning of the project, shall include both technical and field training and shall include all key aspects of visual inspection and sampling procedures for testing requirements. On smaller projects having an estimated duration of less than two (2) weeks of pipelining, the system manufacturer shall furnish a check list containing key elements of the FP installation criteria that is important for the Owner's inspector to ensure quality control and testing requirements are performed in accordance with the contract documents.
   8 Compensation for all work required for the submittal of the QCP shall be included in the price for the various pipelining items contained in the Proposal.

1.7 FP REPAIR/REPLACEMENT

A. Occasionally construction variables will result in the need to repair or replace a defective FP. The Contractor shall outline specific repair or replacement procedures for potential defects that may occur in the installed FP. Repair/replacement procedures shall be as recommended by the FP system manufacturer and shall be submitted as part of the PWS.

B. Defects in the installed FP that will not affect the operation and long term life of the product shall be identified and defined by the Contractor based on the manufacturer's recommendations.

C. Repairable defects that may occur in the installed FP shall be specifically defined by the Contractor based on manufacturer's recommendations, including a detailed step-by-step repair procedure, resulting in a finished product meeting the requirements of these contract specifications.

D. Un-repairable defects that may occur to the FP shall be clearly defined by the Contractor based on the manufacturer's recommendations, including a recommended procedure for the removal and replacement of the FP.

1.8 AS-BUILT DRAWINGS

A. As-Built drawings and pre & post inspection DVD's shall be submitted to the Owner, by the Contractor, within 2 weeks of final acceptance of said work or as specified by the Owner. As-Built drawings will include the identification of the work completed by the Contractor and shall be prepared on one set of Contract Drawings provided to the Contractor at the onset of the project.

B. As-Built drawings shall be kept on the project site at all times, shall include all necessary information as outlined in the PWS or as agreed to by the Owner and the Contractor at the start of the Contract and shall be updated as the work is being completed, and shall be clearly legible.

C. Compensation for all work required for the submittal and approval of As-Built Drawings shall be included in the various pipelining items contained in the Proposal.

1.9 WARRANTY

A. The materials used for the project shall be certified by the manufacturer for the specified purpose. The manufacturer shall warrant the FP to be free from defects in raw materials for one (1) year from the date of installation and acceptance by the Owner. The Contractor shall warrant the FP installation for a period of one (1) year. During the Contractor warranty period any defect, which may materially affect the integrity, strength, function and operation of the pipe, shall be repaired at the Contractor's expense in accordance with procedures included in Section 1.7 FP Repair/Replacement.

B. After a pipe section has been lined and for a period of time up to one (1) year following completion of the project, the Owner may clean and televise all or portions of the lined system. The specific locations will be selected at random by the Owner and may include all sizes of FP from this project. If it is found that any of the FP has developed abnormalities or defects since the time of "Post Construction Television Inspection," the abnormalities or defects shall be repaired or the pipe replaced as defined in Section 1.7 FP Repair/Replacement. If, after inspection of a portion of the lined system under the contract, problems are found, the Owner may televise all the

FP installed on the contract. All verified defects shall be repaired or the pipe replaced by the Contractor and shall be performed in accordance with Section 1.7 FP Repair/Replacement and per the original specifications, all at no additional cost to the Owner.

PART 2 - PRODUCTS

2.1 PIPE MATERIAL

A. The FP installed shall meet the requirements and intent of the contract documents and conform to the product submittals furnished to and accepted by the Owner.

B. The FP System must meet the chemical resistance requirements of these contract documents.

C. The FP delivered to the job site shall, as a minimum contain, the manufacture name or trademark and code, the nominal outside diameter, the cell classification, the DR designation and the ASTM designation of the pipe.

D. All materials, shipped to the project site, shall be accompanied by test reports, as requested by the Owner, certifying that the materials conform to the applicable ASTM standards listed herein. Materials shall be shipped, stored, and handled in a manner consistent with the PWS and the written recommendations of the FP system manufacturer to avoid damage. Damage may include, but is not limited to, gouging, abrasion, flattening, cutting, puncturing, or ultra-violet (UV) degradation. On site storage locations are to be selected by the Contractor and shall be approved by the Owner. All damaged materials shall be promptly removed from the project site at the Contractor's expense and disposed of in accordance with all current applicable agency regulations.

2.2 STRUCTURAL REQUIREMENTS

A. The physical properties, wall thickness and characteristics of the finished FP will vary according to the material installed. It shall be the responsibility of the Contractor to provide a FP system which meets or exceeds the minimum properties specified herein:

B. The FP shall be designed as per the applicable ASTM Standard, depending on the material being installed. The FP design shall assume no bonding to the original pipe wall.

C. The design engineer shall set the long term (50 year extrapolated) Modulus Retention Factor as a percentage of the flexural modulus as determined by ASTM D-790 test method. The Modulus Retention Factor shall be based on long term test

data (ASTM D2990 or equal) submitted by the manufacturer of the product selected to substantiate the long term creep retention factor.

D. The installed FP material shall, at a minimum, meet the structural properties, as listed below.

2.3 MINIMUM PHYSICAL PROPERTIES

Property	Test Method	Per Applicable ASTM
Flexural Modulus of Elasticity	ASTM D-790	HDPE - 118,000psi PVC - 280,000psi PVC Type A - 145,000psi
Flexural Strength	ASTM D-790	HDPE - N/A PVC - 5,000psi PVC Type A - 4,100psi

A. The required structural FP wall thickness shall be based, as a minimum, on the physical properties of the manufactured FP and per the design of the Professional Engineer (see section 1.3.1.6) and in accordance with ASTM F1504, F1533 or F1871 as applicable and the following design parameters:

Design Safety Factor	2.0
Modulus Retention Factor	As submitted and specific to type of pipe material
Ovality	2% or as measured by field inspection
Constrained Soil Modulus	Per AASHTO LRFD Section 12 and AWWA Manual 45
Groundwater Depth	As specified or indicated on the Plans
Soil Depth (above the crown)	As specified or indicated on the Plans
Live Load	Highway, railroad or airport as applicable
Soil Load (assumed)	120 lb/cu. Ft. (or data from specific project soil borings)
Minimum service life	50 years

B. The Contractor shall submit, prior to installation of the lining materials, certification of compliance with these specifications and/or the requirements of the pre-approved FP system. Certified material test results shall be included that confirm that all materials conform to these specifications and/or the pre-approved system. Materials not complying with these requirements will be rejected.

C. The design soil modulus and soil density may be adjusted based on data determined from detailed project soil testing results provided by the Owner.

PART 3 - INSTALLATION

3.1 CONSTRUCTION REQUIREMENTS

A. The Contractor shall clean the interior of the existing host pipe prior to installation of the FP. All debris and obstructions, in the existing pipe, that will affect the intended function and the final FP product delivery to the Owner, shall be removed and properly disposed of.

B. The FP shall be constructed of materials and with methods, that when installed, shall provide a continuous structurally sound FP able to withstand all imposed design loads on a long-term basis.

C. The Contractor may, under the direction of the Owner, utilize any of the existing manholes in the project area as installation access points. If modification of the manhole is required to accommodate the installation of the FP, the cost of modification and restoration to the manhole's original condition will be at the contractors cost. If a street must be closed to traffic because of the location of the sewer, the Contractor shall furnish a detailed traffic detour and control plan and all labor and equipment necessary. The plan shall be in conformance with the requirements of the local agency having jurisdiction over traffic control.

D. Cleaning of Pipe Lines - The Contractor shall remove all internal debris from the pipe line that will interfere with the installation and the final product delivery of the FP as required in these specifications. Solid debris and deposits shall be removed from the system and disposed of properly by the Contractor. Moving material from manhole section to manhole section shall not be allowed. As applicable the contractor shall either plug or install a flow bypass pumping system to properly clean the pipe lines. Precaution shall be taken, by the Contractor in the use of cleaning equipment to avoid damage to the existing pipe. The repair of any damage, caused by the cleaning equipment, shall be the responsibility of the Contractor. The Owner will designate a site for the disposal of all debris removed, from the Owner's sewer system, as a direct result of the cleaning operation. Unless otherwise specified by the Owner, the Contractor shall transport all debris, to the designated site, at no additional cost. Should any dumping fees apply, the Contractor shall make himself aware of the fees prior to the bid and shall be compensated at the respective unit price bid in the Proposal for cleaning.

E. By-passing Existing Sewage Flows - The Contractor shall provide for the flow of existing mainline and service connection effluent around the section or sections of pipe designated for FP installation. Service connection effluent may be plugged only after proper notification to the affected residence and may not remain plugged overnight. Installation of the FP shall not begin until the Contractor has installed a sewage by-pass system and all pumping facilities have been installed and tested

under full operating conditions including the bypass of mainline and side sewer flows. Once the lining process has begun, existing sewage flows shall be maintained, until the FP material is fully processed, is cooled down to ambient or below temperature, fully televised and the FP ends finished. The Contractor shall coordinate sewage bypass and flow interruptions with the Owner at least 14 days in advance and with the property owners and businesses at least 3 business days in advance. The pump and bypass lines shall be of adequate capacity and size to handle peak flows. The Contractor shall submit details of the bypass plan and design to the Owner before proceeding with any FP installation. Compensation for by-pass pumping and all associated plans and approvals shall be at the price bid therefore in the Proposal.

F. Contractor shall perform post-cleaning video inspections of the pipelines. Only PACP certified personnel trained in locating breaks, obstacles and service connections by closed circuit television shall perform the inspection. The Contractor shall provide the Owner a copy of the post-cleaning/pre FP installation DVD and suitable log for review prior to installation of the FP and for later reference by the Owner.

G. Line Obstructions - It shall be the responsibility of the Contractor to clear the line of obstructions that will interfere with the installation and long-term performance of the FP. If pre-installation inspection reveals an obstruction, misalignment, broken or collapsed section or sag that was not identified as part of the original scope of work and will prohibit proper installation of the FP, the Contractor may be directed by the Owner to correct the problem(s) prior to lining by utilizing open cut repair methods. The Contractor shall be compensated for this work under a contingency pay item designated for open cut point repairs. Removal of any previously unknown obstructions shall be considered as a changed condition. The cost of removal of obstructions that appeared on pre-bid video documentation and made available to the Contractor, prior to the bid opening, shall be included in the various unit price items bid in the contract documents.

H. The Contractor shall be responsible for confirming the locations of all branch service connections prior to installing and processing the FP. If required in the contract documents, each connection will be dye tested to determine whether or not the connection is live or abandoned. The cost for dye testing of existing service connections shall be compensated at the unit price bid in the Proposal for Dye Testing of Existing Service Connections. In the event the status of a service connection cannot be adequately defined, the Owner will make the final decision, prior to installation and processing of the FP, as to the status. Typically only service connections deemed “active”, by the Owner, shall be reopened by the Contractor.

I. The Contractor shall be allowed use water from an owner-approved fire hydrant in the project vicinity. Use of an approved double check backflow assembly shall be

required. Contractor shall provide his own approved assembly. Contractor shall pay current market price for all water used on the project.

3.2 INSTALLATION OF FP

A. The FP shall be installed and processed in the host pipe per the manufacturer's specifications as described and submitted in the PWS.

B. FP installation shall be in accordance with ASTM Standards as applicable to each specific pipe material.

C. The FP shall be positioned in the pipeline using the method specified by the manufacturer. Care should be exercised not to damage the FP as a result of installation. The FP should be pulled-in through an existing manhole or access point and fully extend to the next designated manhole or termination point.

D. Prior to installation and as recommended by the manufacturer temperature sensors shall be used to monitor the temperatures during the processing of the FP. Temperatures shall be monitored and logged during processing and cool down.

E. Processing of the FP shall be accomplished by utilizing the appropriate medium in accordance with the manufacturer's recommendation. The heat source in and output temperatures shall be monitored and logged during the processing and cool down cycles. The manufacturer's recommended processing procedure, in accordance with the applicable ASTM installation standard, shall be used for each line segment installed. The FP wall thickness and the existing ground conditions with regard to temperature, moisture level, and thermal conductivity of the host pipe and soil, shall be taken into account by the Contractor during the installation of the FP. Pressures shall be adjusted according to site conditions to ensure a tight expansion out against the host pipe.

F. The Contractor shall cool the FP in accordance with the approved manufacturer's recommendations as described and outlined in the PWS.

G. Ambient temperatures, processing temperatures and processing pressures shall be monitored and recorded, by the Contractor, throughout the installation process to ensure that each phase of the process is achieved as approved in accordance with the FP system manufacturer's requirements.

3.3 FINISH

A. The installed FP shall be fully expanded and continuous over the entire length of a sewer line section and be free from visual defects such as foreign inclusions, cracks, pinholes, major wrinkles and lifts. The FP shall be impervious and free of any

leakage from the pipe to the surrounding ground or from the ground to inside the lined pipe.

B. Any defect, which will or could affect the structural integrity or strength of the FP, shall be repaired or the pipe replaced at the Contractor's expense, in accordance with the procedures submitted under Section1.7 FP Repair/Replacement.

C. The beginning and end of the FP shall be sealed to the existing host pipe. The sealing material shall be compatible with the pipe end and shall provide a watertight seal.

D. If any of the service connections leak water between the host pipe and the installed FP, the connection mainline interface shall be sealed to provide a water tight connection.

E. If the wall of the FP leaks because of a defect, it shall be repaired or removed and replaced with a watertight pipe as recommended by the manufacturer of the system installed.

F. Compensation shall be at the actual length of FP installed and accepted. The length shall be measured from center of manhole to center of manhole. The unit price per linear foot installed shall include all materials, labor, equipment and supplies necessary for the complete FP installation.

3.4 MANHOLE CONNECTIONS AND RECONNECTIONS OF EXISTING SERVICES

A. A seal, consisting of a resin mixture, hydrophilic seal compatible with the installed FP or other system selected by the contractor shall be applied at manhole walls in accordance with the system manufacturer's recommendations. A hydrophilic gasket may be placed between the host pipe and the pipeliner.

B. Existing services shall be internally reconnected unless indicated otherwise in the contract documents

C. Reconnections of existing services shall be made after the FP has been installed, fully processed, cooled down and dimensionally stable. It is the contractor's responsibility to make sure that all active service connections are reconnected.

D. External reconnections, if required, are to be made with a tee fitting in accordance with system manufacturer's recommendations. Compression fittings and saddle connections shall be leak-proof and seated and sealed to the new FP.

E. A CCTV camera and remote reinstatement tool shall be used for internal reconnections. The opening shall be at least 95 percent of the original service

connection opening and the bottom of both openings must match. The opening shall not be more than 100 percent of the service connection opening. The edges of the opening shall not have pipe fragments or FP fragments, which may obstruct flow or snag debris.

F. In the event that service reinstatements result in openings that are greater than 100 percent of the service connection opening, the Contractor shall install a repair, sufficiently in size to completely cover the over-cut service connection. No additional compensation will be paid for the repair of over-cut service connections.

G. Coupons of pipe material resulting from service tap reinstatement shall be collected at the next manhole downstream of the pipe rehabilitation operation prior to leaving the site. Coupons may not be allowed to pass through the system.

H. Compensation shall be for the actual number of services re-connected using either internal or external means as contained in the Proposal. The unit price bid per service line re-connected shall include all materials, labor, equipment and supplies necessary to complete the work as required in the specifications.

3.5 TESTING OF INSTALLED FP

A. The physical properties of the installed FP shall be verified through field sampling and laboratory testing. All materials for testing shall be furnished by the Contractor to the Owner for testing. All materials testing shall be performed at the Owner's expense, by an independent third party laboratory selected by the Owner as recommended by the FP manufacturer. All tests shall be in accordance with applicable ASTM test methods and manufacturer's recommendations to confirm compliance with the requirements specified in these contract documents.

B. The Contractor shall provide samples for testing to the Owner from the actual installed FP. Samples shall be provided, at a minimum from one location per 2500 linear feet of installed pipe. The sample shall be cut from a section of processed FP that has been installed through a like diameter pipe which has been held in place by a suitable heat sink, such as sandbags. All processing, cutting and identification of samples will be witnessed by the Owner and samples shall be immediately furnished to the Owner and transmitted by the Owner to the testing laboratory. The Owner will retain the chain of custody for samples to be tested.

C. On pipelines greater in diameter than is practical to produce restrained samples, the Owner may at its discretion, designate a location in the newly installed FP where the Contractor shall take a sample. The Opening produced from the sample shall be repaired in accordance with manufacturer's recommended repair procedure.

D. The laboratory results shall identify the test sample location as referenced to the nearest manhole and station. Final payment for the project shall be withheld pending receipt and approval of timely and properly conducted test results. One re-testing, based on the manufacturer's recommendations will be permitted at the contractors expense, for proper protocol compliance verification. If properties tested do not meet minimum requirements, the FP shall be repaired or replaced by the Contractor, at no additional cost to the Owner.

E. Chemical resistance - The FP system installed shall meet the chemical resistance requirements for a typical domestic sewage environment. FP samples tested shall be of materials proposed for actual construction.

F. Hydraulic Capacity - Overall, the hydraulic capacity shall be maintained as large as possible. The installed FP shall at a minimum be equal to the full flow capacity of the original pipe before rehabilitation. In those cases where full capacity cannot be achieved after FP installation, the Contractor shall request a waiver of this requirement together with the reasons for the waiver request. Calculated capacities may be derived using a commonly accepted roughness coefficient for the existing pipe material taking into consideration its age and condition.

G. The installed FP thickness shall be measured for each line section installed. If the FP thickness does not meet that specified in the contract and submitted as the approved design by the Contractor then the FP shall be repaired or removed. The FP thickness shall have tolerance of minus 5% plus 10%. The Contractor may use industry proven, non-destructive methods for confirming the thickness of the installed FP.

H. All costs, to the Contractor, associated with providing processed FP samples for testing shall be included in the Lump Sum price bid for Mobilization. Payment for all testing by a laboratory will be paid for, by the Owner, directly to the laboratory under the lump sum reserve for testing item force bid in the Bid Proposal.

3.6 FINAL ACCEPTANCE

A. All FP sample testing and repairs to the installed FP, as applicable, shall be completed, before final acceptance, meeting the requirements of these specifications and documented in written form.

B. The Contractor shall perform a detailed closed-circuit television inspection in the presence of the Owner after installation of the FP and reconnection of the service connections. A radial view (pan and tilt) TV camera shall be used. The camera shall be panned 360 degrees around the circumference of the pipe and along the wall of the finished pipe at 10 foot intervals. The finished FP shall be continuous over the entire length of the installation and shall be free of significant visual defects, damage, deflection, holes, leaks, wrinkles and other defects. It is recognized that the new liner

will conform to the shape and irregularities of the host pipe. Unedited digital documentation of the inspection shall be provided to the Owner within ten (10) working days of the FP installation. The data shall note the inspection date, location of all reconnected service connections, debris, as well as any other defects in the FP, including, but not limited to, gouges, cracks, bumps, or bulges. If post installation inspection documentation is not submitted within Ten (10) working days of the FP installation, the Owner may at its discretion suspend any further installation of FP until the post-installation documentation is submitted. As a result of this suspension, no additional working days will be added to the contract, nor will any adjustment be made for increase in cost. Prior to conducting the closed circuit television inspection, the Contractor shall thoroughly flush the newly installed FP removing all debris, shavings from cutting service connections and build-up that may have accumulated.

C. Bypass pumping or plugging from the upstream manhole shall be utilized to minimize sewage from entering the line during the inspection. In the case of bellies in the line, the pipe shall be cleared of any standing water to provide continuous visibility during the inspection.

3.7 TYPICAL SUGGESTED BID ITEMS

A. Mobilization – Lump Sum - Includes all PWS info, submittals, safety plan, as-built drawings, testing samples, mobilization/demobilization of labor, equipment and materials to the project site.

B. Pre-Lining CCTV Inspection – Per linear foot - Includes pre-cleaning and post cleaning CCTV for Owner review. Does not include CCTV inspection just prior to FP installation. All inspections will be performed by PACP trained and certified personnel.

C. Dye Testing of Service Connections – Per each -Includes dye testing and documentation of existing service connection on each pipe length to be lined.

D. Point Repairs – Per each or by Lump Sum Contingency- Includes excavation and restoration of a section or sections of pipe that are beyond rehabilitation using a FP. Note: Point repair items shall be categorized by pipe size, a minimum length of excavation and depth category of excavation to be paid for in the Proposal. If point repairs are not identified in the contract documents payment shall be on a contingency basis.

E. Standard Pipe cleaning – Per linear foot for each pipe size category – including all labor, equipment, materials and cost of material disposal.

F. Heavy Pipe Cleaning – Per linear foot for each pipe category – including all labor, equipment, materials and cost of material disposal.

G. FP Installation – Per linear foot for each pipe size category and wall thickness - Includes all labor, equipment and materials required for the complete installation of a FP.

H. Traffic Control –Lump Sum – Includes all labor, equipment and material required to implement a traffic control plan for the entire project including the costs of all sub-contracted traffic control specialists.

I. Sewage By-pass – Lump Sum – Includes all labor, equipment and materials required, to implement a sewage by-pass plan for the entire project, including the cost of all sub-contracted sewage by-pass specialists.

J. Service Reconnections – Per each – Includes reconnecting existing live sewer service connections to the installed FP. Owner shall review and verify those connections that are not live and will be left unopened.

K. Service connection sealing – Per each – Includes sealing the interface between the installed FP and the host pipe at the location of the service connection.

L. Post Construction CCTV Inspection - Per linear foot - Includes post lining CCTV for submission to the Owner. All inspections will be performed by PACP trained and certified personnel.

M. Reserve for Testing – Lump Sum Reserve – For Owners use to include testing, required as directed by the Owner, under this contract by an independent laboratory. (The amount will be set by the Owner in the Bid Proposal)

END OF SECTION

Thermoform Technical References

ASTM F1867 / F1216 Appendix X1 Structural Calculations

Maximum Burial Depth (Quick Selection Guide)

Hydraulic Flow Calculations

Thermoform

Below is **Appendix X1 from the ASTM F1867** Installation Standard. This is based on the "Close-Fit liner" theory and formulae, which are identical to those used in ASTM F1216 Appendix X1 for CIPP liners. These calculations are used in determining the minimum liner thickness to meet structural requirements (partially or fully deteriorated conditions).

X1. STRUCTURAL DESIGN CONSIDERATIONS

X1.1 *Terminology:*

X1.1.1 *partially deteriorated pipe, n*—The existing pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe, and the soil adjacent to the existing pipe must provide adequate side support. The conduit may have longitudinal cracks and some distortion of the diameter.

X1.1.2 *fully deteriorated pipe, n*—The existing pipe is not structurally sound and cannot support soil and live loads or is expected to reach this condition over the design life of the installed PVC pipe. This condition is evident when sections of the existing pipe are missing, the existing pipe has lost its original shape, or the existing pipe has corroded due to the effects of the fluid, atmosphere, or soil.

X1.2 *Design:*

X1.2.1 *Partially Deteriorated Design Condition*—The formed PVC pipe is designed to support only the external hydraulic loads due to groundwater (and internal vacuum), since the soil and surcharge loads can be supported by the existing pipe. The groundwater level should be determined and the thickness of the formed PVC pipe should be sufficient to withstand this hydrostatic pressure without collapsing. The following equation may be used to determine the thickness required:

$$P = \frac{2KE_L}{(1-\mu^2)} \times \frac{1}{(DR-1)^3} \times \frac{C}{N} \qquad \text{(X1.1)}$$

where:

P = external pressure, psi (MPa),
DR = dimension ratio of PVC pipe (outside diameter/thickness), and
C = ovality reduction factor =

$$\left[\left(1-\frac{q}{100}\right)/\left(1+\frac{q}{100}\right)\right]^2$$

q = percentage ovality of original pipe =

$$\frac{100 \times (D - D_{min})/D}{100 \times (D_{max} - D)/D}$$

D = mean inside diameter of existing pipe, in. (mm),
D_{min} = minimum inside diameter of existing pipe, in. (mm),
D_{max} = maximum inside diameter of existing pipe, in. (mm),
N = factor of safety (2.0 recommended),
E_L = modulus of elasticity of formed PVC pipe, psi (MPa), reduced to account for long-term effects (see Note X1.1),
K = enhancement factor of the soil and existing pipe adjacent to the new pipe (a value of 7.0 is recommended where there is full support of the existing pipe), and
μ = Poisson's ratio (0.38 average).

Note X1.1—The choice of value (from manufacturer's literature) of E_L will depend on the estimated duration of the application of the load, P, in relation to the design life of the structure. For example, if the total duration of the load, P, is estimated to be 50 years, either continuously applied, or the sum of intermittent periods of loading, the approximately conservative choice of value for E_L will be that given for 50 years of continuous loading at the maximum ground or fluid temperature expected to be reached over the life of the structure.

X1.2.2 Rearrange Eq X1.1 and solve for formed PVC pipe thickness, t:

$$t = \frac{D}{\left[\frac{2KE_L C}{PN(1-\mu^2)}\right]^{\frac{1}{3}} + 1} \qquad \text{(X1.2)}$$

X1.2.3 *Fully Deteriorated Design Condition*—The formed PVC pipe is designed to support hydraulic, soil, and live loads.

$$q_t = \frac{C}{N}\left[32R_w R' E' / (E_L/(D/t)^3)\right]^{\frac{1}{3}} \qquad \text{(X1.3)}$$

where:

q_t = total external pressure on pipe, psi (MPa),
= 0.433 H_w + wHR_w/144 + W_L (English units),
= 0.00981 H_w + wHR_w/1000 + W_L (metric units),
R_w = water buoyancy factor (0.67 minimum) = 1 − 0.33 (H_w/H),
H_w = height of groundwater above top of pipe, ft (m),
H = height of soil above top of pipe, ft (m),
w = soil density, lb/ft^3 (kN/m^3),
W_L = live load, psi (MPa),
R' = coefficient of elastic support = $1/(1+4e^{-0.065H})$ (inch-pound units), $1/(1+4e^{-0.213H})$ (centimeter-kilogram units),
I = moment of inertia of PVC pipe, in.^{3}/in. (mm^3/mm) = $t^3/12$,
t = thickness of PVC, in. (mm),
C = ovality reduction factor (see X1.2.1),
N = factor of safety (2.0 recommended),
E'_s = modulus of soil reaction, psi (MPa) (see Note X1.2),
E_L = modulus of elasticity of formed PVC pipe, psi (MPa), reduced to account for long-term effects (see Note X1.1), and
D = mean inside diameter of existing pipe, in. (mm).

Note X1.2—For definition of modulus of soil reaction, see the Handbook of PVC Pipe.[4]

X1.2.4 Rearrange Eq X1.3 and solve for thickness, t:

$$t = 0.721D\left[\frac{1.5q_t/(CN)}{E_L R_w R' E_L}\right]^{\frac{1}{3}} \qquad \text{(X1.4)}$$

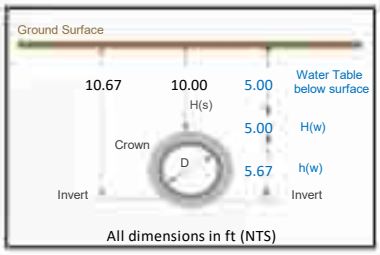
ASTM F1867 / F1216 CALCULATION & DESIGN

ASTM F1216 / ASTM F1867
Appendix X1 Calculation

Project Name: City of ABC123 - Sanitary sewer rehabilitation project
Line/Street: 8"/200mm line @ 10ft/3m soil cover and water table 5ft/1.5m below surface

Fully Deteriorated

I. Buckling Analysis (modified AWWA formula) — Equation X1.3
II. Deflection (Spangler Formula) — Equation X1.4
III. Buckling due to External Water Pressure (Modified Timoshenko) restrained buckling analysis — Equation X1.1
IV. Pressure limited due to Stress — Equation X1.2
V. Select minimum Liner thickness based on largest thickness of I, II, III, or IV.



All dimensions in ft (NTS)

INPUTS			Imperial	Metric		
Pipe Mean Inside Diameter	D	in	8	200	mm	
Ovality	q	%	3	3	%	
External Water, above crown	H(w)	ft	5.00	1.53	m	
External Water, above invert	h(w)	ft	5.67	1.73	m	
Depth of Soil, above top of pipe	H(s)	ft	10.00	3.05	m	
Soil Modulus	E(s)	psi	1000	6.9	MPa	
Liner Pipe Flexural Modulus - Initial	E	psi	367390	2533.7	MPa	Thermoform typical properties
Liner Pipe Flexural Strength - Initial	S	psi	7832	54.0	MPa	Thermoform typical properties
Reduction to account for long-term effects (%)	F(r)	%	58	58.0	%	Thermoform typical properties
Soil Density (Table 2.11)	w	lb/ft^3	120	1920.0	kg/m3	
Live Load (concentrated)	p(c)	lb	16000	7256.2	kg	HS-20 (Highway) loading
Impact Factor (concentrated)	F(sc)		1	1		
Live Load (distributed)	p(d)	lb/ft	640	10240.0	kg/m3	
Impact Factor (distributed)	F(sd)		1	1		
Factor of Safety	N		2	2		
Poisson's Ratio	v		0.3	0.3		
Enhancement Factor	K		7	7		

CALCULATED INTERMEDIATE VALUES						
Total External pressure on pipe	q(t)	psi	9.13	62.94	KPa	q(t) = 0.433 x H(w) + (w x H(s) x R(w))+ W(s)
Water Buoyancy factor	R(w)		0.835	0.835		R(w) = 1 - 0.33 x (H(w)/H(s))
Live Load (Concentrated Load + Distributed Load)	W(s)	psi	0.000	0.00	KPa	W(s) = W(sc) + W(sd)
Coefficient of Elastic Support	B'		0.324	0.324		B' = [1/(1 + (4 x e^(-0.065xH(s)))]
Ovality Reduction Factor	C		0.764	0.764		C = [(1-q/100)/(1+q/100)^2]^3
Flexural Modulus of Elasticity of Liner, long-term	E(L)	psi	154304	1064.2	MPa	E(L) = E*(1-F(r)/100)
Allowable restrained buckling pressure, or	P	psi	2.457	16.94	KPa	P = h(w) x 62.4/144
Quadratic: t2 value			1593.814			For min thickness, maximum compressive hoop stress
Quadratic: t value			24.720			For min thickness, maximum compressive hoop stress
Quadractic: Constant value			-2.966			For min thickness, maximum compressive hoop stress
soln 1:		in	0.036			For min thickness, maximum compressive hoop stress
soln 2:			-0.052			For min thickness, maximum compressive hoop stress

CALCULATED THICKNESS / DEFLECTION				
Minimum Thickness, buckling - **Eq. X1.3**	t	in	0.13	t = 0.721 x D x [(N x q(t))^2/(E(L) x R(w) x B' x C x E(s)]^1/3
Minimum Thickness, stiffness requirement - **Eq. X1.4**	t	in	0.12	t = [D^3/(E/(12 x 0.093))]^1/3, rearranged from X1.4: E x I / D^3 > 0.093
Minimum Thickness, buckling due to external water pressure - **Eq. X1.1**	t	in	0.11	t = D/((2 x K x E(L) x C)/(P x N x (1-v^2))^(1/3) + 1). If water table below pipe = DR 100
Minimum Thickness, maximum compressive hoop stress - **Eq. X1.2**	t	in	0.036	t = largest solution in quadratic eqn, solved in intermediate section
Deflection				

Partially Deteriorated Minimum Dimension Ratio (from X1.3)	DR		72.7	72.7	
Partially Deteriorated Minimum Liner Thickness	in		0.11	2.8	mm
Fully Deteriorated Minimum Dimension Ratio (from largest t above))	DR		63.4	63.4	
Fully Deteriorated Minimum Liner Thickness	in		0.13	3.2	mm
Installed Dimension Ratio of Thermoform	DR		41.0	41.0	
Installed Thermoform Liner thickness	in		0.20	5.0	mm

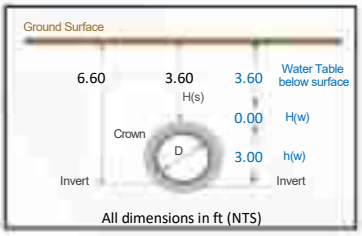
ASTM F1867 / F1216 CALCULATION & DESIGN

ASTM F1216 / ASTM F1867
Appendix X1 Calculation

Project Name: XYZ DOT - Culverts
Line/Street: 36"/900mm at 3.5ft/1.1m soil cover, water table at crown of pipe

Fully Deteriorated

I. Buckling Analysis (modified AWWA formula) — Equation X1.3
II. Deflection (Spangler Formula) — Equation X1.4
III. Buckling due to External Water Pressure (Modified Timoshenko) restrained buckling analysis — Equation X1.1
IV. Pressure limited due to Stress — Equation X1.2
V. Select minimum Liner thickness based on largest thickness of I, II, III, or IV.



All dimensions in ft (NTS)

INPUTS

			Imperial	Metric		
Pipe Mean Inside Diameter	D	in	36	900	mm	
Ovality	q	%	3	3	%	
External Water, above crown	H(w)	ft	0.00	0.00	m	
External Water, above invert	h(w)	ft	3.00	0.91	m	
Depth of Soil, above top of pipe	H(s)	ft	3.60	1.10	m	
Soil Modulus	E(s)	psi	1000	6.9	MPa	
Liner Pipe Flexural Modulus - Initial	E	psi	367390	2533.7	MPa	Thermoform typical properties
Liner Pipe Flexural Strength - Initial	S	psi	7832	54.0	MPa	Thermoform typical properties
Reduction to account for long-term effects (%)	F(r)	%	58	58.0	%	Thermoform typical properties
Soil Density (Table 2.11)	w	lb/ft^3	120	1920.0	kg/m3	
Live Load (concentrated)	p(c)	lb	16000	7256.2	kg	HS-20 (Highway) loading
Impact Factor (concentrated)	F(sc)		1	1		
Live Load (distributed)	p(d)	lb/ft	640	10240.0	kg/m3	
Impact Factor (distributed)	F(sd)		1	1		
Factor of Safety	N		2	2		
Poisson's Ratio	v		0.3	0.3		
Enhancement Factor	K		7	7		

CALCULATED INTERMEDIATE VALUES

Total External pressure on pipe	q(t)	psi	6.34	43.72	KPa	q(t) = 0.433 x H(w) + (w x H(s) x R(w))+ w(s)
Water Buoyancy factor	R(w)		1.000	1.000		R(w) = 1 - 0.33 x (H(w)/H(s))
Live Load (Concentrated Load + Distributed Load)	W(s)	psi	3.340	23.03	KPa	W(s) = W(sc) + W(sd)
Coefficient of Elastic Support	B'		0.240	0.240		B' = [1/(1 + (4 x e^(-0.065xH(s)))]
Ovality Reduction Factor	C		0.764	0.764		C = [(1-q/100)/(1+q/100)^2]^3
Flexural Modulus of Elasticity of Liner, long-term	E(L)	psi	154304	1064.2	MPa	E(L) = E*(1-F(r)/100)
Allowable restrained buckling pressure, or	P	psi	1.300	8.97	KPa	P = h(w) x 62.4/144
Quadratic: t2 value			3012.308			For min thickness, maximum compressive hoop stress
Quadratic: t value			24.720			For min thickness, maximum compressive hoop stress
Quadractic: Constant value			-60.070			For min thickness, maximum compressive hoop stress
soln 1:		in	0.137			For min thickness, maximum compressive hoop stress
soln 2:			-0.145			For min thickness, maximum compressive hoop stress

CALCULATED THICKNESS / DEFLECTION

Minimum Thickness, buckling - Eq. X1.3 (F1216), Eq. X1.4 (F1867)	t	in	0.46	t = 0.721 x D x [(N x q(t))^2/(E(L) x R(w) x B' x C x E(s)]^1/3
Minimum Thickness, buckling due to external water pressure - Eq. X1.1 (F1216), Eq. X1.2 (F1867)	t	in	0.40	t = D/((2 x K x E(L) x C)/(P x N x (1-v^2))^(1/3) + 1). If water table below pipe = DR 100

		Imperial	Metric	
Partially Deteriorated Minimum Dimension Ratio (from X1.1)	DR	89.7	89.7	
Partially Deteriorated Minimum Liner Thickness	in	0.40	10.2	mm
Fully Deteriorated Minimum Dimension Ratio (from largest t above))	DR	77.7	77.7	
Fully Deteriorated Minimum Liner Thickness	in	0.46	11.8	mm
Installed Dimension Ratio of Thermoform	DR	72.0	72.0	
Installed Thermoform Liner thickness	in	0.50	12.7	mm

The tables below are provided for quick selection of Thermoform liner based on depth of burial of the host pipe to be rehabilitated. These values are calculated using Appendix X1 from the ASTM F1867 Installation Standard on page 53. All other assumptions used are listed below.

NOTE: ***These are not substitutions for a proper engineering design provided by a licensed engineer.***

Maximum depth of burial for Thermoform PVC Liner

Liner Thickness / Liner Size	DR60	DR50	DR41	DR35	DR32.5	DR26
4"/100mm	N/A	N/A	N/A	28'/8.5m	32'/9.8m	50'/15.2m
6"/150mm	N/A	13'/4.0m	19'/5.8m	28'/8.5m	32'/9.8m	50'/15.2m
8"/200mm	N/A	13'/4.0m	19'/5.8m	28'/8.5m	32'/9.8m	50'/15.2m
10"/250mm	N/A	13'/4.0m	19'/5.8m	28'/8.5m	32'/9.8m	50'/15.2m
12"/300mm	N/A	13'/4.0m	20'/6.1m	28'/8.5m	32'/9.8m	50'/15.2m
15"/375mm	N/A	13'/4.0m	20'/6.1m	28'/8.5m	32'/9.8m	N/A
18"/450mm	10'/3.0m	14'/4.3m	20'/6.1m	28'/8.5m	32'/9.8m	N/A

Liner Thickness / Liner Size	Utility	Standard	Heavy	X-Heavy	Brute
21"/525mm	7'/2.1m	10'/3.0m	13'/4.0m	16'/4.3m	20'/6.1m
24"/600mm	5'/1.5m	8'/2.4m	10'/3.0m	13'/4.0m	15'/4.6m
27"/675mm	4'/1.2m	6'/1.8m	8'/2.4m	10'/3.0m	12'/3.7m
30"/750mm	***	4'/1.2m	7'/2.1m	9'/2.7m	10'/3.0m
36"/900mm	***	***	4'/1.2m	6'/1.8m	8'/2.4m
42"/1050mm	***	***	***	N/A	N/A
48"/1200mm	***	***	***	N/A	N/A

*** Projects to be evaluated on a case-by-case basis.
Double liners required for fully deteriorated structural conditions.

Assumptions for all calculations:

1. **Pipe Condition:** Fully Deteriorated
2. **Ovality:** 3%
3. **Water Table depth:** At surface
4. **Soil Density:** 120 lb/ft3 / 1925 kg/m3
5. **Soil Modulus:** 1000 psi / 6.9MPa
6. **Traffic/Live Load:** HS-20 16,000lbs / 110MPa
7. **Safety Factor**: 2.0
8. **Poisson's Ratio:** 0.3
9. **Enhancement Factor:** 7.0

Hydraulic Flow Calculations for Lined Pipe

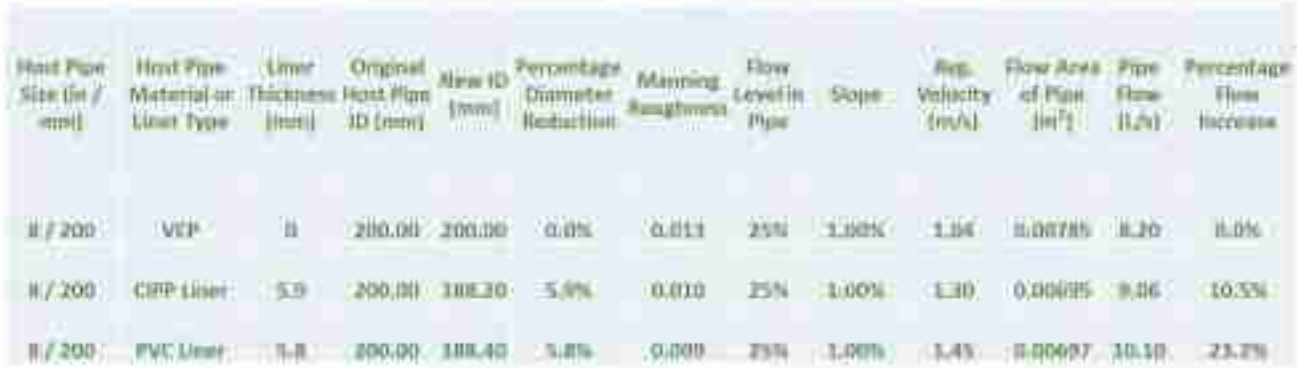
Use Manning Formula for gravity flow velocity in an open channel: $v = (k_n / n)\, R_h^{2/3}\, S^{1/2}$

where: $k_n = 1.486$ n = *Manning coefficient of Roughness (value by pipe/lining material)*

R_h = *Hydraulic Radius* S = *Slope of pipe*

Flow rate is calculated as velocity x cross sectional area: $q = v \times A = (k_n / n)\, R_h^{2/3}\, S^{1/2} \times A$

Below are examples of calculations for different size pipes and host pipe materials:



Host Pipe Size (in / mm)	Host Pipe Material or Liner Type	Liner Thickness (mm)	Original Host Pipe ID (mm)	New ID (mm)	Percentage Diameter Reduction	Manning Roughness	Flow Level in Pipe	Slope	Avg. Velocity (m/s)	Flow Area of Pipe (m²)	Pipe Flow (L/s)	Percentage Flow Increase
8 / 200	VCP	0	200.00	200.00	0.0%	0.013	25%	1.00%	1.04	0.00785	8.20	0.0%
8 / 200	CIPP Liner	5.9	200.00	188.20	5.9%	0.010	25%	1.00%	1.30	0.00695	9.06	10.5%
8 / 200	PVC Liner	5.8	200.00	188.40	5.8%	0.009	25%	1.00%	1.45	0.00697	10.10	23.2%

Host Pipe ID (mm	Host Pipe Material / Liner Type	Liner thickness (mm)	New ID (mm	% Diameter Reducti	Manning Roughn	Flow Level	Slope	Cross-section Area (m	Wetted Perimeter (m)	Hydraulic Radius (m)	Avg. Velocity (m/s)	Pipe Flow (L/s)	% Flow Increa
1050	CSP	0	1050	-	0.022	25%	1.00%	0.216	0.825	0.263	1.86	403.4	0.0%
1050	PVC F&F	16.5	1017	3.1%	0.0177	25%	1.00%	0.203	0.799	0.254	2.27	460.5	14.1%
1050	CSP	0	1050	-	0.022	50%	1.00%	0.433	1.649	0.263	1.86	806.8	0.0%
1050	PVC F&F	16.5	1017	3.1%	0.0177	50%	1.00%	0.406	1.597	0.254	2.27	920.9	14.1%
1050	CSP	0	1050	-	0.022	100%	1.00%	0.866	3.299	0.263	1.86	1613.6	0.0%
1050	PVC F&F	16.5	1017	3.1%	0.0177	100%	1.00%	0.812	3.195	0.254	2.27	1841.9	14.1%

Manning Roughness:

CSP (host)	0.022	Corrugated walls (new pipe)
RCP (host)	0.012	Finished (new pipe)
PVC Liner	0.009	Gun barrel smooth
CSP/PVC	0.0177	Weighted Average of CSP (2/3) and PVC (1/3)

Flow level in pipe: 100% Full

Slope = Rise/Run

Rise = Change in invert depth between inlet and outlet of pipe

Run = Length of host pipe to reline

Slope = 1.00%

EA Engineering Acute Bioassay

RESULTS OF AN ACUTE BIOASSAY WITH *Oncorhynchus mykiss* ON TEST MATERIAL FROM DYNALINER, LLC

Prepared for:

Dynaliner, LLC
3300 Pinson Valley Parkway
Pinson, Alabama 35217

Prepared by:

EA Engineering, Science, and Technology, Inc., PBC
231 Schilling Circle
Hunt Valley, Maryland 21031
For questions, please contact Michael Chanov
ph: 410-584-7000

Results relate only to the items tested or to the samples as received by the laboratory.

This report contains 9 pages plus 2 attachments.

4 August 2017

Wayne L. McCulloch
Laboratory Director

Date

EA Project Number 70003.15

ID# E87550

EA Report Number 7570

I. INTRODUCTION

At the request of Dynaliner, LLC, EA Engineering, Science, and Technology performed a static acute toxicity test on a sample provided by Dynaliner, LLC. The sample was identified as a PVC pipe. *Oncorhynchus mykiss* (rainbow trout) were used as the test species. The objective of the study was to determine the acute toxicity of the sample to the test organisms, expressed as the sample concentration which is lethal to 50 percent of the organisms after 96 hours of exposure (96-hour LC50).

2. METHODS AND MATERIALS

2.1 SAMPLE DESCRIPTION

The sample, identified as a PVC pipe, was shipped to EA. Upon receipt at EA on 18 July 2017, the sample was logged in and assigned EA Toxicology Laboratory Accession Number AT7-290. The 18- inch sample was split into 4 sections and placed in an aquarium with 20L of dechlorinated tap water. The sample was gently mixed for 24 hours before toxicity testing. Following the 24 hour leaching period, the PVC pipe samples were removed. The remaining water constituted the 100 percent sample. A summary of sample identification/receipt information is presented in Table 1.

2.2 TEST ORGANISMS

Oncorhynchus mykiss (rainbow trout) were obtained from Troutlodge in Sumner, Washington on 26 July 2017. The organisms in Lot OM-038 were acclimated to the testing temperature of 12°C and to laboratory dechlorinated tap water. During the holding period, the trout were maintained in an environmentally controlled room at 12°C, with a 16-hour light/8-hour dark photoperiod. The organisms, which swam up on 27 June 2017, were 29 days post swim up when used for testing. The test organisms, *O. mykiss* were exposed to 100, 75, 50, 25, and 12.5 percent sample and a dilution water laboratory control.

2.3 DILUTION WATER

Dechlorinated tap water was used as dilution water for the *O. mykiss* acute toxicity test. The source of the water was the City of Baltimore municipal water system. Upon entering the laboratory, the water passed through a high-capacity, activated-carbon filtration system to remove any possible contaminants such as chlorine and trace organic compounds. This water source has proven safe for aquatic organism toxicity testing at EA as evidenced by maintenance of the multigeneration fathead minnow cultures with no evident loss of fecundity.

2.4 TOXICITY TEST OPERATIONS AND PERFORMANCE

The toxicity testing was conducted following EA's standard operating procedures (EA 2013), which are in accordance with US EPA guidance (US EPA 2002). Test concentrations were prepared by measuring volumes of sample in pipets or graduated cylinders, transferring to a volumetric flask, and bringing to volume with dilution water.

The definitive toxicity test consisted of five exposure concentrations and a dilution water control. The test was conducted in 2-L beakers containing 1 L of test solution. Each test concentration and control had two replicate test chambers. The acute toxicity tests were maintained at a target temperature of 12±1°C with a 16-hour light/8-hour dark photoperiod. The *O. mykiss* were exposed for 96 hours, and were not fed during the exposure period.

Water quality measurements and mortality observations were made daily throughout the study and were recorded on the data sheets. Water quality determinations during testing were performed on the following schedule: temperature, dissolved oxygen, salinity, and pH were measured at test initiation, termination, and daily in one replicate of each exposure concentration and the controls. A summary of the test solution water quality ranges is provided in Table 2. Using the total number of surviving organisms per concentration at the end of the 96-hour exposure period, the median lethal concentration (LC50) value was calculated, using the Tox Calc statistical software package (Version 5.0, Tidepool Scientific Software) and following US EPA guidance (US EPA 2002). Results of the definitive toxicity test are presented in Table 2. Copies of the statistical analyses and the original data sheets, which include all water quality measurements, are presented in Attachment I.

2.5 REFERENCE TOXICANT TEST

A reference toxicant test was conducted by EA on Lot OM-038, using potassium chloride (KCl) as the reference toxicant. The test organisms were exposed to KCl to determine the 48-hour acute response of these test organisms. The tests were performed with a graded concentration series of toxicant and a dilution water control, and the results were compared to the established control chart limits.

2.6 ARCHIVES

Original data sheets, records, memoranda, notes, and computer printouts are archived at EA's Hunt Valley, Maryland. The primary data and other related information will be retained for a period of 5 years unless a longer period of time is requested by Dynaliner, LLC.

3. RESULTS AND DISCUSSION

The results of the 96-hour acute toxicity test with *Oncorhynchus mykiss* complies with current NELAC standards, where applicable.

The *O. mykiss* definitive toxicity test results are presented in Table 2. After 96 hours of exposure, there was 95 percent survival in test concentrations. The laboratory control had 100 percent survival at test termination. The 96-hour LC50 for *O. mykiss* was >100 percent sample.

The results of the reference toxicant tests for the acquired lot of *O. mykiss* were acceptable and fell within the established laboratory control chart limits. The 48-hour LC50 value for the reference toxicant test performed on Lot OM-038 was 2,478 mg/L KCl. The acceptable range for static *O. mykiss* assays based on EA's control charts was 618 – 3,296 mg/L KCl.

4. REFERENCES

EA. 2013. EA Ecotoxicology Laboratory Quality Assurance and Standard Operating Procedures Manual. EA Manual ATS-102. Internal document prepared by EA's Ecotoxicology Laboratory, EA Engineering, Science, and Technology, Inc., Hunt Valley, Maryland.

US EPA. 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fifth Edition. EPA-821-R-02-012. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

TABLE 1 SUMMARY OF SAMPLE IDENTIFICATION INFORMATION

EA Accession Number	Sample Description	Sample Receipt
AT7-290	PVC pipe	1330, 18 July 2017

TABLE 2 RESULTS OF TOXICITY TESTING WITH *Oncorhynchus mykiss* FOR DYNALINER, LLC

Sample Identification:

QC Test Number:	TN-17-234
EA Accession Number:	AT7-290
Test Initiation:	1530, 26 July 2017
Test Termination:	1452, 30 July 2017
Test Duration:	96-hours
Test Organism:	*Oncorhynchus mykiss*

Exposure Concentration (percent sample)	Percent Survival (96-hours)
Control	100
12.5	100
25	100
50	100
75	95
100	100

96-Hour LC50 (percent sample): >100

Selected Test Water Quality Parameters	Range
Temperature (°C):	12.4 – 13.0
pH:	7.9 – 8.5
Dissolved oxygen (mg/L):	4.5 – 10.5
Conductivity (µS/cm):	354 – 406

ATTACHMENT I

Data Sheets and Statistical Analyses
(7 pages)

TOXICITY TEST SET-UP BENCH SHEET

Project Number: 70005.15

Client: Dynaliner

QC Test Number: TN-17-234

TEST ORGANISM INFORMATION

Common Name: Rainbow trout

Scientific Name: O. mykiss

Lot Number: QM-0318

Source: EA Trout Lodge

(S) TSR 8/2/17

Adults Isolated (Time, Date): _____

Neonates Pulled & Fed (Time, Date): _____

Acclimation: ≥ 24 hrs Age: 21 days post-swim-up

Culture Water (T/S): 13.4 °C 0 ppt

TEST SET-UP

TEST INITIATION

Date	Time	Initials	Activity
7/26/17	1510	MJ	Dilutions Made
	1510		Test Vessels Filled
	1530		Organisms Transferred
	1544	HP	Head Counts

CONCENTRATION SERIES

Test Concentration	Volume Test Material	Final Volume
Control	0 ml	2000 ml
12.5%	250ml	
25%	500ml	
50%	1000ml	
75%	1500ml	
100%	2000ml	

Comments:

INTERMEDIATE DILUTION PREPARATION AND FEEDING

DILUTION PREPARATION

Day	Date	Time	Initials	Sample / Diluent
0	7/26/17	1510	MJ	A17-240 Bechler
1				
2	7/28/17	0950	RSB	A17-240 Bechler
3				
4				
5				
6				

FEEDING

Food: _____

Day	Time, Initials, Amount	Time, Initials, Amount	Time, Initials, Amount
0			
1			
2			
3			
4			
5			
6			

ACUTE TOXICITY TEST DATA SHEET

Project Number: 70005.15
Client: Dynaliner
QC Test Number: TN-17-294
Test Material: Effluent
Accession Number: ATT-290
Dilution Water: Dechlor
Accession Number: ——

TEST ORGANISM
Common Name: Rainbow trout
Scientific Name: O. mykiss
TARGET VALUES
Temp: 12±1 °C DO: ≥4.0 mg/L
pH: 6.0 - 9.0 Salinity: 0 ppt
Photoperiod: 16/8 d Light Intensity: 50 - 100 fc

Beginning Date: 7/26/17 Time: 1530
Ending Date: 7/30/17 Time: 1452
TEST TYPE: (Static) / Flowthrough
(Renewal) / Non-renewal
Test Container: 2 L Beaker
Test Volume: 1,000 ml
Test Duration: 96 hrs

Concentration	Rep	Number of Live Organisms					Temperature (°C)					pH					Dissolved Oxygen (mg/L)					Conductivity (µS/cm) / Salinity (ppt)				
		0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96
Control	A	10	10	10	10	10	13.0	12.7	12.7			8.5		8.0			9.7		10.2			354		390		
	B	10	10	10	10	10																				
12.5	A	10	10	10	10	10	13.0		12.8			8.5		8.0			9.8		10.4			355		396		
	B	10	10	10	10	10																				
25	A	10	10	10	10	10	13.0		12.8			8.4		8.0			9.8		10.4			356		395		
	B	10	10	10	10	10																				
50	A	10	10	10	10	10	13.0		12.7			8.4		8.0			9.6		10.5			355		395		
	B	10	10	10	10	10																				
76	A	10	10	10	10	10	13.0		12.5			8.4		8.1			9.5		10.4			355		395		
	B	10	10	9	9	9																				
100	A	10	10	10	10	10	13.0		12.5			8.4		8.1			9.1		10.3			354		394		
	B	10	10	10	10	0																				
Meter Number							678		678			678		678			678		678			678		678		
Time		0944	1515	1502	1451	1452	1518		1130			1518		1130			1518		1130			1518		1130		
Initials		HP	MS	RSB	MS	MS	MS		RSB			MS		RSB			MS		RSB			MS		RSB		

(3) RSB 7/28/17

EPA Test Method: EPA 821-R-02-012 (CHECK ONE)

Ceriodaphnia: 2002.0 ____ Fathead: 2000.0 X
Magna/pulex: 2021.0 ____ Trout: 2019.0 ____
Americamysis: 2007.0 ____ Menidia: 2006.0 ____
Cyprinodon: 2004.0 ____ OTHER: ____

12/02/08
ATS-T01

ACUTE TOXICITY TEST DATA SHEET - OLD SOLUTIONS

Project Number: 70005.15
Client: Dynaliner
QC Test Number: TN-17-284
Test Material: Effluent
Accession Number: AT7-290
Dilution Water: Dechlor
Accession Number: —

TEST ORGANISM
Common Name: Rainbow trout
Scientific Name: O. mykiss

TARGET VALUES
Temp: 12±1 °C
pH: 6.0 - 9.0
Photoperiod: 16/8 d

DO: ≥4.0 mg/L
Salinity: 0 ppt
Light Intensity: 50 - 100 fc

Beginning Date: 7/26/17 Time: 1530
Ending Date: 7/30/17 Time: 1452
TEST TYPE: (Static) / Flowthrough
(Renewal) / Non-renewal
Test Container: 2 L Beaker
Test Volume: 1,000 ml
Test Duration: 96 hrs

Concentration	Rep	Number of Live Organisms				Temperature (°C)				pH				Dissolved Oxygen (mg/L)				Conductivity (µS/cm) Salinity (ppt)			
		[illegible]				0	24	48	72	96	0	24	48	72	96	0	24	48	72	96	0	24	48	72	96
Control						13.0	12.4	13.0	13.0		8.3	8.0	8.3	8.3		7.4	7.3	6.4	6.6		365	403	370	374
12.5%						13.0	12.4	13.0	13.0		8.2	8.0	8.3	8.2		6.9	6.4	6.8	6.0		367	405	374	387
25%						13.0	12.5	12.9	12.9		8.2	8.0	8.3	8.2		5.8	6.2	5.3	5.5		365	401	371	381
50%						13.0	12.5	12.7	12.6		8.2	7.9	8.2	8.2		5.1	6.7	5.8	5.4		374	406	373	385
75%						13.0	12.6	12.7	12.5		8.1	7.9	8.2	8.2		4.6	6.6	5.9	4.5		365	399	373	387
100%						13.0	12.4	12.7	12.5		8.1	7.9	8.2	8.2		4.9	6.8	5.7	4.5		365	401	372	383
Meter Number						678	678	678	678		678	678	678	678		678	678	678	678		678	678	678	678
Time						1336	1134	0846	0900		1336	1134	0846	0900		1336	1134	0846	0900		1336	1134	0846	0900
Initials						MS	RSB	MS	MS		MS	RSB	MS	MS		MS	RSB	MS	MS		MS	RSB	MS	MS

TOXICOLOGY LABORATORY BENCH SHEET

Project Number: 70005.15

Client: Dynalliner

QC Test Number: TN-11-234

Date/Time/Initials	Comments/Activity

RANDOMIZATION CHART

Project Number: 70005.15

Client: Dynaliner

QC Test Number: TN-17-234

6	2	4	1	5	3
4	1	2	6	3	5

TOXICOLOGY LABORATORY CORRECTION BENCH SHEET

Project Number: 70005.16

Client: Dynaliner

QC Test Number: TN-17-234

Correction Explanations

(a) Technician Error-Mathematical

(b) Technician Error-Manual Data Recording

(c) Technician Error-Head Count Observation

(d) Technician Error-Overwrite

(e) Technician Error-Missing Data

(f) Technician Error-Lost Organism

(g) Technician Error-Transcription Error

(h) Technician Error-Other:

(i) Meter Malfunction

ATTACHMENT II

Report Quality Assurance Record
(2 pages)

REPORT QUALITY ASSURANCE RECORD

Client: Dynaliner

Author: Rachael Brooks

Project Number: 70005.15

EA Report Number: 7570

REPORT CHECKLIST

QA/QC ITEM	REVIEWER	DATE
1. Samples collected, transported, and received according to study plan requirements.		8/2/17
2. Samples prepared and processed according to study plan requirements.		8/2/17
3. Data collected using calibrated instruments and equipment.		8/2/17
4. Calculations checked:		
- Hand calculations checked		8/2/17
- Documented and verified statistical procedure used.		8/2/17
5. Data input/statistical analyses complete and correct.		8/4/17
6. Reported results and facts checked against original sources.		8/4/17
7. Data presented in figures and tables correct and in agreement with text.		8/4/17
8. Results reviewed for compliance with study plan requirements.		8/2/17

	AUTHOR	DATE
9. Commentary reviewed and resolved.		8/4/17

10. All study plan and quality assurance/control requirements have been met and the report is approved:

PROJECT MANAGER		8/4/17 DATE
QUALITY CONTROL OFFICER		8/4/17 DATE
SENIOR TECHNICAL REVIEWER		8/4/17 DATE

Thermoform 3rd Party Testing Documentation

- ASTM D1784 Cell Classification Test
- ASTM D2990 Long Term Flexural Creep Test
- ASTM D2837 Long Term Pressure (Hydrostatic Design Basis) Test
- ASTM F1867 Review for Thermoform Relaxation Procedure
- ASTM F1867 Review for DTUL (Heat Deflection Test)

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PROJECT REPORT

REPORT NUMBER: WAR-040419-1-RP1
DATE: 4/8/2019

CLIENT INFORMATION:
Warrior USA LLC
1400 Commerce Parkway
Lancaster, NY 14086
Attn: Tony O'Brien and Brian Kelly

SAMPLE IDENTIFICATION
PSILab received one (1) PVC compound for cell classification testing with client provided identification of "PVC Compound." The client reported that the compound was identical to what is used in the manufacture of Thermoform™ PVC pipe rehabilitation products.

TEST PERFORMED
The sample was tested for cell classification in accordance with *ASTM D1784-11, Standard Specification for Rigid PVC Compounds and Chlorinated CPVC Compounds*. Specific referenced test methods are listed below:

1. Izod Impact Resistance: ASTM D256-18 (2.75J impact)
2. Tensile Strength: ASTM D638-14 (Type IV, 0.2ipm)
3. Tangent Modulus: ASTM D638-14 (Type IV, 0.2ipm)
4. Deflection Temperature: ASTM D648-18 (264psi, 4" span)
5. Rate of Burn: ASTM D635-18 (UHP Methane, 30 seconds burn)
6. Flexural Strength: ATSM D790-17 (not part of ASTM D1784 cell class)

RESULT
Results from the physical properties tests and their corresponding ASTM D1784 cell classifications are shown in table 1 below. Appendix A (Tables 2-4) provides the actual data from each test performed.

Table 1: Summary of Test Results and ASTM D1784 Cell Classification.

Sample ID	Test Performed	Results	ASTM D1784 Classification
PVC Compound	IZOD Impact (Ft-Lb/in)	1.08	2
	Tensile Strength (psi)	4,788	1
	Tangent Modulus (psi)	361,391	4
	Deflection Temperature (°C)	53.4	1
	Rate of Burn	< 25mm & <10s	HB
	Flexural Modulus	367,390	N/A
	Flexural Strength	7,832	N/A

Report Written by:

Steve Ferry
Laboratory Director

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APPENDIX A. Detailed Test Data:

Table 2. ASTM D256 Izod Impact Energy

Specimen	Energy (J)	Energy (Ft-Lb)	Thickness (in)	Width (in)	Ft-Lb/in	J/m	Break Type
1	0.211	0.156	0.3993	0.1415	1.100	58.707	complete
2	0.224	0.165	0.3990	0.1434	1.152	61.499	complete
3	0.188	0.139	0.3987	0.1314	1.056	56.350	complete
4	0.211	0.156	0.3989	0.1372	1.135	60.569	complete
5	0.214	0.158	0.3989	0.1275	1.238	66.080	complete
6	0.191	0.141	0.3987	0.1445	0.975	52.057	complete
7	0.201	0.148	0.3994	0.1408	1.053	56.203	complete
8	0.217	0.160	0.3990	0.1422	1.126	60.080	complete
9	0.175	0.129	0.3988	0.1409	0.916	48.916	complete
10	0.191	0.141	0.3991	0.1355	1.040	55.496	complete
Average					1.079	57.596	
SD					0.097	5.196	

Table 3. ASTM D638 Tensile Properties Results

Name	Width (mm)	Thickness (mm)	Modulus (psi)	Peak Stress (psi)	Stress at Yield (psi)	Strain at Yield (%)
Replicate 1	0.4957	0.1621	376,297	4,866	4,866	2.090
Replicate 2	0.4945	0.1647	366,525	4,858	4,858	2.154
Replicate 3	0.4982	0.1640	344,520	4,712	4,712	2.212
Replicate 4	0.4977	0.1655	350,150	4,644	4,644	2.092
Replicate 5	0.5013	0.1629	369,463	4,861	4,861	2.124
Mean	0.4975	0.1639	361,391	4,788	4,788	2.135
SD	0.0026	0.0014	13,460	103.7	103.7	0.050

Table 4. ASTM D648 Deflection Temperature

Time Start (minutes)	Temperature (C)	Temperature (C)
	Specimen 1	Specimen 2
0	24.1	24.2
5	33.7	33.7
10	43.5	43.6
15	53.4	53.4
Average		53.4

Table 5. ASTM D635 Rate of Burn

Time Start	Burn Time	Burn Distance	Results
	(second)	(mm)	
Specimen 1-10	<10	<25mm	HB (flame did not reach the 25mm starting point)

Table 6. ASTM D790 Flexural Properties Results

Name	Width (in)	Thickness (in)	Modulus (psi)	Flexural Stress at Yield (psi)	Strain at Yield (%)
Replicate 1	0.4980	0.1521	370,546	7,827	4.11
Replicate 2	0.4985	0.1567	368,367	7,877	4.08
Replicate 3	0.4995	0.1473	373,027	7,714	3.96
Replicate 4	0.4980	0.1545	361,679	7,806	4.22
Replicate 5	0.4980	0.1588	363,330	7,935	4.08
Mean	0.4984	0.1539	367,390	7,832	4.09
SD	0.0007	0.0044	4,790	83.0	0.0900

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PROJECT REPORT

REPORT NUMBER: WAR-072220-1-RP3

DATE: February 16, 2021

CLIENT INFORMATION:
Warrior USA LLC
1400 Commerce Parkway
Lancaster, NY 14086
Attn: Tony O'Brien and Brian Kelly

SAMPLE DISCRIPTION:
One sample of Thermoform™ PVC pipe material in flat plate form approximately 0.28 inches in thickness was received from the client on 8/26/2015. The client identified the sample as having been manufactured in accordance with ASTM F1871, *Standard Specification for Folded/Formed Poly(Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation*.

TEST PERFORMED:
The sample was tested for flexural creep (time dependent flexural modulus) in general accordance with ASTM D2990-09, Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics. Four (4) test replicates were prepared and tested per Section 6.3 of ASTM D2990, Flexural Creep, using a three-point static-load configuration, a 4.47 inch span, and a test stress of 700 psi. The ASTM D2990 flexural creep testing was performed at 23±2^{0}C and 50±10% Relative Humidity for the complete duration of testing. Testing was initiated on December 11, 2015 and was completed on February 7, 2017.

The client requested determination of the 50 year modulus by extrapolating from the 6 minute modulus through an approximate average of the long-time moduli data (e.g. approximately log time 3.5) to the 50 year time duration (i.e. 438,000 hours). This extrapolation was performed using the complete data set in a manner that reflected the methodology adopted by similar competitive products. The extrapolation was performed using the average results for the four (4) test replicates.

Additionally, the client requested calculation of the creep factor under dry conditions in general accordance with ISO11296-4 Annex D using the 6 minute and 50 year moduli.

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DISCUSSION

The creep data for the Thermoform™ PVC pipe material was originally reported within the WAR-072220-1-RP1 report issued July 22, 2020. Within this original report the extrapolation was performed using the most linear portion of the ASTM D2990 creep testing data set via standard linear regression analysis (e.g. Excel software). A second extrapolation methodology using the complete data set via standard linear regression analysis was reported within the WAR-072220-1-RP2 report issued February 12, 2021. This final extrapolation methodology reported herein using the complete data set with the extrapolation performed via the client-requested extrapolation methodology resulted in a 140,622 psi calculated 50 year flexural modulus.

RESULTS:

The individual creep test replicate dimensions and test loads are displayed in Table 1, as well as the test stress and test span.

Table 1. Individual creep replicate dimensions and test loads.

	Sample 1	Sample 2	Sample 3	Sample 4
Width, b	0.5040	0.5000	0.4995	0.4990
Depth, d	0.2822	0.2874	0.2879	0.2827
Span, L	4.47	4.47	4.47	4.47
Stress	700	700	700	700
Load, P, lb	4.1903	4.3116	4.3223	4.1634
Load, P, g	1900.7	1955.7	1960.6	1888.5

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The raw time versus displacement creep data is presented in Table 2. Note that due to a data acquisition issue the 1 minute displacement values were inadvertently not obtained.

Table 2. Time versus displacement creep data for each creep test replicate:

		Deflection (in)			
Total Time		Sample 1	Sample 2	Sample 3	Sample 4
1	Min				
6	Min	0.02540	0.02310	0.02750	0.02240
12	Min	0.02595	0.02355	0.02785	0.02280
30	Min	0.02630	0.02385	0.02785	0.02310
1	Hour	0.02670	0.02430	0.02905	0.02350
2	Hour	0.02715	0.02475	0.02915	0.02395
5	Hour	0.02775	0.02535	0.02945	0.02455
20	Hour	0.02900	0.02660	0.03070	0.02570
50	Hour	0.03015	0.02780	0.03185	0.02680
100	Hour	0.03120	0.02895	0.03315	0.02785
200	Hour	0.03290	0.03060	0.03470	0.02955
500	Hour	0.03570	0.03350	0.03770	0.03220
700	Hour	0.03720	0.03510	0.03930	0.03370
1000	Hour	0.03905	0.03700	0.04125	0.03550
1580	Hour	0.04175	0.03965	0.04380	0.03810
1878	Hour	0.04240	0.04040	0.04460	0.03880
2178	Hour	0.04325	0.04115	0.04530	0.03950
2478	Hour	0.04390	0.04200	0.04615	0.04030
2770	Hour	0.04480	0.04280	0.04690	0.04105
3120	Hour	0.04550	0.04350	0.04765	0.04180
3420	Hour	0.04600	0.04400	0.04805	0.04220
3870	Hour	0.04675	0.04485	0.04905	0.04305
4220	Hour	0.04740	0.04550	0.04970	0.04360
4570	Hour	0.04800	0.04610	0.05035	0.04420
4920	Hour	0.04870	0.04675	0.05100	0.04485
5270	Hour	0.04910	0.04720	0.05150	0.04530
5620	Hour	0.04975	0.04785	0.05215	0.04590
5970	Hour	0.05030	0.04845	0.05265	0.04640
6320	Hour	0.05075	0.04890	0.05315	0.04685
6670	Hour	0.05130	0.04945	0.05370	0.04745
7020	Hour	0.05155	0.04970	0.05395	0.04770
7370	Hour	0.05195	0.05005	0.05435	0.04805
7720	Hour	0.05215	0.05030	0.05460	0.04825
8070	Hour	0.05245	0.05050	0.05470	0.04850
8420	Hour	0.05280	0.05085	0.05510	0.04890
8770	Hour	0.05285	0.05095	0.05520	0.04895
9120	Hour	0.05310	0.05120	0.05540	0.04920
9470	Hour	0.05325	0.05130	0.05555	0.04930
9820	Hour	0.05325	0.05135	0.05570	0.04935
10170	Hour	0.05345	0.05155	0.05585	0.04955

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The calculated time dependent flexural modulus creep test results through 10,170 hours test duration are presented in Table 3.

Table 3. Time versus flexural modulus creep results for each creep test replicate:

		Modulus (psi)				
Total Time		Sample 1	Sample 2	Sample 3	Sample 4	Average
1	Min					
6	Min	325,215	351,126	294,434	368,119	334,723
12	Min	318,323	344,417	290,733	361,661	328,783
30	Min	314,086	340,084	290,733	356,964	325,467
1	Hour	309,381	333,787	278,724	350,888	318,195
2	Hour	304,253	327,718	277,768	344,295	313,508
5	Hour	297,675	319,961	274,938	335,880	307,114
20	Hour	284,844	304,925	263,744	320,851	293,591
50	Hour	273,979	291,763	254,221	307,681	281,911
100	Hour	264,759	280,173	244,251	296,081	271,316
200	Hour	251,078	265,066	233,341	279,048	257,133
500	Hour	231,386	242,120	214,773	256,083	236,090
700	Hour	222,056	231,083	206,029	244,684	225,963
1000	Hour	211,536	219,217	196,289	232,278	214,830
1580	Hour	197,856	204,565	184,861	216,427	200,927
1878	Hour	194,822	200,768	181,545	212,522	197,414
2178	Hour	190,994	197,108	178,740	208,756	193,900
2478	Hour	188,166	193,119	175,448	204,612	190,336
2770	Hour	184,386	189,510	172,642	200,874	186,853
3120	Hour	181,549	186,460	169,925	197,269	183,801
3420	Hour	179,575	184,341	168,510	195,400	181,957
3870	Hour	176,695	180,848	165,075	191,541	178,540
4220	Hour	174,272	178,264	162,916	189,125	176,144
4570	Hour	172,093	175,944	160,813	186,558	173,852
4920	Hour	169,620	173,498	158,763	183,854	171,434
5270	Hour	168,238	171,843	157,222	182,028	169,833
5620	Hour	166,040	169,509	155,262	179,648	167,615
5970	Hour	164,224	167,410	153,788	177,713	165,784
6320	Hour	162,768	165,869	152,341	176,006	164,246
6670	Hour	161,023	164,025	150,781	173,780	162,402
7020	Hour	160,242	163,199	150,082	172,869	161,598
7370	Hour	159,008	162,058	148,977	171,610	160,413
7720	Hour	158,398	161,253	148,295	170,899	159,711
8070	Hour	157,492	160,614	148,024	170,018	159,037
8420	Hour	156,448	159,509	146,950	168,627	157,883
8770	Hour	156,300	159,196	146,683	168,455	157,659
9120	Hour	155,564	158,418	146,154	167,599	156,934
9470	Hour	155,126	158,109	145,759	167,259	156,563
9820	Hour	155,126	157,955	145,367	167,089	156,384
10170	Hour	154,546	157,343	144,976	166,415	155,820

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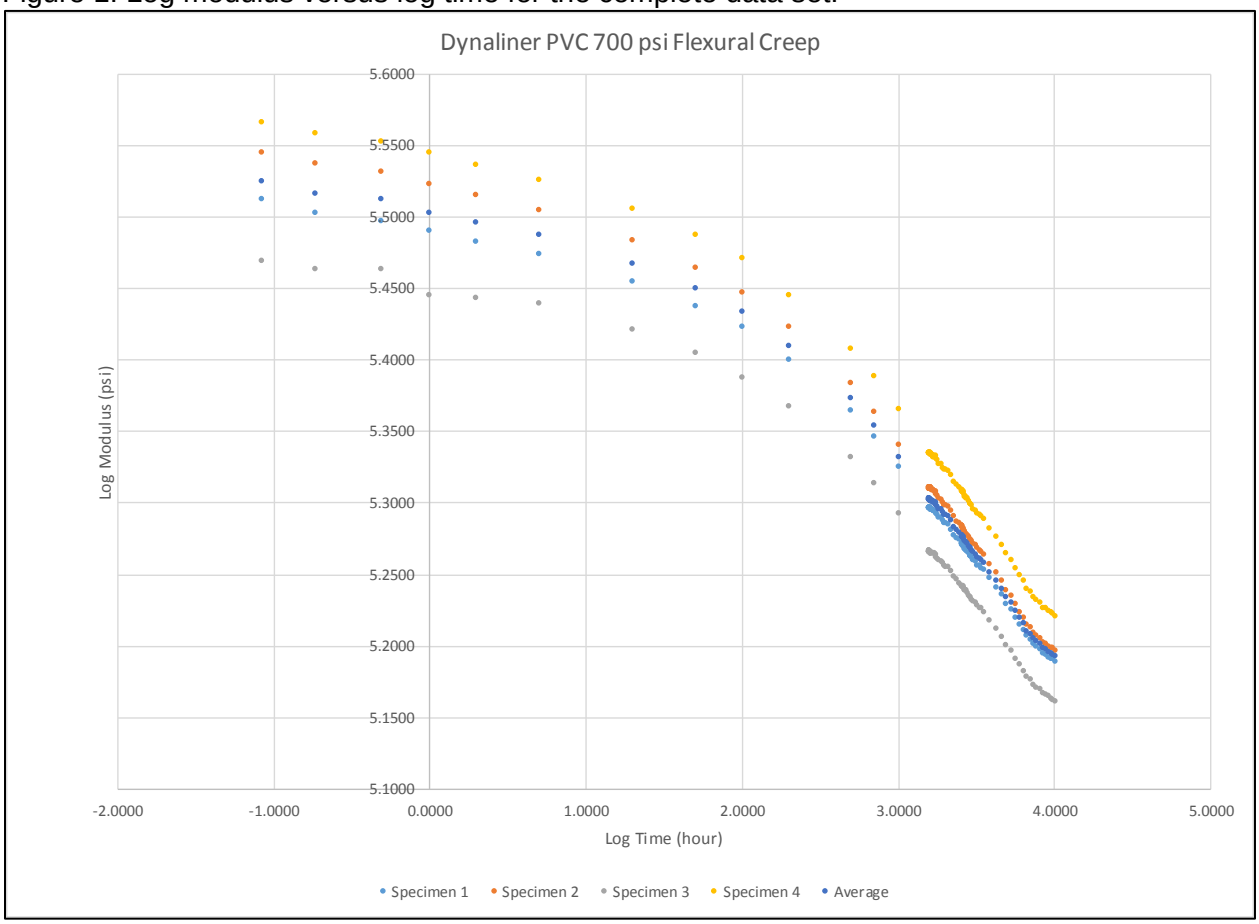
Additionally, graphical data displaying the log modulus versus log time for the complete data set is presented in Figure 1.

Figure 1. Log modulus versus log time for the complete data set.



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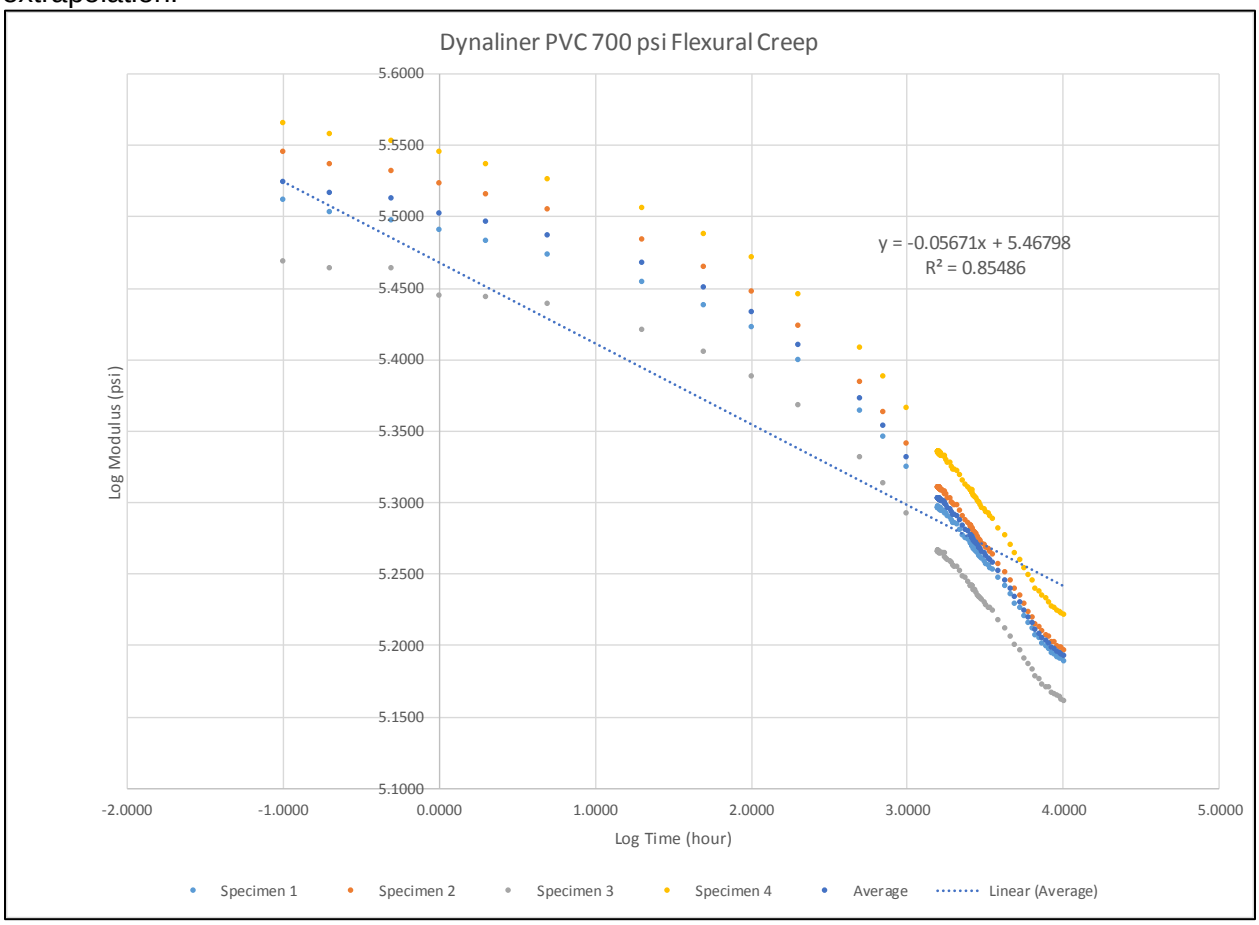
Finally, graphical data displaying the client-requested extrapolation of the log modulus versus log time data (for the complete data set) is presented in Figure 2.

Figure 2. Log modulus versus log time for the complete data set with client-requested extrapolation.



Using the client-requested extrapolation of the complete data set the 50 year (438,000 hour) modulus was calculated to be 140,622 psi. The equation of the line used to extrapolate the 50 year modulus is:

Log(modulus in psi) = -0.05671 * (Log(time in hours)) + 5.46798

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CONCLUSION

The creep factor under dry conditions is 42% when calculated in general accordance with ISO11296-4 Annex D using the 6 minute and 50 year moduli. This calculation is based on the client-requested extrapolation which resulted in a 140,622 psi 50 year modulus divided by the 6 minute modulus of 334,723 psi from Table 3.

Report Written by:

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PROJECT REPORT

REPORT NUMBER: WAR-060520-1-RP1

DATE: July 22, 2020

CLIENT INFORMATION
Warrior USA LLC
1400 Commerce Parkway
Lancaster, NY 14086
Attn: Tony O'Brien and Brian Kelly

BACKGROUND
Warrior owns Thermoform™ PVC alloy pipe liner for rehabilitation of existing sewer and conduits and has performed multiple ASTM D1784 "Cell Classification" testing programs within the past two years, testing for (at minimum), tensile strength and modulus. ASTM D1784 is the *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds* which is the methodology by which PVC pipe materials are tested and classified. These tests were performed for material qualification as well as field-installation materials property verification testing in general accordance with ASTM F1871, *Standard Specification for Folded/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation.* The client has also performed long-term flexural modulus testing on the Thermoform™ PVC alloy pipe liner product in accordance with ASTM D2990, *Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics* for materials qualification circa 2017.

OBJECTIVE
The client requested a determination of the approximate quickburst pressure and an estimate of the pressure rating for the existing Thermoform™ PVC alloy pipe liner product based on historical testing data, although testing is being commenced to formally determine a pressure rating for the product.

SAMPLE DESCRIPTION
Historical test data from multiple projects was reviewed. An average tensile strength at yield for the Thermoform™ PVC alloy pipe liner product of 5405 psi was calculated from ten (10) individual test results.

TEST PERFORMED
Calculations were performed to estimate the quickburst strength of the Thermoform™ PVC alloy pipe liner product in 18-inch nominal diameter DR41 PVC pipe. The "ISO Equation" relating internal pressure to wall (hoop) stress and pipe dimensions was used for this calculation. Specifically:

Stress (S, psi) = Pressure (P, psi) x {(D - t)/(2 x t)}

Where D = Average Outside Diameter and t = Minimum Wall Thickness.

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As such, using the 5405 psi short term tensile yield stress for the Thermoform™ PVC alloy pipe liner product material and 18.00 inch average outside diameter and 0.439 inch minimum wall thickness obtained from the F1871 product specification, a quickburst pressure of 270 psi is calculated.

RESULTS

A quickburst pressure of 270 psi is estimated for a pipe product manufactured in DR41 using the Thermoform™ PVC alloy pipe liner product material.

DISCUSSION

The client also requested an initial estimation of long-term pressure rating for the same Thermoform™ PVC alloy pipe liner product discussed above. Note that the following discussion is an estimate, and that long-term testing is being undertaken to empirically determine the actual long-term material stress rupture strength.

Typically, long-term strength of a pipe material is determined via ASTM D2837, *Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products,* with the underlying test data obtained via ASTM D1598, *Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure*. This is the typical methodology used within North America for determination of the categorized long-term material strength, i.e. the Hydrostatic Design Basis (HDB), which is then used to pressure rate the piping product via application of a Design Factor, resulting in the Hydrostatic Design Stress. From ASTM D2837-13:

3.1.8 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.1.8.1 The PR and HDS/HDB are related by the following equation.

$$PR = 2\,(HDB)\,(DF)/(SDR - 1) = 2\,(HDS)/(SDR - 1) \quad (1)$$

In the case of (pressure) pipe grade PVC, this starts with an ASTM D1784 “12454” material which has 7000 psi tensile strength at yield. ASTM D2837 testing typically yields an HDB of 4000 psi, and with the application of a 0.5 Design Factor (DF) an HDS of 2000 psi. For a DR41 pipe product this would result in a 100 psi pressure rating.

Since the Thermoform™ PVC alloy pipe liner product material has slightly lower strength in comparison to the typical (pressure) pipe grade PVC (5405 psi versus 7000 psi) the pressure rating will of course be slightly lower. Using the 5405 psi tensile strength at yield, and a semi-conservative “de-rating” of 75% for the short-term to long-term strength, an estimated pressure rating of 34 psi for the DR41 Thermoform™ PVC alloy pipe liner product is calculated using a DF of 0.5.

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Specifically:

5405 x 0.25 = 1351 (psi) = “Estimated HDB”

PR = 2 x (1351 psi) x (0.5) / (41 – 1) = 34 psi

Note too that the short-term to long-term strength reduction of 75% is supported by the long-term modulus testing wherein the Thermoform™ PVC alloy pipe liner material exhibited a short-term modulus of 369,000 psi and a 50 year modulus of 90,920 psi, or a 75% reduction.

Report Written by:

Steve Ferry
Laboratory Director

Report Reviewed by:

Robert Sellmer II
Associate Scientist

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PROJECT REPORT

REPORT NUMBER: WAR-041421-1-RP1

DATE: May 7, 2021

CLIENT INFORMATION
Warrior USA LLC
1400 Commerce Parkway
Lancaster, NY 14086
Attn: Tony O'Brien and Brian Kelly

BACKGROUND
Warrior owns Thermoform™ PVC alloy pipe liner which is used for the rehabilitation of existing sewer and conduits and has successfully performed multiple installations over an approximately twelve year span. Within this successful installation time frame the client reported that there have been no examples of movement of the Warrior Thermoform™ PVC pipeline rehabilitation product (post-installation) within the host conduit.

The client reported that a contract requirement was being applied to pipeline rehabilitation bid requests that would require:

'Liners which may be subject to shrinkage, i.e. those that have been heated, winched, pulled or inverted in the installation process, must be left to cool and/or relax for a minimum of 6 hours prior to cutting to re-connect laterals. This time is to allow for relaxation of the liner due to shrinkage, thermal contraction, stress recovery or adjustment in mechanical properties during the installation and curing process.'

OBJECTIVE
The client requested a review of the ASTM F1867, *Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation,* as well as the Warrior Thermoform™ PVC installation requirements to determine of this contract requirement was technically justified.

SAMPLE DESCRIPTION
The following documents were reviewed:

1. ASTM F1871-20
2. ASTM F1867-06(2020)
3. Warrior Thermoform™ PVC installation requirements
4. Historical reports pertaining to Warrior No-Dig Thermoform PVC material properties test results obtained in 2019 which displayed the following results:
   a. Tensile Strength of 4788 psi
   b. Tensile Modulus of 361,400 psi
   c. Flexural Strength of 7832 psi
   d. Flexural Modulus of 367,400 psi
   e. DTUL of 54.9°

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REVIEW PERFORMED

F1871-20:

The ASTM F1871-20 *Standard Specification for Folded/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation* document was reviewed with a general focus on the material properties, and a specific focus on the Heat Deflection Temperature requirement as determined in accordance with ASTM D648 (see Figure 1 below). Within F1871-20 two materials are allowed, both of which have a minimum heat deflection temperature requirement of 46ºC. Note this is consistent with the ASTM D1784 Cell Classification callout for the F1871 allowable materials of 12111 and 32111, both of which require a Heat Deflection Temperature cell of "1", or <55ºC; Note the "Heat Deflection Temperature" defined in F1871 is synonymous with the "Deflection Temperature Under Load," i.e. the "DTUL", as described within ASTM D1784, both of which are determined in accordance with Test Method ASTM D648.

6.1 *Basic Materials*—The pipe shall be made from virgin PVC compound meeting all the requirements for cell classification 12111 or 32111 as defined in Specification D1784 and with minimum physical properties as listed below:

Tensile Strength	Test Method D638	3 600 PSI	(25 MPa)
Tensile Modulus	Test Method D638	155 000 PSI	(1069 MPa)
Flexural Strength	Test Method D790	4 100 PSI	(28 MPa)
Flexural Modulus	Test Method D790	145 000 PSI	(1000 MPa)
Heat Deflection Temperature tested at 264 psi	Test Method D648 (2 MPa)	115 °F	(46 °C)

Figure 1. ASTM F1871-20 Basic Materials requirements.

F1867-06(2020):

The ASTM F1871-20 is required to be installed in accordance with ASTM F1867-06(2020) *Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation* which was reviewed with a general focus on the installation requirements of the folded/formed product, with a specific focus on temperatures and movement (e.g. shrinkage) of the liner post-installation. Section 6.2 of the F1867 standard deals with insertion (see Figure 2).

6.2 *Insertion:*

6.2.1 The reel of flattened pipe should be positioned near the insertion point. The end of the reel of flattened pipe should be tapered and have holes drilled for the attachment of a pulling head. If recommended by the manufacturer, the coil of flattened pipe may be heated to approximately 180°F prior to insertion. An enclosure should be designed so that hot air is continually exiting from it and not allowing ambient air to be drawn in.

Figure 2. ASTM F1867-06(2020) Insertion requirements.

Of particular note within Section 6.2 is the suggestion ("if recommended by the manufacturer") to heat the coil of flattened pipe to "approximately 180ºF prior to insertion." Note that the heating of the flattened pipe is a de facto requirement since it is quite stiff without heating.

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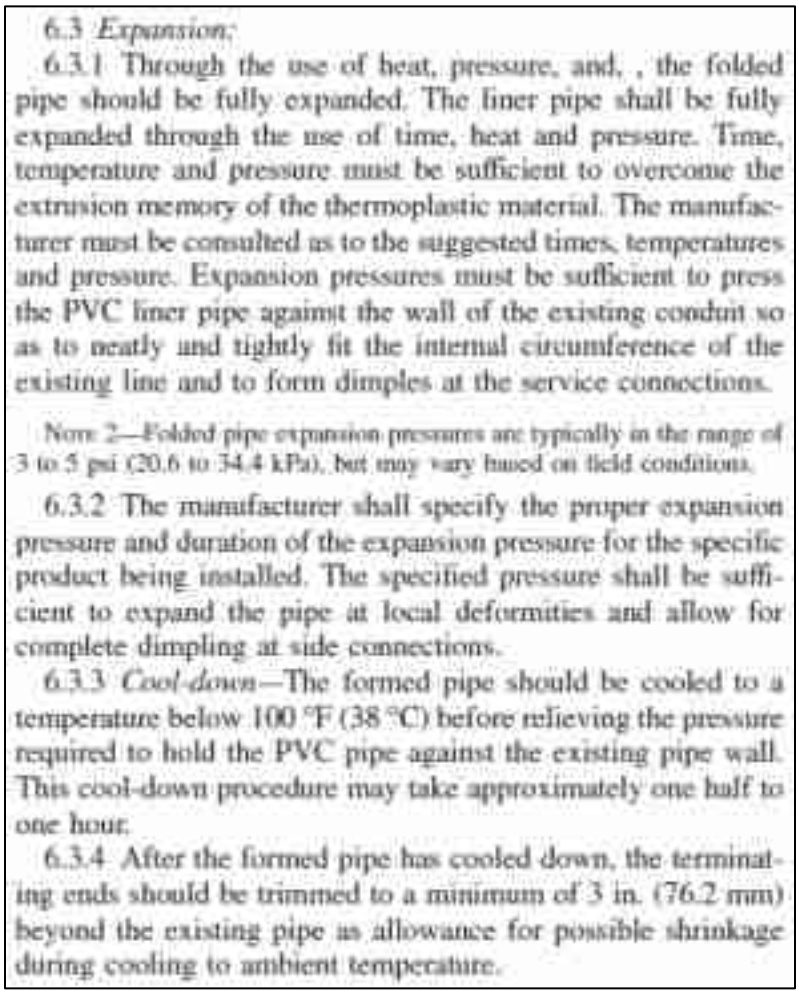
The ASTM F1867 Installation Standard goes on to prescribe the requirements for expansion of the PVC folded/formed liner in Section 6.3 (see Figure 3).

Of particular note within Section 6.3 is the requirement to use heat, pressure, and time to expand the PVC folded/formed liner, with the specific intention that the “time, temperature, and pressure must be sufficient to overcome the extrusion memory of the thermoplastic material.” The actual temperature required for a successful expansion would be as recommended by the manufacturer, although in all cases it would have to be well above the DTUL for the material, or in this case the >46ºC requirement.



6.3 *Expansion:*

6.3.1 Through the use of heat, pressure, and, , the folded pipe should be fully expanded. The liner pipe shall be fully expanded through the use of time, heat and pressure. Time, temperature and pressure must be sufficient to overcome the extrusion memory of the thermoplastic material. The manufacturer must be consulted as to the suggested times, temperatures and pressure. Expansion pressures must be sufficient to press the PVC liner pipe against the wall of the existing conduit so as to neatly and tightly fit the internal circumference of the existing line and to form dimples at the service connections.

Note 2—Folded pipe expansion pressures are typically in the range of 3 to 5 psi (20.6 to 34.4 kPa), but may vary based on field conditions.

6.3.2 The manufacturer shall specify the proper expansion pressure and duration of the expansion pressure for the specific product being installed. The specified pressure shall be sufficient to expand the pipe at local deformities and allow for complete dimpling at side connections.

6.3.3 *Cool-down*—The formed pipe should be cooled to a temperature below 100 °F (38 °C) before relieving the pressure required to hold the PVC pipe against the existing pipe wall. This cool-down procedure may take approximately one half to one hour.

6.3.4 After the formed pipe has cooled down, the terminating ends should be trimmed to a minimum of 3 in. (76.2 mm) beyond the existing pipe as allowance for possible shrinkage during cooling to ambient temperature.

Figure 3. ASTM F1867-06(2020) Expansion requirements.

Finally, the ASTM F1867 Installation Standard goes on to prescribe the requirements for cool-down of the PVC folded/formed liner in Section 6.3.3 (see also Figure 3).

Of particular note within Section 6.3.3 Cool-down is the suggestion to allow the formed pipe to “be cooled to a temperature below 100ºF (38ºC) before relieving the pressure required to hold the PVC pipe against the existing pipe wall.” This is required to hold the now-expanded PVC folded/formed liner tight to the host conduit, i.e. the existing pipe wall, which “locks” the PVC folded/formed liner in place.

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Warrior Thermoform™ PVC installation requirements:
The manufacturer, Warrior Thermoform™, adds to the suggestions and requirements of the ASTM F1867 Installation Practice with significantly greater detail. Various sections from the Warrior Thermoform™ Installation Manual are excised and expounded upon below.

Section 56 of the "Process Stage" has the following guidance:

56.01 'A' Station Steam Plug

56.16 Just in front of the steam plug the Thermoform material should be marked with a series of numbered lines using a Sharpie pen or something similar. This will provide a matrix which will be monitored during the relaxation stage of the process to assess the materials movement.

56.17 The exposed material at the 'B' station end should also be marked with a matrix.

Of particular note within Sections 56.16 and 56.17 is the requirement to mark the pipe "with a series of numbered lines" at both the 'A' and 'B' pipe ends. This marked "matrix" is utilized later to determine if any movement occurs in the PVC folded/formed liner after insertion but prior to expansion, which would of course "lock" in any residual stress etc.

57.00 'A' Station Manifold

57.05 The steam manager must watch closely the temperature gauge on the manifold as it increases. The steam will slowly work its way through the Thermoform material and out through the open end at the 'B' station.

57.06 The objective is to increase the temperature to the optimum figure of 190F (87.7C). Once the temperature gets close to that the steam manager must be ready to introduce air into the steam, via the manifold control valve, so that the temperature can be regulated to maintain the optimum 190F (87.7C).

57.13 When the optimum temperature of 190F (87.7C) has been reached the material at the 'B' station should be checked to see if it has softened sufficiently. If not, the temperature should be maintained until it has.

57.14 When the material has softened sufficiently at the 'B' station end instructions should be given to the steam manager to turn off the steam and maintain the air. The air will speed the process of cooling the material. It is now the time for the relaxation stage of the process.

Of particular note within Sections 57.05 and 57.06 and 57.13 and 57.14 are the requirements to (re)heat the PVC folded/formed liner to approximately 190ºF (87.7ºC) in order to thoroughly heat the pipe in preparation for "relaxation" or "annealing" of the inserted liner.

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Section 58 of the “Process Stage” has the following guidance:

58.00 Relaxation Stage

58.01 The purpose of the relaxation stage of the process is to remove all of the tension from the material caused by the stress imposed upon it when being pulled into the host pipe.

58.02 If the material is not allowed to relax prior to the final processing, there is a real risk of the material shrinking at a future date. Furthermore, there is a risk that it will crack when a robotic cutter attempts to open any lateral / branch connections. This is the result of the material still being under tension. The process of relaxing the material is very straightforward and must not be ignored.

58.03 When the material has softened at the 'B' station the steam manager will be instructed to turn the steam off and maintain the flow of air. At this stage the material in both chambers should be monitored to see if the material is moving into the host pipe. This can be achieved my looking at the lines drawn on the material.

58.04 An allowance of 10 minutes for every 30 meters (100ft) of material should be made for it to relax. During this time the material will cool and possibly shrink back into the host pipe.

58.05 The steam should again be introduced allowing the material to warm and soften again. Instructions will be given to the steam manager to turn the steam back on but before doing so they must make sure that no one is in the chambers.

58.06 The same parameters apply and the temperature should again be monitored and must not exceed 190F (87.7C). The steam manager will adopt exactly the same process of regulating the temperature with air as they did earlier.

58.07 Again, the material is monitored at the 'B' station and when it has softened the steam will be switched off in the same way as before. The lines drawn on the material will again be reviewed in both chambers to see if there is any further movement.

58.08 The process of heating and cooling may have to be repeated until the movement in the chambers has stopped. When you are satisfied that the liner is totally relaxed you can start the final processing of the material. However, before this can be done the exhaust steam plug has to be inserted in the 'B' station end of the material.

Of particular note within Sections 58.01 through 58.08 are the requirements to iteratively heat and cool the pipe in order to fully relax or “anneal” the PVC folded/formed liner after insertion within the host conduit. During this phase the complete liner is heated well above the DTUL temperature while monitoring for movement of the “matrix” lines marked on each end of the pipe. It is well established that stress relaxation can be accelerated by the application of heat (e.g. increasing the temperature) and thus the reduction or elimination of any stress from manufacturing or installation can be accomplished on an accelerated timeline (via the application of heat). Proper completion of these steps will assure that most if not all of the stress within the pulled in place liner has been relieved prior to expansion.

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59.00 'B' Station Exhaust Steam Plug

59.01 Once satisfied that there is no further movement in the Thermoform material the exhaust steam plug can be inserted.

After no further movement of the liner is evident upon heating and cooling, the 'B' Station (i.e. 'B' end) Exhaust Steam Plug can be installed per 59.01 above. Once the 'B' Station Exhaust Steam Plug is installed the final steps of the PVC folded/formed liner installation can be performed, e.g. Final Steam Process, Expansion Phase, and Cooling Phase.

Of utmost importance, the "relaxation" phase occurs prior to expanding the pipe whereupon any stresses would be "locked" into the liner and remain for the life of the rehabilitation. This relaxation process where any stresses are reduced or eliminated prior to expansion and "locking," if performed successfully, eliminates the potential for any shrinkage or movement of the liner to occur.

DISCUSSION

The Thermoform™ PVC alloy pipe liner product has a DTUL or Heat Deflection Temperature (HDT) of >46^{0}C to <55^{0}C. A lower DTUL/HDT is advantageous for many reasons in comparison to other PVC pipeline rehabilitation products with a higher DTUL/HDT. A lower DTUL/HDT assists in the constructability, i.e. in ease of pipeline rehabilitation, by requiring lower heater temperatures and/or shorter heating times, lower winching loads on pull in, extended working time (which can allow for a longer rehabilitation length), as well as requiring lower expansion pressure. From a safety perspective a lower expansion pressure represents a significant risk reduction.

Another advantage of using a material with lower DTUL/HDT is the qualitative fit of the liner within the host conduit, e.g. the fit within the existing pipe. Basically, due to the lower DTUL/HDT as well as lower tensile strength at yield and lower tensile modulus the F1871 product can better "fit" to the host conduit. This qualitatively better fit can provide for an increased mechanical "lock," as well as a smaller annular gap between the liner and host conduit which can reduce "tracking" of wastewater along this annular space.

CONCLUSION

The Thermoform™ PVC alloy pipe liner product has more detailed installation requirements in comparison to the more basic ASTM F1867 Installation Practice and includes a "relaxation" stage during which the pipe is allowed to relax, i.e. the liner is "annealed." Since any residual stresses from manufacturing or installation are reduced or eliminated on an accelerated timeline during this elevated temperature relaxation process no additional relaxation time should be required after expansion and final cooling of the liner.

Report Written by:

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PROJECT REPORT

REPORT NUMBER: WAR-070721-1-RP1

DATE: July 15, 2021

CLIENT INFORMATION
Warrior USA LLC
1400 Commerce Parkway
Lancaster, NY 14086
Attn: Tony O'Brien and Brian Kelly

BACKGROUND
Warrior owns the Thermoform™ PVC alloy pipe liner product line for the rehabilitation of existing sewers and conduits and this product has been successfully installed since 2006. The Thermoform™ products are manufactured in accordance with ASTM F1871, the *Standard Specification for Folded/Formed Poly (Vinyl Chloride) Pipe Type A for Existing Sewer and Conduit Rehabilitation.* The current edition of ASTM F1871 was approved November 1, 2020 and was formally published shortly thereafter. The ASTM F1871 document was originally approved in 1998 and thus has been a product standard in good standing within the ASTM F17.67 Trenchless Plastic Pipeline Technology Subcommittee for over 20 years.

The installation practice for the ASTM F1871 product is ASTM F1867, the *Standard Practice for Installation of Folded/Formed Poly (Vinyl Chloride) (PVC) Pipe Type A for Existing Sewer and Conduit Rehabilitation.* The current edition of ASTM F1867 was approved in 2006, then reapproved in 2012, and finally reapproved again November 15, 2020 and formally published shortly thereafter. The ASTM F1867 document was originally approved in 1998 and thus has also been a product standard in good standing within the ASTM F17.67 Trenchless Plastic Pipeline Technology Subcommittee for over 20 years.

OBJECTIVE
The client requested commentary on the ASTM F1871 material properties, specifically the DTUL or Deflection Temperature Under Load, and the suitability for use within sanitary sewers from a service environment temperature perspective. DTUL is also known as the heat deflection temperature, or heat distortion temperature, and is the temperature at which a material deforms under a specified load.

DISCUSSION
The materials acceptable for use in manufacturing ASTM F1871 products are specified within the product specification within Section 6 as shown below (excerpted from the F1871-20 version):

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6. Materials and Manufacture

6.1 *Basic Materials*—The pipe shall be made from virgin PVC compound meeting all the requirements for cell classification 12111 or 32111 as defined in Specification D1784 and with minimum physical properties as listed below:

Tensile Strength	Test Method D638	3 600 PSI	(25 MPa)
Tensile Modulus	Test Method D638	155 000 PSI	(1069 MPa)
Flexural Strength	Test Method D790	4 100 PSI	(28 MPa)
Flexural Modulus	Test Method D790	145 000 PSI	(1000 MPa)
Heat Deflection Temperature tested at 264 psi	Test Method D648 (2 MPa)	115 °F	(46 °C)

6.1.1 Compounds meeting the above minimum properties that have different cell classifications because one or more properties are greater than those of the specified compounds are also acceptable.

Section 6 of ASTM F1871 thus requires a minimum DTUL of 46ºC when tested in accordance with ASTM D648, the DTUL testing methodology. As required within ASTM D1784, the sub-referenced material specification requirement, the test stress is required to be 264 psi during the DTUL test. Note that Section 6.1.1 also allows for the use of materials with higher performance properties, i.e. greater DTUL test results.

Note that the Warrior Thermoform™ PVC alloy pipe liner typically uses a PVC material with DTUL temperature of 53ºC (approximately 127ºF).

Regarding a DTUL or heat deflection temperature, ASTM D648 offers the following information in Sections 1 and 5 excerpted below:

1. Scope*

1.1 This test method covers the determination of the temperature at which an arbitrary deformation occurs when specimens are subjected to an arbitrary set of testing conditions.

5. Significance and Use

5.1 This test is particularly suited to control and development work. Data obtained by this test method shall not be used to predict the behavior of plastic materials at elevated temperatures except in applications in which the factors of time, temperature, method of loading, and fiber stress are similar to those specified in this test method. The data are not intended for use in design or predicting endurance at elevated temperatures.

As such it is clear from the ASTM D648 testing methodology Scope and Significance and Use sections that the DTUL material requirement is a material quality control requirement and divorced from design and/or performance predictions of the final product.

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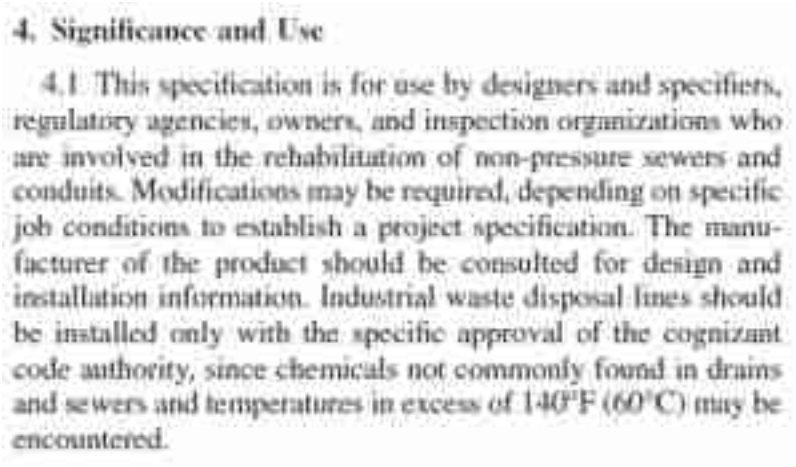
Beyond the fact that the DTUL performance is not related to design or performance, the successful performance of Warrior Thermoform™ PVC alloy pipe liner product is almost certainly due to the fact that there is significant temperature attenuation/reduction of any waste introduced to the sewer conduit first within the building and second within the lateral leading to the main sewer host conduit (which is where the rehabilitation occurs). Related to this, the typical burial depth of a sanitary sewer also allows for extensive cooling since the ground surrounding the sewer line (and lateral) functions as a thermal "heat sink" allowing for significant temperature reduction. Finally, sanitary sewers do not function with full flow, and thus any temperature related effects, if present, would only occur within the flow channel.

It should also be noted that the F1871 product specification specifically cautions against use in elevated temperature service environments such as industrial waste disposal lines within the Significance and Use Section 4 excerpted below:



4. Significance and Use

4.1 This specification is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of non-pressure sewers and conduits. Modifications may be required, depending on specific job conditions to establish a project specification. The manufacturer of the product should be consulted for design and installation information. Industrial waste disposal lines should be installed only with the specific approval of the cognizant code authority, since chemicals not commonly found in drains and sewers and temperatures in excess of 140°F (60°C) may be encountered.

In conclusion, the embedded minimum material requirement of a 46ºC DTUL within the ASTM F1871 product specification is not related to design or predicted product performance. ASTM F1871 PVC pipe rehabilitation products such as Warrior Thermoform™ PVC alloy pipe liner products have exhibited successful performance around the world in a variety of climates for more than 20 years and should continue to do so for the foreseeable future.

Report Written by:

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Thermoform Product Photographs

30 inch corrugated metal pipe fully eroded from corrosive ground water in McCandless Township, Pennsylvania. Guyer Brothers was able to line this pipe after installing aggregate into the void underneath the pipe. The Thermoform Liner later pulled into place provided both a structural liner, as well as, a corrosion resistant liner.

Before Thermoform PVC Lining

After Thermoform PVC Lining

Thermoform

Please follow the youtube link below to see Guyer Brothers installing an 18" Thermoform PVC Liner in Bedford, Pennsylvania.

https://youtu.be/OXyd5xI7I0A?si=KUtc9JCyg_0nSfxQ

Stone laid culvert prepped for lining by another Thermoform Installer.

Stone laid culvert lined with Thermoform PVC Lining showing the versatility of Thermoform.