

**SPECIFICATION
FOR
CURED-IN-PLACE PIPE
RENOVATION OF PRESSURE PIPELINES**

(As submitted by Insituform Technologies, Inc.)

1 INTENT

It is the intent of this specification to provide for the renovation of pressure pipelines by the installation of a cured-in-place pressure pipe lining system. A cured-in-place pressure pipe lining (hereinafter referred to as "pipe lining") is formed by the insertion of an epoxy or vinyl ester resin-impregnated flexible fiber-reinforced felt tube into the existing pipe. The tube is expanded with water or air in an inversion process to fit tightly against the original conduit, and then heated to cure the resin. The finished product is a jointless, pipe lining that is formed to the profile of the existing pipe.

The pipe lining may be designed to either:

- 1.) span and seal pinholes, eliminate leakage through joints and prevent internal corrosion and/or erosion in structurally sound pressure pipe.
- 2.) carry the full internal pressure without consideration of the structural ability of the existing pipe.

The Owner will specify in Section 5.3 of this document which of the pipe design conditions are to be considered.

If intended for the conveyance of potable water, the proposed product shall meet the requirements of ANSI/NSF Standard 61 as evidenced by certification from NSF International or other body approved by the USEPA.

2 REFERENCED DOCUMENTS

This specification references ASTM F1216, including Appendix X1, which is made a part hereof by such reference and shall be the latest edition and revision thereof. In case of conflicting requirements between this specification and F1216, this specification will govern.

3 MATERIALS

- (3.1) The tube shall be fabricated with non-woven synthetic fiber combined with reinforcement material. The tube shall be fabricated to dimensions such that it will stretch to a size that when installed will cure while in contact with the existing pipe.
- (3.2) The outside layer of the tube shall be plastic coated with a translucent flexible material that clearly allows inspection of the resin impregnation (wetout) procedure.
- (3.3) The tube shall have a uniform thickness that when compressed at installation pressures will equal the specified nominal tube thickness.
- (3.4) The tube shall be homogeneous across the entire wall thickness containing no intermediate or encapsulated elastomeric layers. The tube shall contain reinforcement quantities appropriate for the internal pressure requirements.
- (3.5) The wall color of the interior pipe surface after installation shall be a light reflective color so that a clear detailed examination may be made of the final product with closed circuit television inspection equipment or by man-entry.
- (3.6) A vinyl ester or epoxy resin system that is compatible with the inversion process shall be used. When cured the composite shall meet or exceed the design physical properties used in the design submittal of the proposed product (see Section 4.2.A).

4 SUBMITTALS

- (4.1) No later than two weeks before the formal proposal due date, each proposer shall submit to the Owner the required prequalification submittals designated in Section 4.2 for the product to be furnished. After the evaluation of the data, the Owner will notify those firms that have submitted acceptable design packages that they are qualified to furnish proposals for this project.
- (4.2) The following submittals to the Owner are required to meet that which is stated in Section 4.1 above.
 - A Design - Detailed design calculations for both the internal and external loading parameters specified in Section 5 shall be submitted for review and approval. The design submittal shall follow the requirements specified in Section 5. The design submittal shall also clearly identify the physical properties used for design.

These physical properties shall be the basis for acceptance of prequalification submittals of previous field samples (see Section 4.2.E) and acceptance of the final product (see Section 3.6 and 8.5).

- B References - Installation references of projects that are similar in size and scope to this project shall be submitted. The submittal shall include, at a minimum, the client contact name, phone number, and the diameter and footage of pipe rehabilitated.
- C Chemical Resistance - The pipe lining shall meet the chemical resistance requirements of Section 9. Samples for testing shall be of the same resin system and tube materials as proposed for this project. It is required that samples without plastic coating meet these chemical testing requirements.
- D Hydraulic Capacity - The pipe lining shall at a minimum achieve the full flow capacity of the original pipe before rehabilitation. Calculated capacities may be derived using a commonly accepted roughness coefficient for the existing pipe material taking into consideration its age and condition. The roughness coefficient shall be verified by test data.
- E Field Samples - The Contractor shall submit physical property test results from previous installations of the product proposed for this project. These test results must verify that the physical properties used in the design submittal of the proposed product (see Section 4.2.A) have been achieved in previous applications.
- F Reinstatements - The Contractor shall submit details of how existing tees, wyes, air relief valves, blow-off valves, threaded taps, etc., will be reinstated. Reinstatements should provide a sufficient seal to prevent water tracking between the pipe lining and the host pipe.
- G Access Points - The number and location of access points required for installation shall be provided.

5 DESIGN PARAMETERS

- (5.1) The pipe lining shall be designed as ASTM F1216, Appendix X1.3.1 or X1.3.2, depending on the pipe design condition specified in Section 5.3 below.
- (5.2) The pipe lining design shall assume no bonding to the original pipe wall.

(5.3) The design of the pipe lining shall be based on the following parameters, unless otherwise specified by the Owner:

Diameter	_____	, inches
Pipe Design Condition (see 5.1 above)	_____	
Internal Operating Pressure	_____	, psi
Minimum Operating Temperature	_____	, °F
Internal Vacuum, if applicable	_____	, psi
Soil Depth (above top of pipe)	_____	, feet
Ground Water Depth (above invert)	<u>1/3 soil depth*</u>	, feet

*or as specified by the Owner

(5.4) For a pipe lining design following the guidelines of Appendix X1.3.1 of ASTM F1216, the following shall be assumed:

A The physical properties used in the design submittal (see Section 4.2.A) shall be clearly identified. These physical properties shall be the basis for the acceptance of prequalification submittals of previous field samples (see Section 4.2.E) and the acceptance of the final product (see Section 3.6 and 8.5). At a minimum, the pipe lining shall have the following physical properties:

PROPERTY	ASTM TEST METHOD	MINIMUM VALUE*
Initial Flexural Modulus of Elasticity	D790	250,000 psi
Initial Flexural Strength	D790	7,000 psi
Initial Tensile Strength	D638	5,400 psi
Initial Tensile Modulus	D638	325,000 psi

*Values are for design conditions @ 75°F (25°C)

B The external hydrostatic load design (as per Eq. X1.1) shall be based on an enhancement factor (K) of 10.0, an ovality (q) of 0%, a Poisson's ratio of 0.3, a factor of safety of 2.0, and a flexural modulus of elasticity that has been reduced to account for time-related effects of loading (i.e. for the period when the pipe is depressurized and/or emptied).

C The pipe lining shall also be capable of withstanding instantaneous transient vacuum occurrences. For the instantaneous transient vacuum load condition, the design shall also be based on Eq. X1.1. It is assumed that the internal vacuum effect is similar to the external loading effect of groundwater.

The design shall be based on an enhancement factor (K) of 10.0, an ovality (q) of 0%, a Poisson's ratio of 0.3, the initial flexural modulus of elasticity, and a total design factor of safety of 3.0, which consists of a cyclic vacuum loading design factor of 2.0 and an additional factor of safety of 1.5.

- D The pipe lining shall be designed to span over any small holes that exist in the pipeline (as per Eq. X1.6 of ASTM F 1216), under the normal internal pressure design conditions. For the hole spanning condition, the design shall be based on factor of safety of 2.0 and a flexural strength, reduced to account for long-term effects, equal to 1/3 of the initial design flexural strength.
- E If the pipe is above ground, the pipe lining shall be designed to withstand internal pressure and vacuum only (as per Eq. X1.6).
- F The pipe lining shall be capable of withstanding the thermal stresses induced at the minimum operating temperature specified in Section 5.3.

(5.5) For a pipe lining design following the guidelines of Appendix X1.3.2 of ASTM F1216, the following shall be assumed:

- A The physical properties used in the design submittal (see Section 4.2.A) shall be clearly identified. These physical properties shall be the basis for the acceptance of prequalification submittals of previous field samples (see Section 4.2.E) and the acceptance of the final product (see Section 3.6 and 8.5). At a minimum, the pipe lining shall have the following physical properties:

PROPERTY	ASTM TEST METHOD	MINIMUM VALUE*
Initial Flexural Modulus of Elasticity	D790	350,000 psi
Initial Flexural Strength	D790	7,000 psi
Initial Tensile Strength	D638	6,000 psi
Initial Tensile Modulus	D638	350,000 psi

*Values are for design conditions @ 75°F (25°C)

- B The external load design (as per Eq. X1.1, X1.3, and X1.4) shall be based on an enhancement factor (K) of 10.0, an ovality (q) of 0%, a Poisson's ratio of 0.3, a factor of safety of 2.0, and a flexural modulus of elasticity that has been reduced to account for time-related effects of loading (i.e. for the short period when the pipe is depressurized and/or emptied). This loading can be assumed to be present only during times of pipeline depressurization or when the pipeline has been shutdown.

- C The internal pressure design (as per Eq. X1.7) shall be based on factor of safety of 2.0 and a tensile strength, reduced to account for long-term effects, equal to 1/3 of the initial design tensile strength.
- D If the pipe is above ground, the pipe lining shall be designed to withstand internal pressure and vacuum only (as per Eq. X1.7).
- E The pipe lining shall be capable of withstanding the thermal stresses induced at the minimum operating temperature specified in Section 5.3.

6 INSTALLATION

(6.1) Access Cleaning and Inspection

- A 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 shall be undertaken in accordance with local, state, or federal safety regulations.
- B The Contractor shall state in his prequalification submittals (see Section 4) the number and location of access points required. The Owner shall provide rights of access to the pipeline. The Contractor or Owner, as specified in the contract documents, shall provide the excavation, pipe work, reconnection and restoration for installation access points.
- C The Contractor shall remove all internal debris out of the pipeline that will interfere with the installation. Pipes shall be cleaned by the Contractor, as needed, with high-velocity jet cleaners, mechanically powered equipment, cable-attached devices or fluid-propelled devices (e.g., pipe pigs). The Owner shall also provide a dump site for all debris removed from the pipe during the cleaning operation. Unless stated otherwise, it is assumed this site will be at or near the project site. Any hazardous waste material encountered during this project shall be considered as a changed condition.
- D Inspection of pipelines shall be performed by experienced personnel trained in locating breaks, obstacles, etc., by closed-circuit television or man entry. The interior of the pipeline shall be carefully inspected to determine the location of any conditions that may prevent proper installation of the impregnated tube, and it shall be noted so that these conditions can be corrected. A video tape and suitable log shall be kept for reference.

If unseen obstructions are encountered such as, but not limited to, reducers, line valves, protruding connections, etc., that will prevent proper installation, the Contractor shall remove such obstructions on written order from the Owner.

(6.2) Resin Impregnation

- A The tube shall be vacuum-impregnated with resin (wet-out) under controlled conditions. The quantity of resin used for tube impregnation shall be sufficient to fill the volume of air voids in the tube with additional allowances for polymerization shrinkage and loss of resin through cracks and irregularities in the original pipe wall.
- B The Contractor shall designate a location where the tube will be vacuum impregnated prior to installation. To ensure a thorough wetout, the point of vacuum shall be no further than 25 feet from the point of initial resin introduction. After vacuum in the tube is established, the vacuum points shall be no further than 75 feet from the leading edge of the resin. The leading edge of the resin slug shall be as near to perpendicular as possible. Vacuum points shall be sealed as they are vacated. A roller system shall be used to uniformly distribute the resin throughout the tube. The Contractor shall allow the Owner to inspect the materials and procedures used to vacuum impregnate the tube.

(6.3) Bypassing

The Owner shall be responsible for bypassing the flow during the renovation process.

(6.4) Installation

- A The wet out tube shall be inserted through an existing manhole or approved access point by means of an inversion process and the application of an internal pressure head sufficient to extend it to the next designated manhole or termination point.
- B Before the installation begins, the tube manufacturer shall determine the minimum pressure required to hold the tube tight against the existing conduit, and the maximum allowable pressure so as not to damage the tube. Once the installation has started, the pressure shall be maintained between the minimum and maximum pressures until the installation has been completed.

Tube installation forces or pressures shall be limited so as not to stretch the tube longitudinally by more than 5% of the original length.

- C The existing conduit shall be dewatered and free of incoming water. If water is present, alternative measures shall be taken to minimize contact of the water with the inverting tube.
- D The use of a lubricant during inversion is recommended to reduce friction. The lubricant used should be a nontoxic product that has no detrimental effects on the tube or boiler and pump system, will not support the growth of bacteria, and will not adversely affect the fluid to be transported. If utilized for pipes conveying drinking water, it shall meet the requirements of ANSI/NSF Standard 61.

(6.5) Curing

- A After installation is completed, a suitable heat source shall be used to provide heat throughout the pipe. The equipment shall be capable of delivering heat throughout the section to uniformly raise the temperature above the temperature required to effect a cure of the resin. Temperature in the line during the cure period shall be as determined by the Contractor.
- B The heat source shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing water supply. To determine the temperatures during the cure cycle, a gauge shall be placed at the beginning and termination points between the impregnated tube and the invert of the existing pipe. The temperature of the cure water shall be monitored at the termination end by placing a temperature probe through a small hole in the tube, near the invert, into the cure water. The hole in the tube shall be made such that the temperature probe fits tightly and minimizes leakage.
- C Initial cure will occur during temperature heat-up and is completed when exposed portions of the new pipe appear to be hard and sound and the remote temperature sensor indicates that the temperature is of a magnitude to realize an exotherm or cure in the resin. After initial cure is reached, the temperature shall be raised to the post-cure temperature determined by the Contractor. The post-cure temperature shall be held for a period as determined by the Contractor, during which time the recirculation of the water and cycling of the boiler to maintain the temperature continues. The curing process shall take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

(6.6) Cool-Down

The pipe lining shall be cooled to a temperature below 100°F (38°C) before relieving the internal head. Cool-down shall be accomplished by the introduction of cool air or water to replace that being displaced water from the system.

Care shall be taken in the release of the internal head so that a vacuum will not be developed that could damage the newly installed pipe. In addition, the internal temperature during cool-down shall not decrease at a rate greater than 20°F per hour.

7 INTERNAL END SEALS AND REINSTATEMENTS

(7.1) The Contractor shall install end seals at the pipe lining beginning and termination points.

(7.2) The end seals shall be a mechanical expansion type, constructed of stainless steel and elastomeric seals. The end seals shall be rated by the manufacturer for the operating pressure and shall be compatible with the piped fluid. The pipe at the end seal installation point shall be structurally sound and free of any significant pitting or heavy corrosion. This is required to ensure an adequate seal between the pipe lining and the existing pipeline. Otherwise, replacement with a new steel spool piece at these ends may be required.

(7.3) All reinstatements of tees, wyes, air relief valves, blow-off valves, threaded taps, etc., shall be completed following the approved procedures identified in the submittal described in Section 4.2.F of this specification.

8 INSPECTION AND TESTING

(8.1) Inspection and Acceptance

The installation may be inspected visually, if appropriate, or by closed-circuit television if visual inspection cannot be accomplished.

Variations from true line and grade may be inherent because of the conditions of the original piping. No infiltration of groundwater should be observed.

(8.2) The finished pipe shall be continuous over the entire length of an installation run and be free of dry spots, lifts, and delaminations.

- (8.3) For each inversion length designated by the owner in the contract documents or purchase order, one sample shall be prepared using one of the following methods.
- A The sample shall be cut from a section of the cured pipe lining at an intermediate manhole or at the termination point that has been inverted through a like diameter pipe which has been held in place by a suitable heat sink, such as sandbags.
 - B The sample shall be fabricated from material taken from the tube and the resin/hardener system used and cured in a clamped mold placed in the cure water.
- (8.4) The sample shall be large enough to provide a minimum of three specimens and a recommended five specimens for flexural testing and tensile testing.
- (8.5) The specimens shall be tested in accordance with ASTM D790 and D638 to confirm the minimum properties specified in the design submittal of the proposed product (see Section 4.2.A).
- (8.6) The pipe lining shall meet the chemical resistance requirements of Section 9 below.
- (8.7) The pipe lining shall be pressure tested for water-tightness following the test protocol described in Section 10 below.

9 CHEMICAL RESISTANCE

- (9.1) The pipe lining shall meet the minimum chemical resistance requirements listed below. Samples for testing shall be of tube and resin system similar to that proposed for actual construction. It is required that samples without plastic coating meet these chemical testing requirements.
- (9.2) Chemical resistance tests shall be completed in accordance with ASTM Test Method D 543 with the chemical solutions shown in Table 9.1. Exposure shall be for a minimum of one month at 73.4°F (23°C). During this period, the test specimens shall lose no more than 20% of their initial flexural strength and initial flexural modulus of elasticity.
- (9.3) For applications more stringent than standard domestic sewage, it is recommended that chemical-resistance tests be conducted with actual

samples of the fluid flowing in the pipe. These tests can also be accomplished by securing test specimens in the flow stream.

TABLE 9.1 Minimum Chemical Resistance Requirements

Chemical Solution	Concentration, %
Tap water (pH 6-9)	100
Nitric acid	5
Phosphoric acid	10
Sulfuric acid	10
Gasoline	100
Vegetable oil	100
Detergent	0.1
Soap	0.1

10 PRESSURE TESTING FOR WATER-TIGHTNESS

(10.1) This section provides for procedures for pressure testing for water-tightness of pipe lining used in the renovation of pressure pipelines. Pressure testing for water-tightness shall be provided on all sections identified by the Owner in the contract documents or purchase order at the unit price stated.

(10.2) Test Procedure

- A The pipe lining shall be cooled down to the original ambient ground temperature, which existed before installation, prior to proceeding with the pressure test.
- B The test section shall be subjected to a hydrostatic pressure of 1-1/2 times the known operating pressure (specified in Section 5.3) or at the operating pressure plus 50 psi, whichever is less.
- C The pressure test shall be conducted after placement of all appurtenances such as end seals, reinstatements of side connections, corporation stops, etc. To avoid the testing of other associated piping, the side connections, corporation stops, etc., shall be capped or otherwise isolated. When sections of rehabilitated piping are reconnected with new spool pieces, ensure that all flange connections are watertight during the pressure test. Note: The emphasis is that only rehabilitated piping (and its appurtenances) shall be tested. Otherwise, leakage's in other side piping could contribute to a leakage rate measured for the pipe lining.

- D The pipe section to be tested shall be isolated with blind flanges or other appropriate restrained and gasketed method rated for the required test pressure. Means for temperature measurement, air relief and filling the test section with water shall be provided. Valves can be used to fill a test section provided that the line can be isolated and no leakage is evident when the valves are closed. The line tested shall be configured such that leakage from the ends and branch lines can be monitored for leakage.
- E The ends, termination points, elbows, etc. that are removed shall be adequately braced, blocked and supported for the duration of the test. The test pressure shall not exceed the safe pressure on such fittings.
- F The test shall be one hour in duration.
- G The test section shall be filled slowly from any available water source. All air should be expelled from the pipeline during filling. Note: This is a very critical step of the process since any trapped air will compress during pressurization giving erroneous leakage measurements. When filling the pipeline with water, all air release valves and the high elevation end of the pipeline shall be opened until a free flow of water is visible, to release all air from the pipeline to be tested. Ensure the rate of filling does not significantly pressurize the pipeline prematurely.

If the above technique for expelling air is not sufficient, another approach may be more effective. One alternative is to push a pig through the line with the fill water behind it. This is done after each end of the test section is sealed off so the pig remains in the pipe during the pressure test. When the pipe is full and the pig reaches the far end of the test section, the air in front of the pig is bled off through a relief valve in the blind flange or pressure plug at the termination end.

- H Once the pipe is filled, the specified test pressure, based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe in a manner satisfactory to the Owner. The test pressure shall be applied in steps at intervals of 50 psi or one-half of the test pressure, whichever is less, until the required test pressure is reached. The pressure shall be held at each step for a minimum of 30 minutes.
- I A minimum stabilization period of 2 to 3 hours is recommended, but not required, before starting the pressure test. During this time, the test pressure shall be maintained within close proximity of the required test pressure. A small annular gap may exist between the pipe lining wall and the existing pipe. During this stabilization period, the pipe lining

will reround and stretch. Some trapped air may still exist in the pipe and the mean water temperature may fluctuate. These can cause erroneous leakage readings if the pressure test is run during this period. Therefore, the required stabilization period may be considerably longer than expected for some installations. Decreasing make-up water during the stabilization period should indicate that at least one of these effects is present and is gradually being counteracted.

- J Bleed off any air at the ends of the test section prior to beginning the test. As stated previously, the pressure test shall be for a duration of one hour after the stabilization period is completed. Begin the test at the required test pressure. After the one hour test, the amount of make-up water needed to return to the required pressure shall be quantified.

(10.3) Acceptance

The test shall require that the quantified make-up water (from Section 10.2.J above) for the one hour test shall not exceed 20 gallons per inch-diameter, per mile of pipe, per 24 hour day (20 GPDIM). The quantified make-up water for the one hour test shall be extrapolated to the 24 hour rate for comparison purposes. Any visible leakage at termination points shall be eliminated. If not feasible or possible at the time of the test, the termination point leakage shall be kept to a minimum, collected and then deducted from the actual make-up water rate. If the leakage at the test pressure exceeds the allowable, the Contractor shall endeavor to locate the source of the leakage and reduce it in a manner acceptable to the Owner until he meets the requirements, or the Owner agrees to adjust the allowable leakage. The pressure test for water-tightness shall be deemed acceptable if the allowable make-up water rate of 20 GPDIM is equal to or greater than that actually measured during the one hour test (which has been extrapolated to a 24 hour day rate).

11 CLEAN-UP

Upon acceptance of the installation, the Contractor shall reinstate, to original conditions, the project area affected by the operations.

12 PAYMENT

Payment for the work included in this section shall be in accordance with the prices set forth in the proposal for the quantity of work performed. Progress payments shall be made monthly, based on the work performed during that period.