Specification for Cured-in-Place Pipe Rehabilitation

1 Scope

This specification document covers the rehabilitation of gravity pipelines, such as sewers, using the Cured-in-Place Pipe (CIPP) rehabilitation lining process. This specification addresses the CIPP rehabilitation requirements for gravity pipelines without internal pressure. This specification addresses materials, design, resin impregnation, installation, acceptance, sampling testing, warranties, submittals and any special provisions that may be applicable.

2 General Requirements

The CIPP process will renovate the existing pipeline from the inside by the installation of an interior pipe that fits tightly to the inside of the existing pipe. The process will be accomplished through the use of existing access such as maintenance holes or other existing openings and is to be done with no or minimal excavation. The new interior pipe, called a CIPP liner, is provided in sufficient thickness to address the deterioration situation of the existing pipeline. Typical thickness ranges from 4.5 mm to 50 mm depending on the size, condition and depth of the existing pipe.

The CIPP liner will be introduced into the existing pipeline in a soft, flexible and expandable configuration containing thermosetting resin in a viscous liquid state. A resin adsorbent carrier tube called the felt or bag will be used to carry, properly position and uniformly distribute the liquid resin within the existing pipe. Upon final positioning and expanding of the carrier tube against the inside surface of the existing pipe, the resin will be transformed to a solid state by a thermosetting process. The thermoset process will be initiated by applying heat to the resin that was previously catalyzed before its adsorption into the carrier tube. The methods used to introduce the required heat will be by internally circulating heated water or by a flow through of a steam/air mixture.

The process of adsorbing the catalyzed resin into the carrier tube is called resin impregnation or wet-out of the carrier tube. The process of installing the resin impregnated liner tube into the existing pipe is called inversion or pull-in depending on the specific insertion method used and type of carrier tube. The process to make the liquid resin in the carrier tube transform to a solid by the thermoset reaction is called curing.

Following the cure of the CIPP liner the closed ends of the liner at MHs or other accesses will be removed and the pipeline made available for flow. Incoming connections, such as service laterals will be reinstated into the pipeline by cutting corresponding openings in the cured CIPP liner. For non-man entry sized pipelines, service lateral reinstatement will be made from the interior of the pipeline using CCTV monitored robot cutters. For man-entry sized pipelines either CCTV monitored robot cutters will be used or reinstatement will be done by man-entry

The CIPP lining installation process will include the cleaning and preparation of the existing pipeline to a suitable state and the provision of flow bypass when necessary. The CIPP rehabilitation is completed with a CCTV inspection of the finished liner.

3 Referenced Standards

The standards listed below are applicable to the CIPP lining process, materials, installation and testing.

ASTM F1216-03	For Inverted CIPP liners
ASTM F1743-96	For Pulled-in CIPP liners
ASTM D5813-95	CIPP Material
ASTM D790-00	Testing method to be used for CIPP samples
NASSCO???	For cleaning and CCTV??

These standards, in their latest editions, shall apply to the CIPP product and process.

4 Materials

4.1 General

The CIPP liner shall consist of thermosetting resin and an absorbent carrier tube to hold the resin. When the resin and carrier tube are combined followed by installation into the existing pipe and curing they shall result in a finished CIPP liner that meets the requirements of ASTM F1216-03 for inversion liners, ASTM F1743 for pull-in liners and ASTM D5813 for CIPP material. Catalysts shall be used with the resin to initiate and facilitate the thermosetting process that transforms the resin from a liquid state to a solid state.

The final cured-in-place liner material shall provide the mechanical properties in accordance with requirements of ASTM F1216 or F1743 and D5813. The final cured-in-place liner material shall provide the mechanical properties in accordance with the requirements for the specific liner thickness design where these properties are greater than the minimum properties set forth in ASTM F1216 or F1743 and D5813.

The final cured-in-place liner material shall provide chemical resistance properties in accordance with the requirements of ASTM F1216 or F1743 and D5813. The final cured-in-place liner material shall provide chemical resistance in accordance with any special requirements specified for a specific installation as agreed with the purchaser where these requirements exceed the minimum requirements of ASTM F1216 or F1743 and D5813

At a minimum, the cured CIPP liner shall be fully resistant, chemically and mechanically to regular municipal sewage.

4.2 Carrier Tube

The carrier tube shall consist of one or more polyester felt layers with a resin absorbency of 86-88% by volume. The felt material shall be suitable for adsorbing, distributing and holding the resin to be used from initial impregnation of the resin into the carrier tube through installation into the existing pipe and final cure of the resin. The carrier tube construction shall allow vacuum to be used for the resin impregnation process.

For inversion liners, the innermost layer (as installed in the existing pipeline) shall have a waterproof and resin proof polyurethane coating. For pull-in liners the outermost layer and the innermost layer shall have shall have a waterproof and resin proof polyurethane coating where the innermost waterproof and resin proof coating may be provided by using a separate tube installed inside the carrier tube after its installation into the existing pipeline. The waterproof and

resin proof layers shall be sufficiently transparent to allow visual inspection of the resin impregnation process.

As required the felt shall be joined by flame bonding in longitudinal or diagonal directions. The diameters of the felt layers shall be sized in accordance with the requirements for sizing the finished in place liner. The diametric sizing of the various layers shall take into account their relative position inside the existing pipeline and shall incorporate a thickness compensated diametric reduction in accordance with the required stretch out to size of the liner tube after it is fully expanded within the existing pipe. Diametric reduction shall be compatible with the stretching properties of the material used to fabricate the carrier tube.

The thickness of the carrier tube shall be sufficient to provide the required finished liner thickness including consideration of compression of the felt under standard installation conditions including standard conditions for internal pressures (heads) for installation and curing.

Where standard installation conditions cannot be obtained, the felt thickness shall be suitably adjusted to compensate for non-standard installation conditions so that the required in place liner thickness is obtained in accordance with liner thickness design.

The in place liner thickness shall be the thickness required by a liner thickness design made in accordance with ASTM F1216-03 Appendix X1.

The construction of the carrier tube shall provides sufficient longitudinal and circumferential strength to accommodate the forces encountered during installation and curing without ripping, tearing or separating either in the body of the carrier tube or at its seams and joints.

4.3 Resin

Resins shall be polyester, vinyl ester or epoxy thermoset plastic resins as required to achieve the mechanical properties and chemical resistance properties specified for the final cured-in-place liner. The resin shall meet the requirements of ASTM F1216 or F1743.

Where required to obtain for higher flexural modulus properties in the finished liners, polyester resin may have a modulus-enhancing additive (sometimes called a filler or enhancer) up to a proportion by weight not exceeding 25%.

The resin shall have an established history of use in CIPP applications with the carrier tube used. Where required by the purchaser, a reference list of installations shall be provided to substantiate this history of use.

Where required by the purchaser, long-term testing to establish 50 year long-term properties for the resin shall have been done for the resin in accordance with ASTM D2990 at a stress based on a minimum of 25% of yield.

4.4 Catalysts

One or more catalysts (sometimes called initiators or hardeners) shall be used with the resin to initiate, drive and finalize the curing of the liner. Catalysts shall be compatible with the resin, employed in carefully measured quantities and be thoroughly and completely mixed with the resin at time of carrier tube impregnation. The proportion of catalyst(s) used shall be matched to the specific liner in regard to liner thickness and resin type so that the rate of thermoset reaction and the reaction’s exotherm is suitably controlled and will not produce hot spots, blisters or other deleterious effects in or on the liner wall.

4.5 Cured Liner Composite

The cured liner shall be a homogeneous material, be solid throughout and provide an inner surface (to flow) suitable for the intended purpose. The cured liner composite material shall provide the required mechanical and chemical resistance properties.

The thickness of the finished liner shall meet the thickness required in accordance with the liner thickness design. The thickness shall be determined in accordance with ASTM D5813.

The cured liner composite shall have a history of ASTM D790 test results for flexural strength and flexural modulus that supports and substantiates the values used in the liner thickness design. Where required by the purchaser, this history of test results shall be provided.

5 Design

5.1 Dimensions

The carrier tube shall be designed so that its perimeter and length dimensions will provide a finished liner that fits to the inside surface of the existing pipeline without gaps or unacceptable stretching and fits to the required length of the existing pipe without being short or having unacceptable stretching. Any annulus gap between the inside surface of the existing pipe and the outside surface of the liner shall only be due to normal shrinkage in the curing process and not due to improper dimensioning of the carrier tube.

Unacceptable stretching shall be when the liner has thinned below thickness requirement due to improper dimensions of the carrier tube.

Normal shrinkage shall be the shrinkage consistent with the resin used when the resin quantity in the carrier tube is in accordance with the requirements of ASTM F1216 or F1743 and that the liner cool down process has been done in accordance with established industry procedures to minimize thermally induced shrinkage.

The carrier tube thickness shall be designed so that the final in place cured liner thickness shall meet the requirements of the liner thickness design.

5.2 Thickness

The thickness of the final in place CIPP liner shall be designed in accordance with the method described in ASTM F1216-03 Appendix X1. Where required by the purchaser the design calculations shall be provided to the purchaser showing the F1216-X1 design method for the liner installation(s).

The CIPP liner thickness design shall be based on either Partially Deteriorated Existing Pipe Condition or Fully Deteriorated Existing Pipe Condition as specified by the purchaser or the purchaser's engineer. The definition of Partially and Fully deteriorated conditions shall be as provided in ASTM F1216 X1.

The CIPP supplier shall provide and be responsible for the design parameters describing the supplier's CIPP liner. The purchaser shall provide and be responsible for the design parameters describing the purchaser's existing pipeline.

In accordance with ASTM F1216-X1, for partially deteriorated condition the purchaser shall provide the ground water level and for fully deteriorated design the purchaser shall provide the ground water level, soil type and depth and live load.

Where the purchaser is soliciting more than one bid, the purchaser shall provide all the design parameters common to the description the existing pipeline so that the purchaser may receive comparable liner designs for the purchaser's existing pipeline.

The CIPP liner thickness design provided by CIPP supplier (when required) shall be in accordance with the ASTM F1216-X1 design method, shall clearly identify all the required design parameters used as inputs and shall show the results of the design equations from using the input parameters (Equations X1.1 and X1.2 for partially deteriorated and Equations X1.1, X1.2, X1.3 and X1.4 for fully deteriorated) as required by ASTM F1216-X1.

The CIPP supplier shall identify the following physical properties of the CIPP liner used in the thickness design:

Flexural Strength (short-term as per ASTM D790)
Flexural Modulus (short-term as per ASTM D790)
Long-term creep retention factor for the design life
Enhancement factor
Poisson's ratio

Values used for flexural strength and flexural modulus shall be not be more than values reliable and repeatedly obtained from tests of cured-in-place field samples of the CIPP liner and shall not be less than the minimum values specified in ASTM F1216.

Unless otherwise specified in the CIPP thickness design the CIPP liner physical properties used for design shall be:

CIPP Liner Property	Regular Polyester Resin	Modulus Enhanced Polyester Resin
Flexural Strength (D790)	4,000 psi	4,500 psi
Flexural Modulus (D790)	250,000 psi	350,000 psi
Long-term Creep Retention	50%	50%
Enhancement Factor	7	7
Poisson's Ratio	0.3	0.3

6 Resin Impregnation

The carrier tube shall be impregnated with an amount of resin in accordance with ASTM F1216-03 including its requirement for excess resin. The resin shall be catalyzed prior to impregnation. Catalysts shall be thoroughly and uniformly mixed and distributed in the resin.

The amount of resin used shall be the amount required to completely saturate the carrier tube based on its nominal cured-in-place thickness so that all air space in the carrier felt is replaced by resin for the nominal cured tube thickness. Added to this amount of resin shall be the F1216 excess resin requirement. The total resin shall be uniformly distributed throughout the carrier tube.

Vacuuming of the carrier tube shall be used to assist the resin impregnation process. Gauging squeeze rollers shall be used to assist in the distribution of resin. The roller gap shall be the gap that results in the proper amount of resin distributed in the carrier tube.

On completion of impregnation (wet-out) the carrier tube shall be uniform in appearance and free of dry spots.

After resin impregnation, the liner tube shall be stored in a temperature-controlled environment that maintains the liner below catalyst activation temperature. When required, ice may be used to effect temperature control. The impregnated liner shall be shielded from any prolonged exposure to direct sun light.

7 Installation

6.1 Cleaning and Preparation of the Existing Pipeline

The existing pipeline shall be cleaned of all loose dirt, debris, grease or other soft deposits by jetting or other suitable methods. Where hard deposits (such as calcite) will interfere with the installation, curing or final results of the liner, these deposits shall be removed by flailing, reaming or robotic cutting. Where service connections (laterals) may be protruding into the pipeline, protrusions may require trimming to facilitate the liner installation and results. Lateral protrusions left in place shall be smooth, shall not result in irregularity of the liner at the locations and shall not exceed 0.5 inches.

6.2 Flow Bypassing

Mainline flows that cannot be halted by temporarily backing up the pipeline during liner installation and cure shall be bypassed or over-pumped. Bypass capacity (pumps, bypass lines etc) shall be sized to handle the expected flow during the liner installation and cure time period.

Flow from service connections (laterals) shall be halted by temporarily backing up the connections during liner installation and cure when the liner covers the service connection openings. Where service flows cannot be temporarily backed up in this manner (due to excessive flows or incoming heads), provisions shall be made for temporary bypassing of service flow using bypass pumping or other suitable means.

6.3 Installing the CIPP Liner into the Existing Pipeline

The liner shall be installed using the inversion process. The inversion process shall use either water column inversion or pressurized inversion (water or air). The heads or pressures used shall be in accordance with the head/pressure limits for the carrier tube. For water column/pressure inversion the effect of pipeline fall of rise shall be taken into account when applying head/pressure at the inversion location so that the head/pressure anywhere along the run does not exceed allowances for the carrier tube.

The inversion shall proceed in a uniform controlled method and during inversion the head/pressure shall be maintained within a range that facilitates steady and controlled inversion. Unless special circumstances warrant, the head/pressure shall be maintained in the liner at all times during the inversion.

In installations where a pull-in type liner may be used instead of an inversion type liner, pull forces shall be maintained below the rating of the liner carrier tube.

6.4 Curing with Hot Water

Hot water circulated within the liner shall be used to elevate the temperature of the resin to effect a cure. During the cure the water in the liner shall be maintained at a head/pressure in accordance with requirements for the specific the size and thickness of the liner. A boiler of sufficient rating shall be used to add heat to the circulating water. Circulating pump(s) and internal hoses shall be sized to provide sufficient circulation of the hot water to uniformly heat the liner.

The temperature of the circulating hot water shall be monitored at the supply from and return to the boiler. The temperature of the liner outer surface shall be monitored at each end using thermocouples or other suitable measuring devices.

After the CIPP liner has changed to a hard state, the cure heating shall be continued maintaining the liner at an elevated temperature for a period of time dependent on the size, thickness and ongoing temperature measurements to ensure the full level of cure has been achieved.

On completion of the heat cure, the liner shall be cooled down either naturally or by adding cold water to the circulating water while removing water. During cool down the head/pressure in the liner shall be maintained at the cure head. The rate of cool down shall be commensurate with the liner size and thickness to minimize shrinkage and internal stresses.

6.5 Curing with Steam

Steam flowed through the interior of the liner shall be used to elevate temperature of the resin to effect a cure. Compressed air shall be mixed with the steam as required to moderate the steam temperature to produce a controlled heating of the liner, avoid hot spotting and prevent blistering of the polyurethane coating.

The pressure of the steam/air mixture shall be controlled at the injection and venting manifold locations to maintain the required internal pressure on the liner in accordance with the requirements for the carrier tube internal pressure ratings. The temperature of the steam/air mixture shall be controlled and monitored at the mixing manifold. The temperature of the liner outer surface shall be monitored at each end using thermocouples or other suitable measuring devices.

After the CIPP liner has changed to a hard state, the cure heating shall be continued maintaining the liner at an elevated temperature for a period of time dependent on the size, thickness and ongoing temperature measurements to ensure the full level of cure has been achieved.

On completion of the heat cure, the liner shall be cooled down either naturally or by gradually reducing the amount of heating steam in the steam/air mixture to all air. During cool down the pressure in the liner shall be maintained at the cure pressure. The rate of cool down shall be commensurate with the liner size and thickness to minimize shrinkage and internal stresses.

6.6 Opening Liner & Lateral Reinstatement

On completion of the cool-down, the liner shall be cut open at each end releasing the water or air (depending on cure method). The top end shall always be opened or vented first (if not already open) to prevent vacuum being generated when water flows out at the downstream end.

Where service connections (laterals) require reinstatement through the cured liner, openings shall be cut in the liner wall with a CCTV monitored robot cutter. The locations for openings shall be as determined by dimpling of the liner at laterals and, where required, by pre-lining measurements made of the locations of the laterals.

Depending on the number of laterals to be reinstated, reinstatement may commence by cutting a sufficient opening at each lateral to relieve any standing flow followed by returning to cut each lateral opening out to the full interior size of the existing lateral connection.

Lateral reinstatement openings shall be neat, free of jagged edges or lips and conform to the size of the existing service lateral at the sewer.

6.7 CCTV Inspection of Finished Liner

On completion of all installation and lateral reinstatements, the complete CIPP liner shall be CCTV inspected over its entire length using a pan and tilt color camera. The inspection shall be free of steam of vapor that obscures the picture and the flow level in the sewer shall be held sufficiently low to provided for a clear view of the lined pipeline. During the inspection, each lateral reinstatement shall be clearly visible on the inspection. A copy of the inspection (on videotape, CD or DVD) shall be provided to the owner.

7 Acceptance, Samples and Testing

7.1 Fit and Finish

The finished liner shall fit tightly to the existing pipeline as indicated by reflection of the shape and surface of the existing pipeline in the liner. The liner shall be free of sags, folds, lifts or other irregularities that indicate an improper fit or inadequately cured zones. Cosmetic wrinkling is acceptable especially where this may be due to non-uniform size of the existing pipeline.

The liner shall have no leakage or infiltration through the wall of the liner. Cut ends and lateral reinstatements shall provide a solid homogeneous wall section without separations or delaminating within the liner wall.

7.2 Samples

Where required (either by the ASTM F1216 or contract requirements) samples of the cured liner shall be provided to the owner for testing.

Restrained type samples shall be made by extending the liner through a form with a diameter as close as possible to the existing pipeline. The form may be located at the end MH or at an intermediate MH. The formed sample may be provided with insulation to contain cure heat to produce a similar cure environment to that within the host pipe. Samples forms that are not insulated may produce lower physical properties than those obtained within the host pipe. The length of the form shall be sufficient to obtain a cylindrical liner sample of sufficient length that is not effected by edge effects of the form. The actual test coupons shall be cut from the central portion of the formed sample for determination of physical properties and thickness.

Plate samples shall be used where restrained sample cannot be made or are not required. The plate samples shall be contained in a sample box and made from the same carrier tube material (same nominal thickness) and resin as used for liner. Plate samples shall be cured in the same heat environment and for the same time as for the liner.

7.3 Sample Testing & Results

The samples shall be tested in accordance with the requirements of ASTM F1216. The testing shall be done by the owner at an independent testing facility experienced in CIPP testing. Alternatively, the testing may be done for the owner by the contractor also at an independent testing facility experienced in CIPP testing.

Thickness: The liner thickness, when determined in accordance with ASTM D5813-95 shall meet or exceed the design thickness for the specific liner installation.

Flexural Strength Property: The flexural strength when tested in accordance with ASTM D790 shall meet or exceed the flexural strength used in the liner design or the minimum prescribed in ASTM F1216 whichever is higher.

Flexural Modulus Property: The flexural modulus when tested in accordance with ASTM D790 shall meet or exceed the flexural modulus used in the liner design or the minimum prescribed in ASTM F1216 whichever is higher.

7.4 Reconciliation of Test Results

Where a tested thickness occurs below the design thickness and the tested physical properties are above the design values, the design thickness shall be re-calculated based on the actual installed tested properties. Where tested thickness meets or exceeds the re-calculated design thickness, the liner thickness shall be considered acceptable.

Where tested physical properties are below the design properties and the tested thickness is above the design thickness, the design thickness shall be re-calculated based on the actual installed tested properties. Where the tested thickness meets or exceeds the re-calculated thickness, the physical properties shall be considered acceptable providing they meet or exceed the minimum properties in accordance with the F1216.

8 Warranty

The finished liner shall be warranted against defects in materials and installation for a period of 1 year from the date of substantial completion of the installation.

9 Submittals

The CIPP contractor shall make the following submittals as checked either at time of bid or after award as checked.

Submittal	With Bid	After Award
Liner Designs by ASTM F1216 X1 method		
Test Results for CIPP liner by ASTM D790 method		
Carrier Tube Manufacturer & Specifications		
Resin Type, Manufacturer and specifications		
Long-term testing to establish creep retention factor		

10 Special Provision/Specifications

As required, add here.