

Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)¹

This standard is issued under the fixed designation F 1743; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice describes the procedures for the reconstruction of pipelines and conduits (4 to 96 in. (10 to 244 cm) diameter) by the pulled-in-place installation of a resin-impregnated, flexible fabric tube into an existing conduit and secondarily inflated through the inversion of a calibration hose by the use of a hydrostatic head or air pressure (see Fig. 1). The resin is cured by circulating hot water or by the introduction of controlled steam into the tube. When cured, the finished cured-in-place pipe will be continuous and tight fitting. This reconstruction process may be used in a variety of gravity and pressure applications such as sanitary sewers, storm sewers, process piping, electrical conduits, and ventilation systems.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for informational purposes only.

NOTE 1—There are no ISO standards covering the primary subject matter of this practice.

1.3 *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.*

2. Referenced Documents

2.1 ASTM Standards:

- D 543 Test Method of Resistance of Plastics to Chemical Reagents²
- D 638 Test Method for Tensile Properties of Plastics²
- D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials²
- D 903 Test Method for Peel or Stripping Strength of Adhesive Bonds³

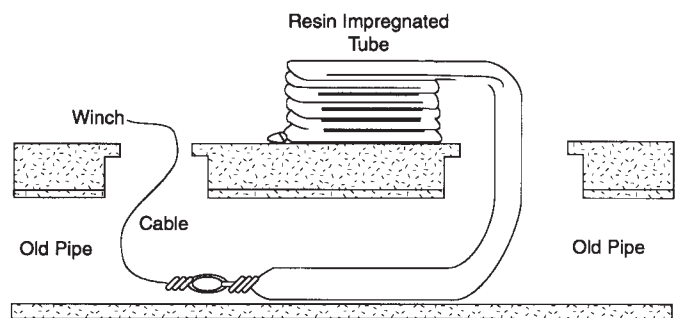
¹ This practice is under the jurisdiction of ASTM Committee F-17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.67 on Trenchless Plastic Pipeline Technology.

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² Annual Book of ASTM Standards, Vol 08.01.

³ Annual Book of ASTM Standards, Vol 15.06.

Step 1 – Pull resin-impregnated tube into existing pipe.



Step 2 – Calibration hose inversion

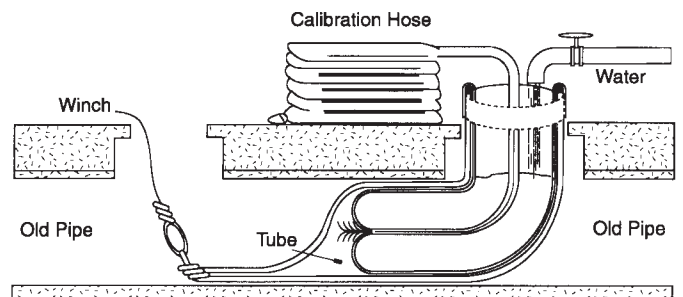


FIG. 1 Cured-in-Place Pipe Installation Methods

- D 1600 Terminology for Abbreviated Terms Relating to Plastics²
- D 1682 Test Method for Breaking Load and Elongation of Textile Fabrics⁴
- D 3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials⁵

⁴ Discontinued: See 1991 Annual Book of ASTM Standards, Vol 07.01.

⁵ Annual Book of ASTM Standards, Vol 15.03.

D 3567 Practice for Determining Dimensions of Reinforced Thermosetting Resin Pipe (RTRP) and Fittings⁶

D 4814 Specification for Automotive Spark—Ignition Engine Fuel⁷

D 5813 Specification for Cured-in-Place Thermosetting Resin Sewer Pipe⁶

F 412 Terminology Relating to Plastic Piping Systems⁶

F 1216 Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube⁶

2.2 *AWWA Standard:*

M28 Manual on Cleaning and Lining Water Mains⁸

2.3 *NASSCO Standard:*

Recommended Specifications for Sewer Collection System Rehabilitation⁹

NOTE 2—An ASTM specification for cured-in-place pipe materials appropriate for use in this practice is under preparation and will be referenced in this practice when published.

3. Terminology

3.1 *General*—Definitions are in accordance with Terminology F 412. Abbreviations are in accordance with Terminology D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration hose*—an impermeable bladder which is inverted within the resin-impregnated fabric tube by hydrostatic head or air pressure and may optionally be removed or remain in place as a permanent part of the installed cured-in-place pipe as described in 5.2.2.

3.2.2 *cured-in-place pipe (CIPP)*—a hollow cylinder consisting of a fabric tube with cured (cross-linked) thermosetting resin. Interior or exterior plastic coatings, or both, may be included. The CIPP is formed within an existing pipe and takes the shape of and fits tightly to the pipe.

3.2.3 *delamination*—separation of layers of the CIPP.

3.2.4 *dry spot*—an area of fabric of the finished CIPP which is deficient or devoid of resin.

3.2.5 *fabric tube*—flexible needled felt, or equivalent, woven or nonwoven material(s), or both, formed into a tubular shape which during the installation process is saturated with resin and holds the resin in place during the installation and curing process.

3.2.6 *inversion*—the process of turning the calibration hose inside out by the use of water pressure or air pressure.

3.2.7 *lift*—a portion of the CIPP that is a departure from the existing conduit wall forming a section of reverse curvature in the CIPP.

4. Significance and Use

4.1 This practice is for use by designers and specifiers, regulatory agencies, owners, and inspection organizations who are involved in the rehabilitation of conduits through the use of

a resin-impregnated fabric tube pulled-in-place through an existing conduit and secondarily inflated through the inversion of a calibration hose. Modifications may be required for specific job conditions.

5. Recommended Materials and Manufacture

5.1 *General*—The resins, fabric tube, tube coatings, or other materials, such as the permanent calibration hose when combined as a composite structure, shall produce CIPP that meets the requirements of this specification.

5.2 *CIPP Wall Composition*—The wall shall consist of a plastic coated fabric tube filled with a thermosetting (cross-linked) resin, and if used, a filler.

5.2.1 *Fabric Tube*—The fabric tube should consist of one or more layers of flexible needled felt, or equivalent, woven or nonwoven material(s), or both, capable of carrying resin, withstanding installation pressures, and curing temperatures. The material(s) of construction should be able to stretch to fit irregular pipe sections and negotiate bends. Longitudinal and circumferential joints between multiple layers of fabric should be staggered so as not to overlap. The outside layer of the fabric tube should have an impermeable flexible coating(s) whose function is to contain the resin during and after fabric tube impregnation. The outer coating(s) must facilitate monitoring of resin saturation of the material(s) of construction of the fabric tube. The fabric tube should be fabricated to a size that, when installed, will tightly fit the internal circumference and the length of the original conduit. Allowance should be made for circumferential and longitudinal stretching of the fabric tube during installation. As required, the fabric tube should meet minimum tensile strength requirements in the longitudinal and transverse directions as specified in 7.1. All the material(s) of construction for the fabric tube should be compatible with the resin system used.

5.2.2 *Calibration Hose:*

5.2.2.1 *Removable Calibration Hose*—The removable calibration hose should consist of an impermeable plastic, or impermeable plastic coating(s) on flexible woven or nonwoven material(s), or both, that do not absorb resin and are capable of being removed from the CIPP.

5.2.2.2 *Permanent Calibration Hose*—The permanent calibration hose should consist of an impermeable plastic coating on a flexible needled felt or equivalent woven or nonwoven material(s), or both, that are capable of absorbing resin and are of a thickness to become fully saturated with resin. The calibration hose should be translucent to facilitate post-installation inspection. The calibration hose should be fabricated to a size that, when installed, will tightly fit the internal circumference and the length of the resin saturated fabric tube. Once inverted, the calibration hose becomes part of the fabric tube, and once properly cured, should bond permanently with the fabric tube. The properties of the calibration hose should meet minimum tensile strength requirements in the longitudinal and transverse directions as specified in 7.1. All the material(s) of construction for the calibration hose should be compatible with the resin system used.

5.2.3 *Resin*—A chemically resistant isophthalic based polyester, or vinyl ester thermoset resin and catalyst system or an

⁶ Annual Book of ASTM Standards, Vol 08.04.

⁷ Annual Book of ASTM Standards, Vol 05.03.

⁸ Available from the American Water Works Association, 6666 W. Quincey Ave., Denver, CO 80235.

⁹ Available from the National Association of Sewer Service Companies, 101 Wymore Rd., Suite 501, Altamonte, FL 32714.

epoxy resin and hardener that is compatible with the installation process should be used. The resin should be able to cure in the presence of water and the initiation temperature for cure should be less than 180°F (82.2°C). The cured resin/fabric tube system, with or without the calibration hose, shall be expected to have as a minimum the initial structural properties given in Table 1. These physical properties should be determined in accordance with Section 8. The cured resin/fabric tube system, with or without the calibration hose, should meet the minimum chemical resistance requirements as specified in 7.2.

6. Installation Recommendations

6.1 Cleaning and Pre-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*—All internal debris should be removed from the original pipeline. Gravity pipes 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. Pressure pipelines should be cleaned with cable attached devices or fluid propelled devices in accordance with AWWA M28.

6.1.3 *Inspection of Pipelines*—Inspection of pipelines should be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed-circuit television or man entry. The interior of the pipeline should be carefully inspected to determine the location of any conditions that may prevent proper installation of the impregnated tube, such as protruding service taps, collapsed or crushed pipe, and reductions in the cross-sectional area of more than 40 %. These conditions should be noted so that they can be corrected.

6.1.4 *Line Obstructions*—The original pipeline should be clear of obstructions such as solids, dropped joints, protruding service connections, crushed or collapsed pipe, and reductions in the cross-sectional area of more than 40 % that may hinder or prevent the installation of the resin-impregnated fabric tube. If inspection reveals an obstruction that cannot be removed by conventional sewer-cleaning equipment, then a point-repair excavation should be made to uncover and remove or repair the obstruction.

6.2 *Resin Impregnation*—The fabric tube should be totally impregnated with resin (wet-out) and run through a set of rollers separated by a space, calibrated under controlled conditions to ensure proper distribution of resin. The volume of

resin used should be sufficient to fully saturate all the voids of the fabric tube material, as well as all resin-absorbing material of the calibration hose at nominal thickness and diameter. The volume should be adjusted by adding 3 to 15 % excess resin to allow for the change in resin volume due to polymerization, the change in resin volume due to thermal expansion or contraction, and resin migration through the perforations of the fabric tube and out onto the host pipe.

6.3 *Bypassing*—If bypassing of the flow is required around the sections of pipe designated for reconstruction, 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 should be of adequate capacity and size to handle the flow. Services within this reach will be temporarily out of service.

6.3.1 Public advisory services shall notify all parties whose service laterals will be out of commission and advise against water usage until the main line is back in service.

6.4 Installation Methods:

6.4.1 *Perforation of Resin-Impregnated Tube*—Prior to pulling the resin-impregnated fabric tube in place, the outer impermeable plastic coating may optionally be perforated. When the resin-impregnated fabric tube is perforated, this should allow resin to be forced through the perforations and out against the existing conduit by the force of the hydrostatic head or air pressure against the inner wall of the calibration hose. The perforation should be done after fabric tube impregnation with a perforating roller device at the point of manufacture or at the jobsite. Perforations should be made on both sides of the lay-flat fabric tube covering the full circumference with a spacing no less than 1.5 in. (38.1 mm) apart. Perforating slits should be a minimum of 0.25 in. (6.4 mm) long.

6.4.2 *Pulling Resin-Impregnated Tube into Position*—The wet-out fabric tube should be pulled into place using a power winch. The saturated fabric tube should be pulled through an existing manhole or other approved access to fully extend to the next designated manhole or termination point. Care should be exercised not to damage the tube as a result of friction during pull-in, especially where curvilinear alignments, multi-linear alignments, multiple offsets, protruding services, and other friction-producing host pipe conditions are present. Once the fabric tube is in place, it should be attached to a vertical standpipe so that the calibration hose can invert into the center of the resin-impregnated fabric tube. The vertical standpipe should be of sufficient height of water head to hold the fabric tube tight to the existing pipe wall, producing dimples at side connections. A device such as a dynamometer or load cell should be provided on the winch or cable to monitor the pulling force. Measure the overall elongation of the fabric tube after pull-in completion. The acceptable longitudinal elongation shall not be more than 5 % of the overall length measured after the calibration hose has been installed, or exceed the recommended pulling force.

6.4.3 *Hydrostatic Head Calibration Hose Inversion*—The calibration hose should be inserted into the vertical inversion standpipe, with the impermeable plastic membrane side out. At the lower end of the inversion standpipe, the calibration hose should be turned inside out and attached to the standpipe so

TABLE 1 CIPP Initial Structural Properties^A

| Property | Test Method | Minimum Value | |
|---|-------------|---------------|--------|
| | | psi | (MPa) |
| Flexural strength | D 790 | 4 500 | (31) |
| Flexural modulus | D 790 | 250 000 | (1724) |
| Tensile strength (for pressure pipes only) | D 638 | 3 000 | (21) |

^AThe values in Table 1 are for field inspection. The purchaser should consult the manufacturer for the long-term structural properties.

that a leakproof seal is created. The resin-impregnated fabric tube should also be attached to the standpipe so that the calibration hose can invert into the center of the resin-impregnated tube. The inversion head should be adjusted to be of sufficient height of water head to cause the calibration hose to invert from the initial point of inversion to the point of termination and hold the resin-impregnated fabric tube tight to the pipe wall, producing dimples at side connections. Care should be taken during the inversion so as not to overstress the felt fiber. At the request of the purchaser, the fabric tube manufacturer should provide information on the maximum allowable axial and longitudinal tensile stress for the fabric tube.

6.4.3.1 An alternative method of installation is top inversion. In this case, the calibration hose and resin-impregnated fabric tube are attached to a top ring. In this case, the tube itself forms the standpipe for generation of the hydrostatic head. Other methods of installation are also available and should be submitted for acceptance by the purchaser.

6.4.4 *Using Air Pressure*—The resin-impregnated fabric tube should be perforated as described in 6.4.1. Once perforated, the wet-out fabric tube should be pulled into place using a power winch as described in 6.4.2. The calibration hose should be inserted through the guide chute or tube of the pressure containment device in which the calibration hose has been loaded, with the impermeable plastic membrane side out. At the end of the guide chute, the calibration hose should be turned inside out and attached so that a leakproof seal is created. The resin-impregnated tube should also be attached to the guide chute so that the calibration hose can invert into the center of the resin-impregnated tube. The inversion air pressure should be adjusted to be of sufficient pressure to cause the calibration hose to invert from point of inversion to point of termination and hold the resin saturated fabric tube tight to the pipe wall, producing dimples at side connections. Care should be taken during the inversion so as not to overstress the woven and nonwoven materials. Take suitable precautions to eliminate hazards to personnel in the proximity of the construction when pressurized air is being used.

6.5 *Lubricant During Installation*—The use of a lubricant during installation is recommended to reduce friction during inversion. This lubricant should be poured into the fluid in the standpipe in order to coat the calibration hose during inversion. When air is used to invert the calibration hose, the lubricant should be applied directly to the calibration hose. The lubricant used should be a nontoxic, oil-based product that has no detrimental effects on the tube or boiler and pump system, and will not adversely affect the fluid to be transported.

6.6 *Curing:*

6.6.1 *Using Circulating Heated Water*—After installation is completed, suitable heat source and water recirculation equipment are required to circulate heated water throughout the section to uniformly raise the water temperature above the temperature required to effect a cure of the resin. The water temperature in the line during the cure period should be as recommended by the resin manufacturer or seller.

6.6.1.1 The heat source should be fitted with suitable monitors to measure the temperature of the incoming and

outgoing water supply. Temperature sensors should also be placed between the resin-impregnated tube and the host pipe invert at both termination points to monitor the temperatures during cure.

6.6.1.2 Initial cure will occur during temperature heat-up and is completed when exposed portions of the CIPP 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 should be raised to the post-cure temperature and held there for a period recommended by the resin manufacturer or seller. During post-cure, the recirculation of the water and cycling of the boiler to maintain the temperature continues. The curing of the CIPP must take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

6.6.2 *Using Steam*—After installation is completed, suitable steam-generating equipment is required to distribute steam throughout the pipe. The equipment should be capable of delivering steam throughout the section to uniformly raise the temperature within the pipe above the temperature required to effect a cure of the resin. The temperature in the line during the cure period should be as recommended by the resin manufacturer or seller.

6.6.2.1 The steam-generating equipment should be fitted with a suitable monitor to measure the temperature of the outgoing steam. Temperature sensors should also be placed between the resin-impregnated tube and the host pipe invert at both termination points to monitor the temperatures during cure.

6.6.2.2 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 should be raised to the post-cure temperature and held there for a period recommended by the resin manufacturer or seller, during which time the distribution and control of steam to maintain the temperature continues. The curing of the CIPP must take into account the existing pipe material, the resin system, and ground conditions (temperature, moisture level, and thermal conductivity of soil).

6.6.3 *Required Pressures*—As required by the purchase agreement, the estimated maximum and minimum pressure required to hold the flexible tube tight against the existing conduit during the curing process should be provided by the seller and shall be increased to include consideration of external ground water, if present. Once the cure has started and dimpling for laterals is completed, the required pressures should be maintained until the cure has been completed. For water or steam, the pressure should be maintained within the estimated maximum and minimum pressure during the curing process. If the steam pressure or hydrostatic head drops below the recommended minimum during the cure, the CIPP should be inspected for lifts or delaminations and evaluated for its ability to fully meet the applicable requirements of 6.8 and Section 8.

6.7 *Cool-Down:*

6.7.1 *Using Cool Water after Heated Water Cure*—The new CIPP should be cooled to a temperature below 100°F (38°C) before relieving the static head in the inversion standpipe. Cool-down may be accomplished by the introduction of cool water into the inversion standpipe to replace water being drained from a small hole made in the downstream end. Take care to cool down the CIPP in a controlled manner, as recommended by the resin manufacturer or the seller. Care should be taken to release the static head so that a vacuum will not be developed that could damage the newly installed CIPP.

6.7.2 *Using Cool Water after Steam Cure*—The new CIPP should be cooled to a temperature below 100°F (38°C) before relieving the internal pressure within the section. Cool-down may be accomplished by the introduction of cool water into the section to replace the mixture of air and steam being drained from a small hole made in the downstream end. Take care to cool the CIPP in a controlled manner as recommended by the resin manufacturer or the seller. Care should be taken to release the air pressure so that a vacuum will not be developed that could damage the newly installed CIPP.

6.8 *Workmanship*—The finished CIPP should be continuous over the entire length of an installation and be free of dry spots, lifts, and delaminations. If these conditions are present, the CIPP will be evaluated for its ability to meet the applicable requirements of Section 8. Where the CIPP does not meet the requirements of Section 8 or specifically stated requirements of the purchase agreement, or both, the affected portions of CIPP will be removed and replaced with an equivalent repair.

6.8.1 If the CIPP does not fit tightly against the original pipe at its termination point(s), the full circumference of the CIPP exiting the existing host pipe or conduit should be sealed by filling with a resin mixture compatible with the CIPP.

6.9 *Service Connections*—After the new CIPP has been installed, the existing active (or inactive) service connections should be reinstated. This should generally be done without excavation, and in the case of non-man entry pipes, from the interior of the pipeline by means of a television camera and a remote-control cutting device. Service connections shall be reinstated to at least 90 % of the original area as it enters the host pipe or conduit.

NOTE 3—In many cases, a seal is provided where the formed CIPP dimples at service connections. However, this practice should not be construed to provide a 100 % watertight seal at all service connections. If total elimination of infiltration and inflow is desired, other means, which are beyond the scope of this practice, may be necessary to seal service connections and to rehabilitate service lines and manholes.

7. Material Requirements

7.1 *Fabric Tube Strength*—If required by the purchaser in the purchase agreement, the fabric tube, and seam (if applicable) as a quality control test, when tested in accordance with Test Method D 1682 shall have a minimum tensile strength of 750 psi (5 MPa) in both the longitudinal and transverse directions.

7.2 Chemical Resistance:

7.2.1 *Chemical Resistance Requirements*—The cured resin/fabric tube matrix, with or without the calibration hose, shall be evaluated in a laminate form for qualification testing of long-term chemical exposure to a variety of chemical effluents

and should be evaluated in a manner consistent with 6.4.1 of Specification D 5813. The specimens shall be capable of exposure to the solutions in Table 2 at a temperature of 73.4 ± 3.6°F (23 ± 2°C), with a percentage retention of flexural modulus of elasticity of at least 80 % after one year exposure. Flexural properties, after exposure to the chemical solution(s), shall be based on dimensions of the specimens after exposure.

7.2.2 *Chemical Resistance Procedures*—The CIPP laminates should be constructed of identical fabric and resin components that will be used for anticipated in-field installations. The cured resin/fabric tube laminates, with or without the calibration hose should be exposed to the chemical agents in a manner consistent with Test Method D 543. The edges of the test coupons should be left exposed and not treated with resin, unless otherwise specified by the purchaser. The specimen thicknesses should be in the range of 0.125 to 0.25 in. (3.2 to 6.4 mm), with the sample dimensions suitable for preparing a minimum of five specimens for flexural testing as described in 8.1.4. Flexural properties after exposure to the chemical solutions should be based on the dimensions of the specimen after exposure.

7.2.2.1 For applications other than standard domestic sewerage, 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 depositing CIPP test samples in the active pipe.

7.2.2.2 As required by the purchaser, additional chemical resistance requirements for the CIPP may be evaluated as described in 6.4 of Specification D 5813.

8. Recommended Inspection Practices

8.1 For each installation length designated by the purchaser in the purchase agreement, the preparation of CIPP samples is required from one or both of the following two methods:

8.1.1 The samples should be cut from a section of cured CIPP at an intermediate manhole or at the termination point that has been installed through a like diameter section of pipe or other tubular restraining means which has been held in place by a suitable heat sink, such as sandbags.

8.1.2 The sample should be fabricated from material taken from the fabric tube and the resin/catalyst system used, and cured in a clamped mold, placed in the downtube when heated circulated water is used, and in the silencer when steam is used. When the CIPP is constructed of oriented continuous or discontinuous fibers to enhance the physical properties of the CIPP, this method of sample preparation is recommended in order to allow testing in the axial (that is, along the length) and

TABLE 2 Minimum Chemical Resistance Requirements for Domestic Sanitary Sewer Applications

| Chemical Solution | Concentration, % |
|----------------------------|------------------|
| Nitric acid | 1 |
| Sulfuric acid | 5 |
| ASTM Fuel C ^A | 100 |
| Vegetable oil ^B | 100 |
| Detergent ^C | 0.1 |
| Soap ^C | 0.1 |

^AIn accordance with Specification D 4814.

^BCottonseed, corn, or mineral oil.

^CIn accordance with Test Method D 543.

circumferential (that is, hoop) directions of the CIPP. This method is also recommended when large-diameter CIPP is installed that may otherwise not be prepared with a tubular restraint.

8.1.3 The CIPP samples for each of these cases should be large enough to provide a minimum of three specimens and a recommended five specimens for flexural testing and also for tensile testing for internal pressure applications. The flexural and tensile specimens should be prepared in a manner consistent with 8.3.1 of Specification D 5813. For flexural and tensile properties, the full wall thickness of the CIPP samples shall be tested. Any plastic coatings or other CIPP layers not included in the structural design of the CIPP may be carefully ground off of the specimens prior to testing. If the sample is irregular or distorted such that proper testing is inhibited, attempts shall be made to machine any wall thickness from the inside pipe face of the sample. Any machining of the outside pipe face of the sample shall be done carefully so as to minimize the removal of material from the outer structural wall of the sample. Individual specimens should be clearly marked for easy identification and retained until final disposition or CIPP acceptance, or both, has been given.

8.1.4 *Short-Term Flexural (Bending) Properties*—The initial tangent flexural modulus of elasticity and flexural stress should be measured for gravity and pressure pipe applications in accordance with Test Method D 790, Test Method I, Procedure A and should meet the requirements of Table 1 within the 16:1 length to depth constraints. For specimens greater than 0.5 in. (12.7 mm) in depth, the width-to-depth ratio of the specimen should be increased to a minimum of 1:1 and should not exceed 4:1. For samples prepared in accordance with 8.1.1, determine flexural properties in the axial direction where the length of the test specimen is cut along the longitudinal axis of the pipe. Special consideration should be given to the preparation of flexural specimens to ensure opposite sides are parallel and adjacent edges are perpendicular. Flexural specimens should be tested such that the inside pipe face is tested in tension and the outside pipe face is in compression.

8.1.4.1 *Fiber-Reinforced CIPP Flexural Properties*—Where the CIPP is reinforced with oriented continuous or discontinuous fibers to enhance the physical properties of the CIPP, specimens should be sampled in accordance with 8.1.2, and flexural properties should be determined in accordance with 8.1.3 along the longitudinal axis and circumferential axis of the installed CIPP.

8.1.5 *Short-Term Tensile Properties*—The tensile strength should be measured for pressure pipe applications in accordance with Test Method D 638. Specimens should be prepared in accordance with Types I, II, and III of Fig. 1 of Test Method D 638. Specimens greater than 0.55 in. (14 mm) thick should maintain all dimensions for a Type III specimen, except the thickness will be that of the CIPP sample obtained. The rate of specimen testing should be carried out in accordance with Table 1 of Test Method D 638. Specimens should be prepared in accordance with 8.1.1 and tested along the longitudinal axis of the installed CIPP.

8.1.5.1 *Fiber-Reinforced CIPP Tensile Testing*—Where the CIPP is reinforced with oriented continuous or discontinuous

fibers to enhance the physical properties of the CIPP, specimens should be sampled in accordance with 8.1.2 and tensile properties should be determined in accordance with Test Method D 3039 and tested along the longitudinal axis and circumferential axis of the installed CIPP.

8.1.6 *CIPP Wall Thickness*—The method of obtaining CIPP wall thickness measurements should be determined in a manner consistent with 8.1.2 of Specification D 5813. Thickness measurements should be made in accordance with Practice D 3567 for samples prepared in accordance with 8.1. Make a minimum of eight measurements at evenly spaced intervals around the circumference of the sample to ensure that minimum and maximum thicknesses have been determined. Deduct from the measured values the thickness of any plastic coatings or CIPP layers not included in the structural design of the CIPP. The average thickness should be calculated using all measured values and shall meet or exceed minimum design thickness as agreed upon between purchaser and seller. The minimum wall thickness at any point shall not be less than 87.5 % of the specified design thickness as agreed upon between purchaser and seller.

8.2 *Gravity Pipe Leakage Testing*—If required by the owner in the contract documents or purchase order, gravity pipes should be tested using an exfiltration test method where the CIPP is plugged at both ends and filled with water. This test should take place after the CIPP has cooled down to ambient temperature. This test is limited to pipe lengths with no service laterals and diameters of 36 in. or less. The allowable water exfiltration for any length of pipe between termination points should not exceed 50 U.S. gallons per inch of internal pipe diameter per mile per day, providing that all air has been bled from the line. During exfiltration testing, the maximum internal pipe pressure at the lowest end should not exceed 10 ft (3.0 m) of water or 4.3 psi (29.7 kPa), and the water level inside of the inversion standpipe should be 2 ft (0.6 m) higher than the top of the pipe or 2 ft (0.6 m) higher than groundwater level, whichever is greater. The leakage quantity should be gaged by the water level in a temporary standpipe placed in the upstream plug. The test should be conducted for a minimum of 1 h.

NOTE 4—It is impractical to test pipes above 36 in. diameter for leakage due to the technology available in the pipe rehabilitation industry. Post inspection of larger pipes will detect major leaks or blockages.

8.3 *Pressure Pipe Testing*—If required by the purchaser in the purchase agreement, pressure pipes should be subjected to a hydrostatic pressure test. A pressure and leakage test at twice the known working pressure or at the working pressure plus 50 psi, whichever is less, is recommended. The pressure should initially be held at the known working pressure for a period not less than 12 h, then increased to the test pressure for an additional period of 2 to 3 h to allow for stabilization of the CIPP. After this period, the pressure test will begin for a minimum of 1 h. The allowable leakage during the pressure test should be 20 U.S. gallons per inch of internal pipe diameter per mile per day, providing that all air has been evacuated from the line prior to testing and the CIPP has cooled down to ambient temperature.

NOTE 5—The allowable leakage for gravity and pressure pipe testing is a function of water loss at the end seals and trapped air in the pipe.

8.4 *Delamination Test*—If required by the purchaser in the purchase agreement, a delamination test should be performed on each installation length specified. CIPP samples should be prepared in accordance with 8.1.2, except that a portion of the fabric tube material in the sample should be dry and isolated from the resin in order to separate tube layers for testing (consult the tube manufacturer for further information). Delamination testing should be in accordance with Test Method D 903 with the following exceptions:

8.4.1 The rate of travel of the power-actuated grip should be 1 in. (25 mm)/min.

8.4.2 Five test specimens should be tested for each installation specified.

8.4.3 The thickness of the test specimen should be minimized, but should be sufficient to adequately test delamination of nonhomogeneous CIPP layers.

8.5 The peel or stripping strength between any nonhomogeneous layers of the CIPP laminate should be a minimum of 10 lb/in. (178.60 g/mm) for typical CIPP applications.

NOTE 6—The purchaser may designate the similar layers between which the delamination test will be conducted.

NOTE 7—For additional details on conducting the delamination test, contact the seller.

8.6 *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. All service entrances should be accounted for and be unobstructed.

9. Keywords

9.1 cured-in-place pipe; installation—underground; plastic pipe—thermoset; rehabilitation; thermosetting resin pipe

APPENDIX

(Nonmandatory Information)

X1. DESIGN CONSIDERATIONS

X1.1 *General Guidelines*—The design thickness of the CIPP is a function of the resin, materials of construction of the fabric tube, and the condition of the existing pipe. In addition, depending on the condition of the pipe, the design thickness of

the CIPP may also be a function of groundwater, soil type, and influence of live loading surrounding the host pipe. For guidance relating to terminology of piping conditions and related design equations, see Appendix X1 of Practice F 1216.

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