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Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)[1]

This standard is issued under the fixed designation F 2019; 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 covers the procedures for the reconstruction of pipelines and conduits (4 to 48 in. (100 to 1200 mm) diameter) by the pulled-in place installation of a resin-impregnated, flexible fabric tube into an existing conduit followed by inflation with compressed air (see Fig. 1). The resin/fabric tube is cured by flow through the fabric tube of mixed air and steam. When cured, the finished cured-in-place pipe will be continuous and tight fitting. This reconstruction process can be used in a variety of gravity flow 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.

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 Testing Method of Resistance of Plastics to Chemical Reagents[2]

D 578 Specifications for Glass Fiber Strands[3]

D 638 Testing Method for Tensile Properties of Plastics[2]

D 790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics[2]

D 1682 Test Method for Breaking Load and Elongation of Textile Fabrics[4]

D 3567 Practice for Determining Dimensions of Reinforced Thermosetting Resin Pipe (RTRP) and Fittings[5]

D 5813 Specification for Cured-in-Place Thermosetting Resin Sewer Pipe[5]

F 412 Terminology Relating to Plastic Piping Systems[5]

F 1216 Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube[5]

F 1417 Test Method for Installation Acceptance of Gravity Plastic Sewer Lines Using Low Pressure Air Testing[5]

2.2 *AWWA Standard:*

Manual on Cleaning and Lining Water Mains, M28[6]

2.3 *NASSCO Standard:*

Recommended Specifications for Sewer Collection System Rehabilitation[7]

3. Terminology

3.1 *General:*

3.1.1 Definitions are in accordance with Terminology F 412. Abbreviations are in accordance with Abbreviations D 1600, unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration hose*—an impermeable bladder installed inside the fabric tube, and inflated with air or steam to press the tube firmly against the wall of the existing pipe until the resin is cured with air and steam. The calibration hose is removed when the installation is finished.

3.2.2 *cured-in-place pipe (CIPP)*—a hollow cylinder consisting of a glass reinforced plastic (GRP) fabric tube with cured thermosetting resin. External foils are included. The CIPP is formed within an existing pipe and takes the shape of the pipe.

3.2.3 *delamination*—separation of the layers in the sandwich constructed CIPP

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

3.2.5 *E-CR glass*—an E-glass type that is resistant to normal sewer effluents as tested according to 6.4.1 and 6.4.2 of Specifications D 5813

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[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.

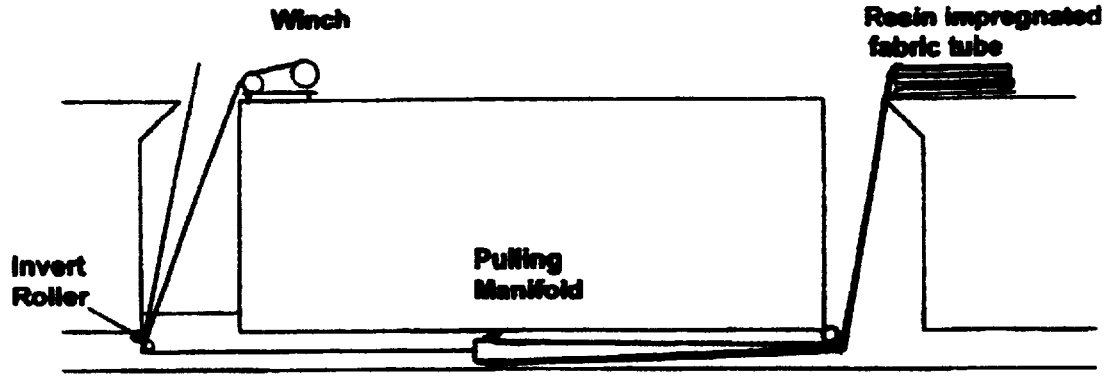
[3] *Annual Book of ASTM Standards*, Vol 07.01.

[4] Discontinued; see *1991 Annual Book of ASTM Standards*, Vol 07.01.

[5] *Annual Book of ASTM Standards*, Vol 08.04.

[6] Available from American Water Works Association 6666 West Quincy Ave., Denver CO 80235.

[7] Available from National Association of Sewer Service Companies, 423 W. King Street, Suite 3000, Chambersburg, PA 17201



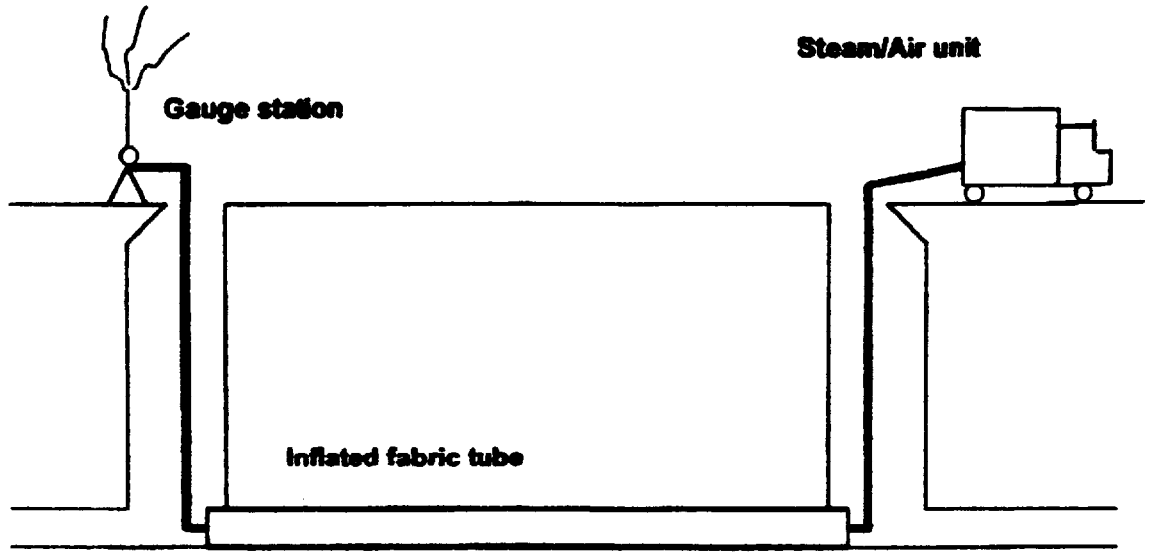


FIG. 1 Cured-In-Place Pipe Installation Method (Air/Steam)

3.2.6 *fabric tube*—flexible sandwich fiberglass materials formed into a tubular shape which during the installation is saturated with resin and holds the resin in place as a permanent part of the installed cured-in-place pipe as further described in 5.2.1.

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

3.2.8 *slip-foil*—a plastic foil installed prior to the fabric tube covering the lower third of the circumference of the existing pipe to reduce friction.

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 subsequently inflated and cured. As for any standard practice, modifications may be required for specific job conditions.

5. Recommended Materials and Manufacture

5.1 *General*—The fabric tube, resin and external preliners shall produce a CIPP that meets the requirements of these specifications.

5.2 *CIPP Wall Composition*—The wall shall consist of a corrosion resistant fiberglass fabric tube (Fig. 2) saturated with a thermosetting (cross-linked) resin, and if used a filler material.

5.2.1 *Fabric Tube*—The fabric tube shall consist of at least

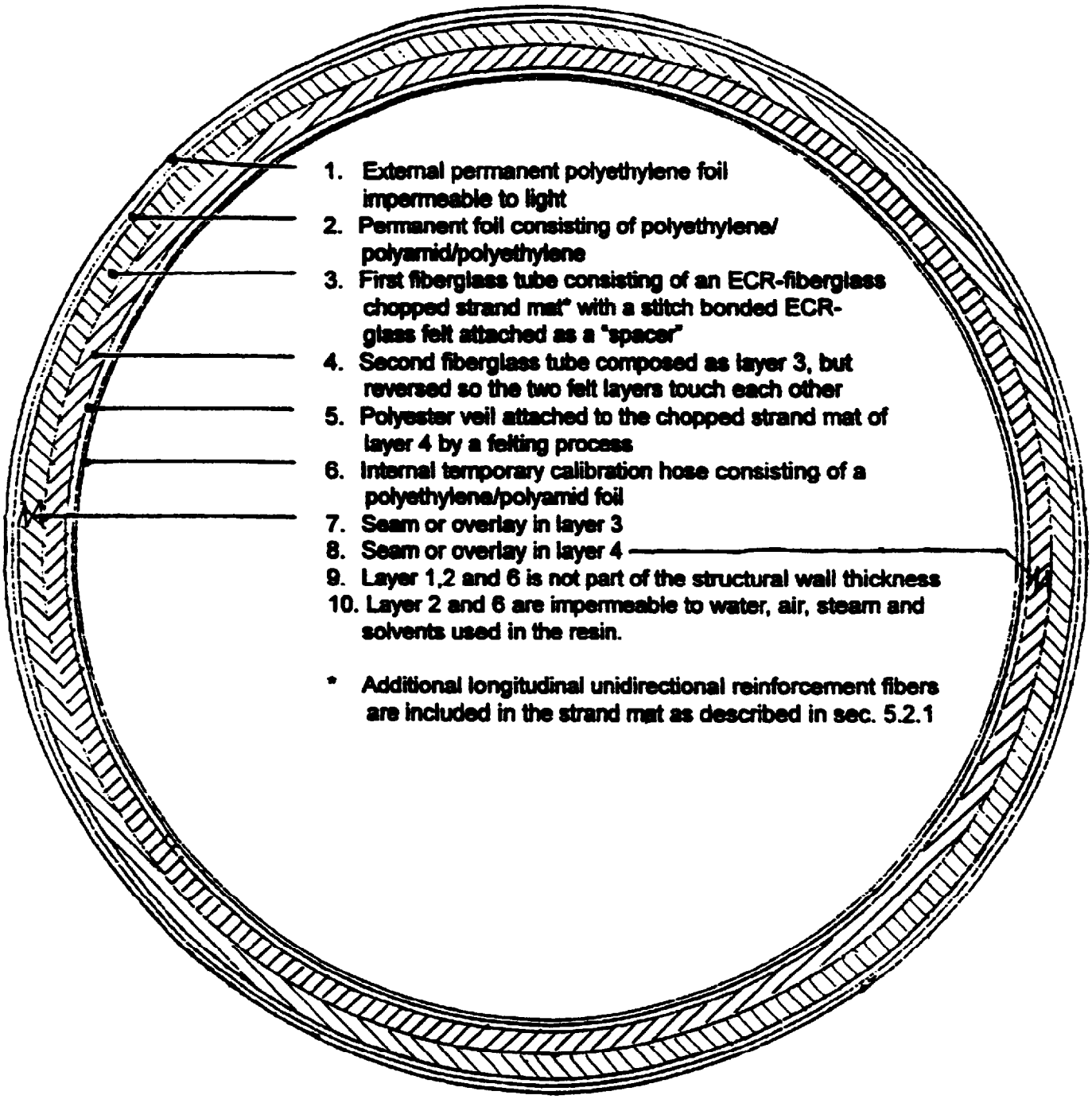


FIG. 2 Composition of Fabric Tube

two separate tubes made of corrosion resistant (E-CR) glass fibers in accordance with Specification D 578. The internal surface shall consist of a veil preferably made of polyester. The fabric tube shall further be constructed with longitudinal unidirectional glass roving of sufficient strength to negotiate a pulling force at least equal to the weight of the liner. The fabric tube shall tolerate up to 10 % circumferential changes in the existing conduit.

5.2.2 *External Foils*—The external foils (Layers 1 and 2 in Fig. 2) shall consist of one or more layers of styrene and light proof tube shaped plastic foils.

5.2.3 *Calibration hose*—The calibration hose (Layer 6 in Fig. 2) which is installed during the construction of the fabric tube, shall consist of a tube shaped plastic foil able to resist styrene and temperatures up to 260°F (126°C) while exposed to the installation pressure sufficient to keep the fabric tube tight against the pipe wall. It shall further release easily from the inside wall for removal, when the installation is finished.

5.2.4 *Resin*—The resin system shall consist of a chemically resistant isophthalic polyester or vinyl ester thermoset resin and catalyst system or an epoxy resin and hardener that is compatible to the installation process. The resin system shall

have an initiating temperature less than 180°F (82°C).

5.2.5 *Properties*—The cured CIPP product shall at least have the initial structural properties given in Table 1. These physical properties should be determined in accordance with Section 7 of this practice.

5.2.6 *Chemical Resistance*—The cured resin/fabric matrix shall after the calibration hose is removed be evaluated in a laminate 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 and 6.4.2 of Specifications D 5813.

6. Installation Recommendations

6.1 *Cleaning and Pre-Inspection*:

6.1.1 *Safety*—Prior to entering access areas such as manholes, and performing inspection and 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 the 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 according to NASSCO Recommended Specifications for Sewer Collection System Rehabilitation. Pressure pipelines should be cleaned with cable attached devices or fluid propelled devices according to AWWA Manual on Cleaning and Lining Water Mains, M28.

6.1.3 *Line Obstructions*—The original pipeline should be clear of obstructions such as solids, dropped joints, protruding service connections, 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 the inspection reveals an obstruction that cannot be removed by conventional sewer cleaning equipment, then a point repair should be made to remove the obstruction.

6.1.4 *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 they can be corrected prior to the installation.

6.1.5 *Pre-Measurement of Service Connections*—A pre-measuring of all service locations must be performed by experienced personnel. Due to the unidirectional reinforcement of the fabric tube visible indentations by the lateral connections may not be readily identified.

TABLE 1 CIPP Initial Structural Properties[A]

Property	Test Method	Minimum value PSI	(MPA)
Flexural Strength	D 790	6500[B]	45
Flexural Modulus	D 790	725000	5000

[A]The values in Table 1 are for test results on field specimens. The purchaser should consult the manufacturer for the long-term structural properties.

[B]The value indicates minimum strength both in the circumferential and longitudinal direction

6.1.5.1 The measurements should be noted in a log also containing information about the clockwise position of the opening.

6.1.6 *Bypassing*—If bypassing the flow is required around the sections of pipe designated for reconstruction, the bypass should be made by plugging the line at the up-stream end of the pipe to be reconstructed and pumping the flow to a downstream point or adjacent system.

6.1.6.1 The pump and bypass lines should be of adequate capacity and size to handle the flow. Services within the reach will be temporarily out of service.

6.1.7 Public advisory services will be required to notify all parties whose service laterals will be out of commission and to advise against water usage until the lateral line is back in service.

6.2 *Installation Methods*:

6.2.1 *Slipfoil and Winch Cable*—Upon verification of the removal of all debris and protrusions a slipfoil and a winch cable is pulled through the line. The slip foil should cover approximately the lower third of the circumference of the pipe. At the upstream end it is locked in place, typically by being inserted underneath the plug used to block the flow in the manhole.

6.2.2 *Invert Roller and Pulling Manifold*—An invert guide roller is placed in the winch manhole. The invert roller should allow the pulling manifold to enter the manhole before the pulling is terminated. The pulling manifold is attached to the end of the liner with sufficient strength to transfer the pulling force. It contains a mounting point for the air/stream hose. During the mounting of the pulling manifold care should be taken to ensure an airtight fit of the calibration hose to the manifold.

6.3 *Resin Impregnation*—The fabric tube should be totally impregnated with resin (wet-out). The impregnation can either take place before the external foils are mounted or with a light penetrable foil mounted. The impregnation equipment should contain devices to secure a proper distribution of the resin. Following the impregnation and mounting of the light penetrable foil the fabric tube should be exposed to a resin thickening procedure. Finally the light proof foil should be mounted.

6.3.1 *Storage*—The impregnated liner should be stored in area where the temperature is controlled to 70°F (°C) or less.

6.4 *Pulling Resin Impregnated Tube into Position*—The wet-out fabric tube should be pulled in place using a power winch. The fabric tube should be pulled into place through an existing manhole or other approved access point to fully extend to the designated manhole or termination point. The pulling speed should not exceed 15 ft/min. (5 m/min.). When entered into the access point the fabric tube should be folded in half and placed on top of the slipfoil. Care should be exercised not to damage the tube during the pulling phase. Especially where curvilinear alignments, multilinear alignments, multiple offsets, protruding elements and other friction producing pipe conditions are present. The pulling should be considered completed when the pulling manifold and 1 to 2 ft (0.3 to 0.6 m) of linear has entered the termination point. Measure the

overall elongation of the fabric tube after the pull-in completion. The acceptable longitudinal elongation shall be less than 2 % of the overall length. Next the length of the fabric tube should be adjusted to extend 1 to 2 ft into the access point and mounted with an inlet manifold. The manifolds are connected to inlet- and outlet air/steam hoses and the inlet manifold is mounted with temperature and pressure sensors. Temperature sensors are further mounted approximately one foot into the existing pipe on the outside of the fabric tube from the access and termination point.

6.5 *Curing with Steam*:

6.5.1 *Installation Set-up*—The inlet air/steam hose is connected to the installation equipment, which is equipped with an air compressor and a steam source or sufficient capacity. It is further equipped with monitoring and control equipment for adjustment of air/steam temperature and pressure according to the manufacturer's instructions for the curing process (Fig. 1).

6.5.1.1 The outlet air/steam hose is mounted to a gauge station, equipped with adjustment valve, temperature and pressure gauge.

6.5.2 *Processing*—The fabric tube should be inflated with air until it is fitting tight against the wall of the existing pipe. The desired pressure is maintained by adjustment of the outlet valve.

6.5.2.1 The temperature in the airflow should now be adjusted to follow the manufacturer's instructions for the curing temperature. (**Warning**—Adequate safety precautions shall be taken during the curing process when high air pressure and steam are placed within the liner.)

6.5.2.2 When a temperature of 180°F (81°C) has been reached at the sensor attached to the outside of the fabric tube at the termination point the air compressor should be shut off and a post curing with steam at 260°F (126°C) should take place to ensure the full development of chemical resistance and resin strength. Following the post curing the steam is gradually replaced with air and the cured fabric tube is cooled down to 140°F (60°C), measured at the outside sensors. This cooling can be assisted by mixing water into the air flow.

6.5.2.3 Finally the manifolds and next the calibration hose are removed.

6.5.3 *Curing Control*—A full protocol for time, temperatures and pressures should be maintained as documentation for the correct curing of the fabric tube.

6.6 *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 7. Where the CIPP does not meet the requirements of Section 7 or specifically stated requirements of the purchase agreement, or both, the affected portions of the CIPP will be removed and replaced with an acceptable repair as specified in 6.2 of Specification D 5813.

6.7 *Service Connections*—After the new CIPP has been installed, the existing service connections should be reinstated. This should generally be done without excavation and in cases of non man-entry pipes from the interior of the pipeline by the means of a television camera and a remotely controlled cutting device. Service connections shall be reinstated to at least 95 % of the original area as it enters the host pipe or conduit. All laterals where a plug by the end of the lateral was not visible by the pre-inspection, should be reinstated, if the purchase agreement does not specify it differently.

NOTE 1—In many cases, a seal is provided between the existing pipe and the fabric tube at the service connections. If total elimination of infiltration and inflow is desired, other means, which are beyond the scope of this standard, may be necessary to seal service connections and to rehabilitate service lines and manholes.

7. Recommended Inspection Practices

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

7.1.1 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 conduit or other tubular restraining means which has been held in place by a suitable heat sink such as sandbags.

7.1.2 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 a designated chamber in the outlet gage station. This sampling method is preferred in order to allow testing in the axial (along the length) and circumferential (that is, hoop) directions of the Fiberglass reinforcement in the CIPP. The sample should be marked showing axial and circumferential directions.

7.1.3 The CIPP samples for each of these cases should be large enough to provide a minimum of three specimens and recommended five specimens for flexural testing. The flexural specimens should be prepared in a manner consistent with 8.3.1 of Specifications D 5813. For flexural properties the full wall thickness of the CIPP samples shall be tested. Layers 1, 2 and 6 is not part of the structural wall thickness (Fig. 2). If the sample is irregular or distorted in such a manner that the proper testing is inhibited, attempts shall be made to machine any wall thickness from the inside pipe face of the sample without cutting into the Fiberglass reinforcement. 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.

7.1.4 *Short Term Flexural Properties*—The initial tangent modulus of elasticity and flexural strength should be measured for gravity pipe applications in accordance with Test Method D 790, Test Method 1—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. Samples should be prepared in accordance with 7.1.2, to determine the flexural properties in the hoop direction.

7.1.4.1 Special consideration should be given to the preparation of flexural specimens to ensure the 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 face in compression.

7.1.5 *CIPP Wall Thickness*—The method of obtaining the CIPP wall thickness measurements should be determined in a manner consistent with 8.1.2 of Specifications D 5813. Thickness measurements should only incorporate layers 3 to 5 (Fig. 2) and be made in accordance with Practice D 3567 for samples prepared in accordance with 7.1. Make a minimum of eight measurements at evenly spaced intervals around the circumference of the sample to ensure that the minimum and maximum thickness have been determined. The average thickness should be calculated using all measured values and shall meet or exceed minimum design thickness as agreed between purchaser and seller. The minimum wall thickness at any point shall not be less than 87.5 % of the average specified design thickness as agreed between purchaser and seller.

NOTE 2—A local reduction in wall thickness may reduce the in service safety factor.

7.2 *Gravity Pipe Leakage Testing*—If required by the owner in the contract documents or purchase order, gravity pipes should be tested using an ex-filtration test method where the CIPP, after it is cooled down to ambient temperature and the calibration hose is removed, but before the laterals are re-opened, is plugged in both ends. The testing should be performed with either air or water.

7.2.1 Air testing should be according to Test Method F 1417.

7.2.2 Water testing is limited to diameters of 36 in. (mm) or less. The allowable water exfiltration for any length of pipe between termination points should not exceed 50 gal/in. (L/cm) of internal pipe diameter per mile per day (46.6 L/cm internal diameter per km. per day), providing that all air has been bled from the line. During the exfiltration test, the maximum internal water pressure at the lowest end should not exceed 4.3 psi (0.3 bar) or 10 ft (m) of water. The water pressure in the top end should be at least 0.9 Psi (0.06 bar) or 2 ft (m) higher than the top of the pipe or 2 ft (m) higher than the groundwater table, which ever is the greatest. The leakage should be gauged by refilling water in a calibrated stand pipe mounted in the upstream plug. The test should be conducted for at least one hour.

NOTE 3—It is impractical to test pipes above 36 in. diameter for leakage due to the technology available in the pipeline rehabilitation industry. Man entry inspection of larger pipes will detect major leaks.

NOTE 4—The allowable leakage for gravity pipe testing is a function of loss at end seals and by water testing of compression of air trapped in the pipe.

7.3 *Inspection and Acceptance*—The installation should be visually inspected to assure compliance with 6.6 if appropriate, or by closed circuit television if visual inspection cannot be accomplished. Variations from the true line and grade may be inherent because of the condition of the original piping. No infiltration of ground water should be observed through the CIPP. In cases of visible leakage repairs shall be made according to agreement with the owner. All service openings shall be accounted for and be unobstructed.

8. Keywords

8.1 cured-in-place pipe (CIPP); glass reinforced plastic (GRP); rehabilitation; steam cured

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.