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Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube[1,2]

This standard is issued under the fixed designation F1216; 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 (2 in. to 108 in. diameter) by the installation of a resin-impregnated, flexible tube which is inverted into the existing conduit by use of a hydrostatic head or air pressure. The resin is cured by circulating hot water, introducing controlled steam within the tube, or by photoinitiated reaction. When cured, the finished pipe will be continuous and tight-fitting. This reconstruction process ~~can be~~ is 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 standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific precautionary statements, see 7.4.2.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents
D638 Test Method for Tensile Properties of Plastics
D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
D903 Test Method for Peel or Stripping Strength of Adhesive Bonds
D1600 Terminology for Abbreviated Terms Relating to Plastics
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings

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

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[2] The following report has been published on one of the processes: Driver, F. T., and Olson, M. R., "*Demonstration of Sewer Relining by the Insituform Process, Northbrook, Illinois*," EPA-600/2-83-064, Environmental Protection Agency, 1983. Interested parties can obtain copies from the Environmental Protection Agency or from a local technical library.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

D3839 Guide for Underground Installation of "Fiberglass" (Glass-Fiber Reinforced Thermosetting-Resin) Pipe
D5813 Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
E797/E797M Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method
F412 Terminology Relating to Plastic Piping Systems

2.2 *AWWA Standard:*[4]
~~Manual on Cleaning and Lining Water Mains,~~ M 28 Rehabilitation of Water Mains, Third Ed.

2.3 *NASSCO Standard:*[5]
~~Recommended Specifications for Sewer Collection System Rehabilitation~~Sewer Pipe Cleaning Specification Guideline

3. Terminology

3.1 Definitions are in accordance with Terminology F412 and abbreviations are in accordance with Terminology D1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cured-in-place pipe (CIPP)*—a hollow cylinder containing a nonwoven or a woven material, or a combination of nonwoven and woven material surrounded by a cured thermosetting resin. Plastic coatings may be included. This pipe is formed within an existing pipe. Therefore, it takes the shape of and fits tightly to the existing pipe.

3.2.2 *inversion*—the process of turning the resin-impregnated tube inside out by the use of water pressure or air pressure.

3.2.3 *lift*—a portion of the CIPP that has cured in a position such that it has pulled away from the existing pipe wall.

3.2.4 *photoinitiated reaction*—~~The~~the polymerization of a resin system initiated by light or other electromagnetic radiation.

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 tube inverted through the existing conduit. As for any practice, modifications may be required for specific job conditions.

5. Materials

5.1 *Tube*—The tube ~~should~~shall consist of one or more layers of flexible needled felt or an equivalent nonwoven or woven material, or a combination of nonwoven and woven materials, capable of carrying resin, withstanding installation pressures and curing temperatures. The tube ~~should~~ and any non-structural plastic coating or flexible membrane included in the tube construction shall be compatible with the resin system used. The material ~~should~~shall be able to stretch to fit irregular pipe sections and negotiate bends. The ~~outside layer of the tube should be plastic coated with a material that is compatible with the resin system used. The tube should be~~ tube shall be fabricated to a size that, when installed, will tightly fit the internal circumference and the length of the original conduit. Allowance ~~should~~shall be made for circumferential stretching during inversion.

5.2 *Resin*—A general purpose, unsaturated, styrene-based, thermoset resin and catalyst system or an epoxy resin and hardener that is compatible with the inversion process ~~should~~shall be used. The resin must 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 CIPP system ~~can~~shall be expected to have as a minimum the initial structural properties given in Table 1. These physical strength properties ~~should~~shall be determined in accordance with Section 8.

6. Design Considerations

6.1 *General Guidelines*—The design thickness of the CIPP is largely a function of the condition of the existing pipe. Design equations and details are given in Appendix X1.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.
[5] Available from the National Association of Sewer Service Companies, ~~2470 Longstone Lane, Suite M Marriottsville, MD 21104.~~5285 Westview Drive, Suite 202, Frederick, MD 21703. http://www.nassco.org/

TABLE 1 CIPP Initial Structural Properties[A]

Property	Test Method	Minimum Value psi	(MPa)
Flexural strength	D790	4500	(31)
Flexural modulus	D790	250 000	(1724)
Tensile strength (for pressure pipes only)	D638	3000	(21)

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

7. Installation

7.1 *Cleaning and Inspection:*

7.1.1 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.

7.1.2 *Cleaning of Pipeline*—All internal debris ~~should~~ that will interfere with the installation or adversely affect the performance of the CIPP shall be removed from the original pipeline. Gravity pipes ~~should be~~ are cleaned with hydraulically powered equipment, high-velocity jet cleaners, ~~or~~ mechanically powered ~~equipment (see NASSCO Recommended Specifications for Sewer Collection System Rehabilitation). Pressure pipelines should be~~ equipment, or other applicable method(s) (see NASSCO Sewer Pipe Cleaning Specification Guideline). Pressure pipelines are cleaned with cable-attached ~~devices or fluid-propelled devices as shown in AWWA Manual on Cleaning and Lining Water Mains, M 28.~~devices, fluid-propelled devices, or other applicable method(s) (see Chapter 3 "Pipe Cleaning Methods" in AWWA, M 28 Rehabilitation of Water Mains, Third Ed.).

7.1.3 *Inspection of Pipelines*—Inspection of pipelines ~~should~~shall be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed-circuit television or ~~man~~worker entry. The interior of the pipeline ~~should~~shall 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.~~shall be noted and corrected prior to installation of CIPP.

7.1.4 *Line Obstructions*—The original pipeline ~~should~~shall 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 will prevent the insertion~~ to ensure proper installation of the resin-impregnated tube. If inspection reveals an obstruction that cannot be removed by conventional sewer cleaning equipment, then a point repair excavation ~~should~~shall be made to uncover and remove or repair the ~~obstruction.~~obstruction prior to the installation of the CIPP.

7.2 *Resin Impregnation*—The tube ~~should~~shall be vacuum-impregnated with resin (wet-out) under controlled conditions. The volume of resin used ~~should~~shall be sufficient to fill all ~~voids~~ the void space present in the tube material at nominal thickness and diameter. The volume ~~should~~shall be adjusted by adding ~~5 % to 10 %~~ excess resin for the change in resin volume due to polymerization and to allow for any migration of resin into the cracks and joints in the original pipe.

NOTE 1—In pipelines 8 in. diameter and less, 5 % to 10 % excess resin should be added.

7.3 *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~~shall be of adequate capacity and size to handle the flow. Services within this reach will be temporarily out of service.

7.3.1 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 mainline is back in service.

7.4 *Inversion:*

7.4.1 *Using Hydrostatic Head*—The wet-out tube ~~should~~shall be inserted through an existing manhole or other approved access by means of an inversion process and the application of a hydrostatic head sufficient to fully extend it to the next designated manhole or termination point. The tube ~~should~~shall be inserted into the vertical inversion standpipe with the impermeable plastic membrane side out. At the lower end of the inversion standpipe, the tube ~~should~~shall be turned inside out and attached to the standpipe so that a leakproof seal is created. The inversion head ~~should~~shall be adjusted to be of sufficient height to cause the impregnated tube to invert from point of inversion to point of termination and hold the tube tight to the pipe wall, producing dimples at side connections. Care ~~should~~shall be taken during the inversion so as not to over-stress the felt fiber.

7.4.1.1 An alternative method of installation is a top inversion. In this case, the tube is attached to a top ring and is inverted to form a standpipe from the tube itself or another method accepted by the engineer.

NOTE 2—The tube manufacturer should provide information on the maximum allowable tensile stress for the tube.

7.4.2 *Using Air Pressure*—The wet-out tube ~~should~~shall be inserted through an existing manhole or other approved access by means of an inversion process and the application of air pressure sufficient to fully extend it to the next designated manhole or termination point. The tube ~~should~~shall be connected by an attachment at the upper end of the guide chute so that a leakproof seal is created and with the impermeable plastic membranes side out. As the tube enters the guide chute, the tube ~~should~~shall be turned inside out. The inversion air pressure ~~should~~shall be adjusted to be of sufficient pressure to cause the impregnated tube to invert from point of inversion to point of termination and hold the tube tight to the pipe wall, producing dimples at side connections. Care ~~should~~shall be taken during the inversion so as not to overstress the woven and nonwoven materials. **Warning—**Suitable precautions ~~should~~shall be taken to eliminate hazards to personnel in the proximity of the construction when pressurized air is being use.

7.4.3 *Required Pressures*—Before the inversion begins, the tube manufacturer shall provide 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 inversion has started, the pressure shall be maintained between the minimum and maximum pressures until the inversion has been completed.

NOTE 3—After inversion is completed, pressures can be adjusted to facilitate the safe installation of condensate removal equipment or other mechanisms required to transition to the curing process.

7.5 *Lubricant*—~~The use of a lubricant during inversion is recommended~~When lubricant is used to reduce friction during ~~inversion. This~~inversion, the lubricant ~~should~~shall be poured into the inversion water in the downtube or applied directly to the tube. The lubricant used ~~should~~shall be a ~~nontoxic, oil-based~~ 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.

7.6 *Curing:*

7.6.1 *Using Circulating Heated Water*—After inversion is completed, a suitable heat source and water recirculation equipment are required to circulate heated water throughout the pipe. The equipment ~~should~~shall be capable of delivering hot water throughout the section to uniformly raise the water temperature above the temperature required to effect a cure of the resin. Water temperature in the line during the cure period ~~should~~shall be as recommended by the resin manufacturer.

7.6.1.1 The heat source ~~should~~shall be fitted with suitable monitors to gauge the temperature of the incoming and outgoing water supply. Another such gauge ~~should~~shall be placed between the impregnated tube and the pipe invert at the termination to determine the temperatures during cure.

7.6.1.2 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~~shall be raised to the post-cure temperature recommended by the resin manufacturer. The post-cure temperature ~~should~~shall be held for a period as recommended by the resin manufacturer, during which time 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).

7.6.2 *Using Steam*—After inversion is completed, suitable steam-generating equipment is required ~~to distribute steam throughout the pipe. The equipment should~~ and shall be capable of ~~delivering steam~~ producing a sufficient amount of thermal energy throughout the section to uniformly raise the temperature within the pipe above the temperature required to effect a cure of the resin. The volume of air being sent through the pipe shall be sufficient to minimize condensation of the steam occurring during the curing. The temperature in the line during the cure period ~~should~~shall be as recommended by the resin manufacturer.

7.6.2.1 The steam-generating equipment ~~should~~shall be fitted with a suitable monitor to gauge the temperature of the outgoing steam. The temperature of the resin being cured ~~should~~shall be monitored by placing gauges between the impregnated tube and the existing pipe at both ends to determine the temperature during cure.

7.6.2.2 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~~shall be raised to post-cure temperatures recommended by the resin manufacturer. The post-cure temperature ~~should~~shall be held for a period as recommended by the resin manufacturer, during which time the distribution ~~and~~ of thermal energy via control of steam ~~to maintain the temperature continues.~~and air flow maintains the stated temperature. The curing of the CIPP must take into account the existing pipe material, the resin system, the current vertical alignment (that is, sags), and ground conditions (temperature, moisture level, and thermal conductivity of soil).

7.6.3 *Using Photoinitiated Reaction*—After the inversion is completed, while the tube is expanded under pressure, a light curing assembly may be drawn through the pipe. Prior to initiating the curing process, the installer shall use closed-circuit television (CCTV) camera(s) in coordination with or mounted on the light curing assembly to verify that the tube is properly positioned and fitted to the host pipe. Any anomalies shall be corrected prior to initiating the curing process.

7.6.3.1 The curing lights shall be tuned or optimized for the photoinitiated resin system; or conversely the photo initiators shall be optimized to the output of the curing lights.

7.6.3.2 *Processing*—Before the inversion begins, for dynamic curing processes the CIPP system manufacturer shall provide the rate of travel for the light assembly through the pipe for each installation length, or as required for each specific tube dimensions. The rate shall be optimized to initiate polymerization and facilitate the cure of the CIPP resin.

7.6.3.3 *Curing Control*—A full protocol shall be defined by the manufacturer and recorded and maintained as documentation verifying the curing process. Data collected may include time, rate of travel of the light curing assembly for dynamic curing processes, pressures, temperature in the tube and the power output of the light assembly.

7.6.4 *Required Pressures*—~~As required by the purchase agreement, the~~ The estimated maximum and minimum pressure required to hold the flexible tube tight against the existing conduit during the curing process ~~should~~shall be provided by the ~~seller~~ tube manufacturer and shall be increased to include consideration of the external ground water, if present. Once the cure has started and dimpling for laterals is completed, the required pressures ~~should~~shall be maintained until the cure has been completed. The pressure ~~should~~shall 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~~shall be inspected for lifts or delaminations and evaluated for its ability to fully meet the applicable requirements of 7.8 and Section 8.

7.7 *Cool-Down:*

7.7.1 *Using Cool Water After Heated Water Cure*—The new pipe 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. Care ~~should~~shall be taken in the release of the static head so that a vacuum will not be developed that could damage the newly installed pipe.

7.7.2 *Using Cool Water After Steam Cure*—The new pipe should be cooled to a temperature below 113 °F (45 °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. Care ~~should~~shall be taken in the release of the air pressure so that a vacuum will not be developed that could damage the newly installed pipe.

7.8 *Workmanship*—The finished pipe ~~should~~shall be continuous over the entire length of an inversion run and be free of dry spots, lifts, and delaminations. If these conditions are present, remove and replace the CIPP in these areas.

7.8.1 If the CIPP does not fit tightly against the original pipe at its termination point(s), the space between the pipes ~~should~~shall be sealed by ~~filling with a resin mixture compatible with the CIPP.~~an approved method using compatible materials, if required by the owner in contract documents.

7.9 *Service Connections*—After the new pipe has been cured in place, the existing active service connections ~~should~~shall be reconnected. This should generally be done without excavation, and in the case of ~~non-man~~non-worker entry pipes, from the interior of the pipeline by means of a television camera and a remote-control cutting device.

8. Inspection Practices

8.1 For each inversion length designated by the owner in the Contract documents or purchase order, the preparation of a CIPP sample is required, using one of the following two methods, depending on access and the size of the host pipe.

8.1.1 For pipe sizes of 18 in. or less, the sample ~~should~~shall be cut from a section of cured CIPP 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.

8.1.2 In medium and large-diameter applications and areas with limited access, the sample ~~should~~shall be fabricated from material taken from the tube and the resin/catalyst system used and cured in a clamped mold placed in the downtube when circulating heated water is used and in the silencer when steam is used. This method can also be used for sizes 18 in. or less, in situations where preparing samples in accordance with 8.1.1 can not be obtained due to physical constrains, if approved by the owner.

8.1.3 The samples for each of these cases ~~should~~shall be large enough to provide a minimum of three specimens and a recommended five specimens for flexural testing and also for tensile testing, if applicable. The following test procedures ~~should~~shall be followed after the sample is cured and removed.

8.1.3.1 *Short-Term Flexural (Bending) Properties*—The initial tangent flexural modulus of elasticity and flexural stress ~~should~~shall be measured for gravity and pressure pipe applications in accordance with Test Methods D790 and ~~should~~shall meet the requirements of Table 1.

8.1.3.2 *Tensile Properties*—The tensile strength ~~should~~shall be measured for pressure pipe applications in accordance with Test Method D638 and must meet the requirements of Table 1.

8.2 *Gravity Pipe Leakage Testing*—If required by the owner in the contract documents or purchase order, gravity pipes ~~should~~shall be tested using an exfiltration test method where the CIPP is plugged at both ends and filled with water. This test ~~should~~shall 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~~shall 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~~shall 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~~shall be 2 ft (0.6 m) higher than the top of the pipe or 2 ft (0.6 m) higher than the groundwater level, whichever is greater. The leakage quantity ~~should~~shall be gauged by the water level in a temporary standpipe placed in the upstream plug. The test ~~should~~shall be conducted for a minimum of one hour.

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 owner in the contract documents or purchase order, pressure pipes ~~should~~shall be subjected to a hydrostatic pressure test. A recommended pressure and leakage test would be at twice the known working pressure or at the working pressure plus 50 psi, whichever is less. Hold this pressure for a period of two to three hours to allow for stabilization of the CIPP. After this period, the pressure test will begin for a minimum of one hour. The allowable leakage during the pressure test ~~should~~shall 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 owner in the contract documents or purchase order, a delamination test ~~should~~shall be performed on each inversion length specified. The CIPP samples ~~should~~shall be prepared in accordance with 8.1.2, except that a portion of the tube material in the sample ~~should~~shall be dry and isolated from the resin in order to separate tube layers for testing. (Consult the tube manufacturer for further information.) Delamination testing shall be in accordance with Test Method D903, with the following exceptions:

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

8.4.2 Five test specimens shall be tested for each inversion specified.

8.4.3 The thickness of the test specimen shall 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~~shall be a minimum of 10 lb/in. (178.60 g/mm) of width for typical CIPP applications.

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

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

8.6 *CIPP Wall Thickness*—The method of obtaining CIPP wall thickness measurements ~~should~~shall be determined in a manner consistent with 8.1.2 of Specification D5813. Thickness measurements ~~should~~shall be made in accordance with Practice D3567 for samples prepared in accordance with 8.1. Make a minimum of eight measurements at evenly spaced intervals around the circumference of the pipe 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~~shall 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 purchase and seller.

8.6.1 *Ultrasonic Testing of Wall Thickness*—An alternative method to 8.6 for measuring the wall thickness may be performed within the installed CIPP at either end of the pipe by the ultrasonic pulse echo method as described in Practice E797/E797M. A minimum of eight (8) evenly spaced measurements ~~should~~shall be made around the internal circumference of the installed CIPP within the host pipe at a distance of 12 in. to 18 in. from the end of the pipe. For pipe diameters of fifteen (15) in. or greater, a minimum of sixteen (16) evenly spaced measurements shall be recorded. The ultrasonic method to be used is the flaw detector with A-scan display and direct thickness readout as defined in 6.1.2 of E797/E797M. A calibration block shall be manufactured from the identical materials used in the installed CIPP to calibrate sound velocity through the liner. Calibration of the transducer shall be performed daily in accordance with the equipment manufacturer's recommendations. The average thickness ~~should~~shall 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.

8.7 *Inspection and Acceptance*—The installation ~~may~~shall be inspected visually if ~~appropriate,~~practical, 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.~~ shall be observed through the CIPP itself. All service entrances ~~should~~shall be accounted for and be unobstructed.

APPENDIXES

(Nonmandatory Information)

X1. DESIGN CONSIDERATIONS

X1.1 *Terminology*:

X1.1.1 *partially deteriorated pipe*—the original pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe. The soil adjacent to the existing pipe must provide adequate side support. The pipe may have longitudinal cracks and up to 10.0 % distortion of the diameter. If the distortion of the diameter is greater than 10.0 %, alternative design methods are ~~required (see~~ required.~~Note 1).~~