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Standard Practice for Sectional Repair of Existing Gravity Flow, Non-Pressure Pipelines and Conduits by Pushed or Pulled-In-Place Installation of Cured-In-Place Thermosetting Resin Pipe (CIPP)[1]

This standard is issued under the fixed designation F3541; 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 sectional repair of gravity flow, non-pressure pipelines and conduits 3 in. to 60 in. (75 mm to 1500 mm) diameter by the installation of a resin-saturated liner which is placed onto or wrapped around a carrier device, pushed or pulled into an existing pipeline or conduit and expanded against the interior of the host pipe or conduit with air pressure. The resin is cured under ambient conditions, by photoinitiated reaction or with the application of heat. When cured, the finished sectional repair will be tight-fitting across its installed length. This repair process is used in a variety of gravity flow, non-pressure applications such as sanitary sewers, storm sewers, drains, electrical conduits and ventilation systems.

1.2 *Units*—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 *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.*

1.4 *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:*[2]

D543 Practices for Evaluating the Resistance of Plastics to Chemical Reagents

D578/D578M Specification for Glass Fiber Strands

D790 Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

D1600 Terminology for Abbreviated Terms Relating to Plastics

D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings

D5813 Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems

F412 Terminology Relating to Plastic Piping Systems

F1216 Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube

F2019 Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic Cured-in-Place (GRP-CIPP) Using the UV-Light Curing Method

2.2 *ASCE Standard:*[3]

Manual of Practice 145, Design of Close-Fit Liners for the Rehabilitation of Gravity Pipes

[1] This test method 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] 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.

[3] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

2.3 *ISO Standard:*[4]

ISO 11296-4 , Plastics piping systems for renovation of underground non-pressure drainage and sewerage networks — Part 4: Lining with cured-in-place pipes

2.4 *NSF Standard:*[5]

NSF/ANSI-14 , SE10990 – Rehabilitation by Point Repair of Existing Pipe

3. Terminology

3.1 *Definitions*—Unless otherwise indicated, definitions are in accordance with Terminology F412, and abbreviations are in accordance with Terminology D1600.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *binding material, n*—A material utilized to secure the resin-saturated liner to the carrier device prior to placement into the pipeline.

3.2.1.1 *Discussion*—Examples include, but are not limited to, wire, nylon ties, adhesive tape or elastomeric bands.

3.2.2 *carrier device, n*—An apparatus utilized to deliver the resin-saturated liner to a section of host pipe identified for repair by pushing or pulling force.

3.2.3 *catalyst, n*—A curing agent, hardener, initiator, diluent, admixture, or combination thereof.

3.2.4 *cured-in-place pipe (CIPP), n*—A hollow cylinder consisting of a liner cured (cross-linked) with a thermosetting resin. The CIPP is installed inside an existing pipe and pressed against the pipe interior to form a tight fit.

3.2.5 *delamination, n*—Separation of layers of the CIPP.

3.2.6 *design reconciliation, n*—A process conducted post-construction to determine whether the original design objectives for the installation have been met.

3.2.6.1 *Discussion*—Design reconciliation is completed to assess the net impact of post-construction variations present including fit, finish, wall thickness and mechanical properties on the installed product's ability to conform to design requirements as established by the owner or engineer.

3.2.7 *dry spot, n*—An area of the installed CIPP which is deficient or void of resin.

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

3.2.9 *photoinitiated reaction, n*—The polymerization of a resin system initiated by light or other electromagnetic radiation.

3.2.10 *protective membrane, n*—An impermeable polymer sleeve or film that is used to prevent resin contact with the carrier device, resin contamination or washout, when required, is properly sized for the host pipe diameter, and is designed to accommodate the application, installation, resin system and curing process.

3.2.11 *release agent, n*—A non-reactive, sacrificial chemical applied to a surface to prevent bonding.

3.2.12 *tight-fitting, adj*—conformance of a lining system to the host pipe interior geometry whereas intimate contact is realized across the entire perimeter.

3.2.13 *wellpoint system, n*—A series of closely spaced, small diameter, shallow wells connected to a common header pipe and pumped with a high-efficiency vacuum dewatering pump.

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 gravity flow, non-pressure pipes through the use of a resin-saturated liner installed within a section of damaged or leaking existing pipe. As for any practice, modifications may be required for specific job conditions.

5. Materials

5.1 *Liner*—The liner utilized shall consist of one or more layers of fiberglass matting, reinforced composite, flexible needled felt or an equivalent nonwoven or woven material, or a combination thereof. The liner shall be capable of carrying resin, withstanding installation pressures and curing temperatures, bridging pipe defects, conforming to irregular shapes and negotiating bends as applicable. The liner shall be a manufactured tube or an overlapping flat sheet, with or without a plastic coating, that is compatible with the resin system used, and fabricated to a size that, when installed, will be tight-fitting across the entire length identified for sectional repair. The liner shall be appropriately sized to extend at least 1 ft (0.30 m) in all directions beyond the limits of the host pipe defect when installed.

5.1.1 *Fiberglass Matting*—Chemically resistant E-CR fiberglass meeting Specification D578/D578M or similar material meeting the requirements herein; consisting of single or multiple layers of woven or nonwoven material, with or without chopped strand mat.

5.1.2 *Reinforced Composite*—Needled felt, or an equivalent woven or non-woven material, with E-CR fiberglass meeting Specification D578/D578M or similar reinforcement material meeting the requirements herein.

5.1.3 *Overlapping Flat Sheet*—Liners designed as overlapping flat sheets having a minimum circumference = $\pi \times D_i \times 1.1$, where D_i = inside diameter of the host pipe. When multiple layers of liner are required to achieve the desired thickness, the ends of the liner are tapered as required to obtain a smooth transition to the host pipe by adding additional layers in a stepwise fashion in accordance with the manufacturer's guidelines such that each subsequent layer is slightly longer than the adjacent, underlying layer.

5.1.4 *Manufactured Tubes*—Liners manufactured as tubes shall be sized per the manufacturer's recommendations relative to the host pipe inside diameter to permit radial expansion and a tight fit against the host pipe during installation and cure.

5.1.5 *Resin*—A chemically resistant, thermosetting resin and catalyst system that is cured under ambient conditions, by

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, https://www.iso.org.

[5] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48105, http://www.nsf.org.

photoinitiated reaction or with the application of heat and is compatible with the installation process shall be used. Resin systems that are heat cured shall have an initiating temperature less than 180 °F (82 °C).

5.2 *CIPP System:*

5.2.1 *Mechanical Properties*—The CIPP system shall have as a minimum the initial mechanical properties given in Table 1. These mechanical properties shall be determined in accordance with Section 7.

6. Installation

6.1 *Cleaning and Pre-Inspection:*

6.1.1 Prior to entering access areas, such as manholes and cleanouts, and performing inspection or cleaning operations, an evaluation of the atmosphere to determine the presence of toxic or flammable vapors or lack of oxygen shall be undertaken in accordance with local, state, or federal safety regulations.

6.1.2 *Cleaning of Pipeline*—To the extent practical, all internal debris shall be removed from the original pipeline using hydraulically powered equipment, high-velocity jet cleaners, or mechanically powered equipment.

6.1.3 *Inspection of Pipelines*—Inspection of pipelines shall be performed by experienced personnel trained in locating breaks, obstacles, and service connections by closed circuit television (CCTV) or worker-entry techniques. The interior of the pipeline shall be carefully inspected to determine the location of any conditions that will prevent proper installation of the resin-saturated liner. The manufacturer shall provide guidance as needed to determine whether existing conditions will prohibit a successful installation or if additional measures are necessary in advance of lining. This includes addressing points of infiltration that will cause resin wash out or adversely impact the cure and finished quality of the CIPP sectional repair. Corrective actions include, but are not limited to, injecting chemical grout, dewatering using a wellpoint system, or utilizing a protective membrane as defined in 3.2.10 and described in 6.4.4.

6.1.4 *Line Obstructions*—The original pipeline shall be clear of obstructions that will hinder or prevent the installation of the resin-saturated liner. If inspection reveals an obstruction that cannot be removed by conventional sewer cleaning equipment, a point repair excavation shall be made to uncover and remove or repair the obstruction.

6.2 *Resin Saturation*—The liner shall be fully saturated with resin (wet out) under controlled conditions and free of any dry spots or resin lean areas. The resin system shall be proportionally mixed, handled and applied in accordance with manufacturer's recommendations. The volume of resin used shall be sufficient to fully saturate the liner material and shall be adjusted by adding excess resin to account for the change in resin volume due to polymerization, to allow for migration of resin into the cracks and joints in the original pipe, and to account for any resin loss expected during the liner insertion process. For each CIPP installation, wet out data shall be recorded and retained by the user for quality assurance and record keeping purposes, and submitted to the purchaser as required.

TABLE 1 CIPP Initial Mechanical Properties[A]

Property	Test Method	Minimum Value	
		psi	(MPa)
Flexural Strength[B]	D790	Declared value, but not less than 4 500	Declared value, but not less than 31
Flexural Modulus[B]	D790	Declared value, but not less than 250 000	Declared value, but not less than 1 724

[A] The values in Table 1 are for test results on field specimens. The purchaser shall consult the manufacturer for the long-term mechanical properties.
[B] The value indicates minimum strength in the circumferential direction.

6.3 *Bypassing*—If bypassing of the flow is required around the sections of pipe designated for reconstruction, the bypass shall be made by capturing flow from all contributing points upstream of the pipe to be reconstructed and discharging the flow to a downstream point or adjacent system. The bypass pumping and piping system shall be of adequate capacity and size to handle the flow. Prior to cleaning and pre-inspection and during installation, all upstream contributing flows impacting the repair area shall be isolated and bypassed around the repair area. Bypassing shall be coordinated between all parties involved.

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

6.4 *Liner Insertion:*

6.4.1 The carrier device shall be able to navigate the host pipe alignment and geometry to the point of installation without compromise to the host pipe, installation process or finished quality of the CIPP; shall be designed to expand with air pressure to press the resin-saturated liner tightly against the interior of the host pipe for the duration of cure; shall be compatible with the curing process; and, when required, shall have flow-thru capabilities for flow control.

6.4.2 When required, a protective membrane shall be secured to the carrier device and a compatible release agent shall be liberally applied to its entire surface area as required.

6.4.3 The resin-saturated liner shall be centered and rolled tightly against the carrier device and secured with binding material. The binding material shall be placed approximately 1 in. (25 mm) from each end of the liner and spaced along the remaining length of the repair, typically 1.5 ft to 2.0 ft (0.46 m to 0.61 m) apart; shall be used to secure the leading edge of the liner to the front of the carrier device as required to ensure the liner's position is maintained as it is pushed or pulled into the host pipe; and shall be designed to release or break under tension when the carrier device is pressurized and the resin-saturated liner is expanded against the host pipe.

6.4.4 When required, to prevent resin contamination or washout and as directed by the manufacturer, a protective membrane shall be attached to the resin-saturated liner across the affected area.

6.4.5 The resin-saturated liner shall be positioned into the host pipe using push rods or a winching process. Prior to insertion and as directed by the manufacturer, the carrier device shall be inflated to a low pressure to increase rigidity and reduce material drag along the pipe invert. The carrier device

shall be equipped with adequate air supply for proper inflation and full expansion of the liner against the host pipe interior for the duration of cure.

6.4.6 CCTV inspection shall be conducted concurrently with the placement of the resin-saturated liner to verify proper positioning and the host pipe condition and resin saturation in accordance with 6.2 prior to inflation and cure.

6.5 *Curing*—The resin-saturated liner shall be cured in accordance with manufacturer's recommendations, and the curing process shall be documented and submitted to the purchaser as required. The estimated minimum and maximum pressures recommended to form a tight-fitting liner against the existing pipe during the curing process shall be provided by the manufacturer.

6.5.1 *Using Air or Air/Steam*—Curing of the resin-saturated liner shall be accomplished without pressure interruption with air or a mixture of air and steam for the duration of time in accordance with the manufacturer's recommendations for a complete cure. For CIPP cured under ambient conditions, to the extent practical, a representative coupon of the resin impregnated liner suspended at the access point shall be used to confirm curing time as required.

6.5.2 *Using Photoinitiated Reaction*—While the liner is expanded under pressure against the host pipe, a CCTV inspection shall be performed to verify that the liner is properly positioned and tight-fitting. Any anomalies shall be corrected prior to initiating the curing process.

6.5.2.1 The curing lights shall be tuned or optimized for the photoinitiated resin system; or conversely the photoinitiators shall be optimized to the output of the curing lights.

6.5.2.2 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 liner dimensions to initiate polymerization and facilitate the cure of the CIPP resin.

6.5.2.3 A full curing protocol shall be provided by the manufacturer and be recorded and maintained as documentation verifying the curing process. As a minimum, data collected shall include time, rate of travel of the light curing assembly for dynamic curing processes, pressures, and the power output of the light assembly.

6.6 *Overlapping Installations*—For CIPP installations that span distances beyond the capabilities of the carrier device, longer lengths shall be accomplished by installing multiple repairs end-to-end with a minimum overlap to adjacent CIPP sections in accordance with manufacturer's recommendations. To the extent practical, installations shall progress from the furthest point downstream towards the upstream end so that overlapping ends of the CIPP are streamlined with the flow.

6.7 *Workmanship:*

6.7.1 The finished CIPP shall be continuous over its entire length and be free of dry spots, lifts, uncured areas, unusual discolorations, and delaminations. If these conditions are present, CIPP in these areas shall be removed and replaced. The CIPP shall be tight-fitting against the host pipe at its termination points with transitions at each end that do not create a ledge, a change in direction of flow, or a location where debris will accumulate during uniform flow conditions. In sections of pipe of constant internal diameter and straight alignment, the CIPP shall not introduce surface irregularities in addition to those of the host pipe which exceed 2 % of the nominal diameter or 0.25 in. (6 mm), whichever is greater. Applications where surface irregularities exceeding 2 % of the nominal diameter or 0.25 in. (6 mm), whichever is greater, are anticipated due to geometric features, condition or alignment of the host pipe shall be evaluated by the owner, engineer and manufacturer to determine feasibility and compliance of this practice. Examples include CIPP that is installed through bends, joint offsets, diameter transitions and other discontinuities in the host pipe which can result in localized radial or longitudinal fins or folds, or other surface irregularities in the CIPP.

6.7.2 *Service Connections*—After the new CIPP has been installed, any existing, active service connections shall be reinstated. This shall be performed without excavation and, in cases of non-worker-entry sized pipes, from the interior of the pipeline by the means of CCTV inspection and a remote-control cutting device. Reinstated service connections shall be cut smooth and free of burrs and rough edges. All laterals where a plug by the end of the lateral was not visible by the pre-inspection shall be reinstated if the purchase agreement does not specify it differently.

7. Inspection Practices

7.1 *Sampling*—CIPP samples for mechanical properties testing shall be prepared when required and as directed by the engineer or purchaser. Representative samples of the resin-saturated liner shall be restrained in a like diameter pipe or prepared in a clamped mold and cured in the same manner as the installed CIPP. Samples shall be prepared in a manhole or other point of access, or under simulated conditions above ground, and shall be of adequate size to perform flexural properties testing as described in 7.2.

7.2 *Short-Term Flexural (Bending) Properties*—For isotropic materials, the tangent flexural modulus of elasticity and flexural strength shall be measured in accordance with Test Method D790. For anisotropic composites, flexural testing shall be conducted in the hoop direction on specimens cut from plate samples in accordance with Test Method D790 or on curved beam specimens cut from restrained samples in accordance with the modified Test Method D790 method as described in Annex B of ISO 11296-4 and Practice F2019, Appendix X2. Flexural properties shall meet or exceed values listed in Table 1.

7.3 *CIPP Wall Thickness*—The method of obtaining CIPP wall thickness measurements shall be determined in a manner consistent with Specification D5813. Thickness measurements shall be made in accordance with Practice D3567 for samples prepared in accordance with 7.1. 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 shall be calculated using all measured values and