INTERNATIONAL

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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 F1743; 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 96 in. (5 cm 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, by the introduction of controlled steam into the tube, or by photoinitiated reaction. 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 standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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, 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]

C1920 Practice for Cleaning of Vitrified Clay Sanitary Sewer Pipelines
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
D1682 Test Method for Breaking Load and Elongation of Textile Fabric (Withdrawn 1992)[3]
D3039/D3039M Test Method for Tensile Properties of Polymer Matrix Composite Materials
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
D4814 Specification for Automotive Spark-Ignition Engine Fuel
D5813 Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems
E797 Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method
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

2.2 *AWWA Standard:*[4]

M28 Manual on Cleaning and Lining Water Mains[4]

[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] 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] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235, http://www.awwa.org.

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

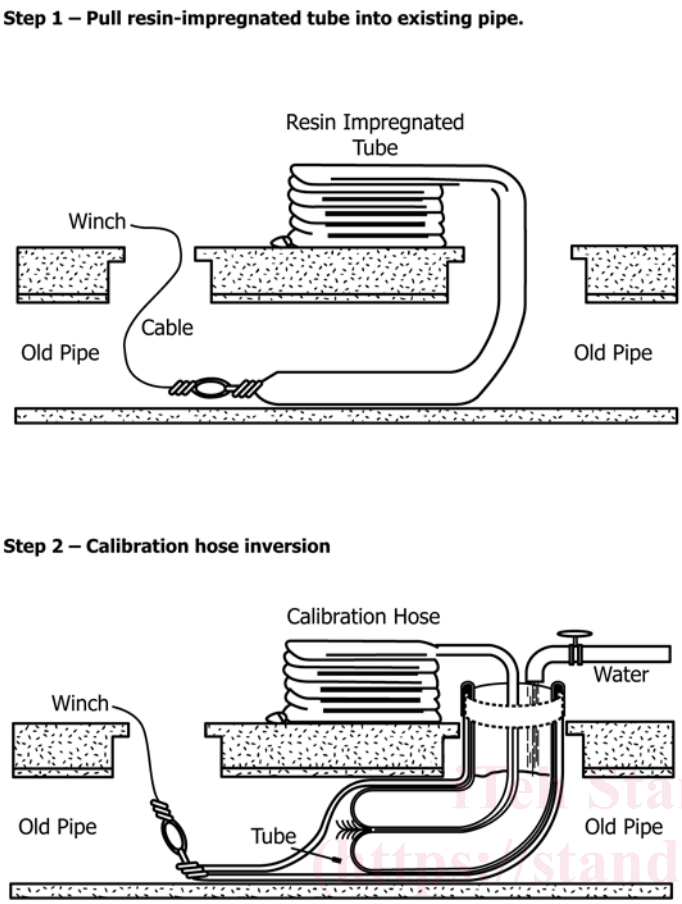

FIG. 1 Cured-in-Place Pipe Installation Methods

2.3 *NASSCO Standard:*[5]
Recommended Specifications for Sewer Collection System Rehabilitation

3. Terminology

3.1 *General*—Definitions are in accordance with Terminology F412. Abbreviations are in accordance with Terminology D1600, 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.

3.2.8 *photoinitiated reaction*—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 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

[5] Available from the National Association of Sewer Service Companies, NASSCO 11521 Cronridge Drive, Suite J Owings Mills, MD 21117, http://www.nassco.org.

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 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 shall be removed from the original pipeline. Non-pressure gravity pipes shall be cleaned with hydraulically powered equipment, high-velocity jet cleaners, or mechanically powered equipment in accordance with manufacturers guidelines, Practice C1920, for VCP pipe or NASSCO Recommended Specifications for Sewer Collection System Rehabilitation, as applicable. Pressure pipelines should be cleaned with cable attached devices or fluid propelled devices in accordance with AWWA M28.

TABLE 1 CIPP Initial Structural Properties[A]

Property	Test Method	Minimum Value psi	Minimum Value (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.

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, multilinear 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 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 *Using photoinitiated reaction*—After installation is completed, while the fabric 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 the closed-circuit television (CCTV) camera(s) in coordination with or mounted on the light curing assembly to verify that the fabric tube is properly positioned and fitted to the host pipe. Any anomalies shall be corrected prior to initiating the curing process.

6.6.3.1 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.

6.6.3.2 *Processing*—Before the installation 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 fabric tube dimensions. The rate shall be optimized to initiate polymerization and facilitate the cure of the CIPP resin.

6.6.3.3 *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.

6.6.4 *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. 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 2—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 D1682 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 D5813. The specimens shall be capable of exposure to the solutions in Table 2 at a temperature of 73.4 °F ± 3.6 °F (23 °C ± 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.