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An American National Standard

Standard Test Method for Evaluating the Oxidative Resistance of Crosslinked Polyethylene (PEX) Tubing and Systems to Hot Chlorinated Water[1]

This standard is issued under the fixed designation F 2023; 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 test method describes the general requirements for evaluating the long-term, chlorinated water, oxidative resistance of cross-linked polyethylene (PEX) tubing produced in accordance with Specification F 876 or PEX tubing/fitting systems in accordance with Specification F 877 used in hot-and-cold water distribution systems by exposure to hot, chlorinated water. This test method outlines the requirements of a pressurized flow-through test system, typical test pressures, test-fluid characteristics, failure type, and data analysis.

NOTE 1—Other known disinfecting systems (chlorine dioxide, ozone, and chloramine) are currently used for protection of potable water; however, free-chlorine is by far the most common system in use today. Disinfecting systems other than chlorine have not been evaluated by this method.

1.2 Guidelines and requirements for test temperatures, test hoop stresses, and other test criteria have been established by prior testing of PEX tubing produced by the three most common commercial methods of cross-linking: silane, peroxide, and electron-beam (see Note 2). Other related system components that typically appear in a PEX hot-and-cold water distribution system can be evaluated with the PEX tubing. When testing PEX tubing and fittings as a system, it is recommended that the anticipated end-use fitting type(s) and material(s) be included in the test circuit since it is known that some fitting types and materials can impact failure times. Specimens used shall be representative of the piping product(s) and material(s) under investigation.

NOTE 2—The procedures described in this test method (with some modifications of test temperatures or stresses, or both) have been used to evaluate pipes manufactured from polybutylene (PB), polyethylene (PE), polypropylene (PP), multilayer (polymer-metal composite), copper, and stainless steel.

1.3 This test method is applicable to PEX tubing and systems used for transport of potable water containing free-chlorine for disinfecting purposes. The oxidizing potential of the test-fluid specified in this test method exceeds that typically found in potable water systems across the United States.

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

1.5 The following precautionary caveat pertains only to the test method portion, Section 12, of this specification. *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:* [2]

D 1600 Terminology for Abbreviated Terms Relating to Plastics

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings

F 412 Terminology Relating to Plastic Piping Systems

F 876 Specification for Crosslinked Polyethylene (PEX) Tubing

F 877 Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems

F 948 Test Method for Time-to-Failure of Plastic Piping Systems and Components Under Constant Internal Pressure With Flow

2.2 *ISO Standards:*

ISO 9080 Thermoplastic Pipe for Transport of Fluids—Methods of Extrapolation of Hydrostatic Stress Rupture Data to Determine the Long Term Strength of Thermoplastic Pipe[3]

ISO 13760 Plastic Pipe for the Conveyance of Fluids Under Pressure—Miners Rule—Calculation Method for Cumulative Damage[3]

[1] This test method is under the jurisdiction of ASTM Committee F17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

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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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

2.3 *Plastics Pipe Institute (PPI) Document:*

TN-16 Rate Process Method for Projecting Performance of Polyethylene Piping Components[4]

2.4 *American Water Works Association (AWWA) Document:*

1996 WATER:\STATS Survey[5]

3. Terminology

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

3.1.1 *brittle failure (Stage II)*, *n*—failure in the tubing wall that is characterized by little or no material deformation in the failure area and is the result of a single crack emanating from the interior of the tubing to the outside surface typically resulting in a pinhole leak, see Fig. 1. Brittle failures produced with this test method shall not be used for data analysis.

3.1.2 *ductile failure (Stage I)*, *n*—failure in the tubing wall that is characterized by obvious localized deformation of the material visible with the unaided eye, see Fig. 1. Ductile failures produced with this test method shall not be used for data analysis.

3.1.3 *environmental or oxidative failure (Stage III)*, *n*—failure in the tubing wall characterized by a large number of cracks emanating from the interior surface of the tubing wall, see Fig. 1.

3.1.3.1 *Discussion*—Stage III failures may also be identified by a color shift in the failure area (typically brown or reddish-brown). Identification of oxidative failure, when not obvious by inspection with the unaided eye, can be performed with a 25× microscope or other similar device yielding the same level of magnification. Only Stage III environmental failures shall be used for data analysis.

3.1.4 *hot-and-cold water distribution system*, *n*—a combination of components such as tubing, fittings, valves, and so forth, that when installed as a complete system, make up the interior water supply system of a commercial or residential structure.

3.1.5 *long-term oxidative resistance*, *n*—the extrapolated time-to-failure prediction as determined by analysis of time-to-failure test data by multiple linear regression utilizing the rate process method of PPI TN-16 or Model Q of ISO 9080. Where applicable, application of Miners Rule in accordance with ISO 13760 can be used to estimate time-to-failure at several differing conditions of temperature or stress, or both.

3.1.6 *multiple linear regression*, *n*—a three or four coefficient mathematical model used to analyze time-to-failure data from different temperatures and stresses to extrapolate projected time-to-failure at selected temperatures or stresses.

3.1.7 *Miners Rule*, *n*—a mathematical method for estimating the cumulative, irreversible damage that results from exposure to each of several differing conditions of stress or temperature, or both.

3.1.8 *oxidation reduction potential (ORP)*, *n*—a measure of the total oxidizing power of a solution by means of a platinum-redox electrode. For a further explanation of ORP see Appendix X2.

3.1.9 *unaided eye*, *n*—observable without visual enhancement beyond correction for normal vision.

4. Summary of Test Method

4.1 The PEX tubing or tubing/fitting assemblies are exposed to pressurized test-fluid until failure. All time-to-fail data used for analysis shall be the result of oxidative degradation (Stage III). A minimum number of test temperature and hoop stress conditions are required to allow accurate data analysis and time-to-failure extrapolations.

5. Significance and Use

5.1 Environment or oxidative time-to-fail data derived from this test method, analyzed in accordance with Section 13, are suitable for extrapolation to typical end-use temperatures and hoop stresses. The extrapolated value(s) provides a relative indication of the resistance of the tested PEX tubing or system to the oxidative effects of hot, chlorinated water for conditions equivalent to those conditions under which the test data were obtained. The performance of a material or piping product under actual conditions of installation and use is dependent upon a number of factors including installation methods, use patterns, water quality, nature and magnitude of localized stresses, and other variables of an actual, operating hot-and-cold water distribution system that are not addressed in this test method. As such, the extrapolated values do not constitute a representation that a PEX tube or system with a given extrapolated time-to-failure value will perform for that period of time under actual use conditions.

6. Apparatus

6.1 *Pressurized Flow-Through Test System*—A system comprised of the necessary pump(s), fittings, piping, heaters, sensors, and meters that is capable of maintaining the required test pressures within the tolerance specified in 9.1.4, the required test temperatures within the tolerance of 9.1.3, and

[4] Available from the Plastics Pipe Institute (PPI), 1825 Connecticut Ave., NW, Suite 680, Washington, DC 20009.

[5] Available from American Water Works Association (AWWA), 1401 New York Ave., NW, Suite 640, Washington, DC 20005.

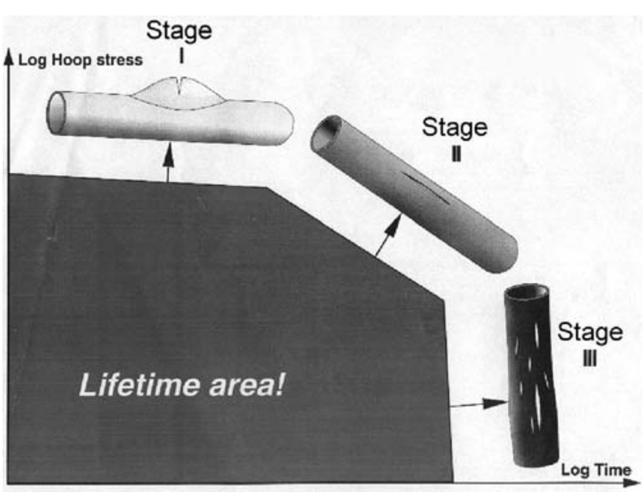

FIG. 1 Pictorial Illustration of Failure Types

flow the test-fluid through the specimens continually at a flow rate within the tolerance specified in 9.1.5. Cyclic pressure variations, such as those produced by some pumping systems, shall not produce pressure excursions that exceed the tolerance stated in 9.1.4.

6.1.1 *Recirculating Test System*—A flow-through test system that repeatedly reconditions the test-fluid and passes it through the specimens. For purposes of this test method, the test-fluid shall be monitored at a sufficient frequency to ensure that it continuously meets the test-fluid parameters and water quality criteria. A portion of the total system volume shall be purged and replaced with fresh test-fluid continually.

6.1.2 *Single-Pass Test System*—A flow-through test system that passes the test-fluid through the specimens only once and is discarded.

6.2 *Specimen Holders*—Test specimens shall be supported to minimize or eliminate externally induced stresses. Specimens shall be allowed to freely expand bi-directionally

7. Sampling, Test Specimens, and Test Units

7.1 *Sampling*—Select at random, a sufficient amount of tubing to satisfy the specimen requirements of this test method. When testing as a system, randomly select a sufficient quantity of fittings.

7.2 *Test Specimen Size*—The PEX tubing specimens shall be 12 to 18 in. (300 to 460 mm) in length between fitting closures or between fitting joints.

7.2.1 *Dimensions Measurement*—Measure and record the critical dimensions for tubing and fittings. For tubing, measure the average outside diameter and wall-thickness in accordance with Test Method D 2122. For fittings, measure those dimensions critical to the function of the joint, as well as minimum body wall thickness.

7.3 *Testing as a System*—When testing PEX tubing and related system components (such as fittings) as a system, the other components shall be attached to the PEX tubing in the same manner as in actual service. For fittings, the particular fitting style shall be installed in accordance with the manufacturer's instructions or the ASTM specification when applicable.

7.4 *Minimum Required Test Units*—A minimum of six test units is required. A test unit is comprised of two or more individual time-to-failure data points at the same temperature and hoop stress condition. Statistical reliability of the analysis of the resultant data will be benefited by obtaining additional data points at each temperature/hoop stress condition.

7.4.1 *Test Unit Distribution*—Time-to-failure data points shall be obtained at 2 test hoop stresses at each of a minimum of 3 test temperatures for a minimum of 12 data points. As an alternate, obtain time-to-failure data for the temperature/hoop stress combinations of the three-temperature matrix of PPI TN-16, see Note 3. Hoop stresses shall be separated by a least 80 psi (0.55 MPa).

NOTE 3—When using the PPI TN-16 matrix, Temperature T_3, which requires testing at only one stress, refers to the lowest test temperature.

7.4.2 *Test Temperature Selection*—Temperatures of 239°F (115°C), 221°F (105°C), and 203°F (95°C) have been utilized in prior testing of PEX, see Note 4. Adjacent test temperatures shall be separated by at least 18°F (10°C). Other test temperatures may be used, but the maximum test temperature shall not exceed 239°F (115°C).

NOTE 4—Prior testing indicates that for the test temperatures stated in 7.4.2, hoop stresses to yield Stage III failures within reasonable testing times are between 160 psi (1.10 MPa) and 400 psi (2.76 MPa). For a true SDR9 tube, those hoop stresses correspond to test pressures of 40 psig (275.9 kPa) to 100 psig (689.7 kPa). If a selected test hoop stress produces Stage I or Stage II failures, the stress will need to be reduced to produce Stage III failures at all temperatures.

7.4.2.1 *Relationship of Internal Pressure to Hoop Stress*—The hoop stress in the tubing wall is calculated by the following expression, commonly known as the ISO equation:

$$2S/P = DR - 1 \quad (1)$$

or

$$2S/P = (D_o/t) - 1 \quad (2)$$

where:

S	=	stress in the circumferential or hoop direction, psi (MPa),
P	=	internal pressure, psig (kPa),
t	=	minimum wall thickness, in. (mm),
DR	=	dimension ratio, DR, and
D_o	=	average outside diameter, in. (mm).

8. Calibration and Standardization

8.1 *Measuring Equipment*—All measuring and testing equipment having an effect on the accuracy or validity of the calibrations or tests shall be calibrated or verified, or both, before being put into service.

9. Test Fluid

9.1 *Internal Test Fluid*—The test fluid shall be reverse osmosis (RO) or deionized (DI) water prepared in accordance with 9.1.1, or potable water (tap water) prepared in accordance with 9.1.2.

9.1.1 *RO or DI Water Test-Fluid Preparation*—Test fluid prepared from RO or DI water shall have a pH in the range from 6.5 to 8.0 and contain 2.5 ppm to 5 ppm (milligrams per litre) of free-chlorine. The chosen pH shall be maintained to ±0.2 and the chosen free-chlorine concentration shall be maintained to ±0.2 ppm. The pH and free-chlorine concentration combination shall yield a minimum ORP of 825 mV for the test fluid, see Note 5.

9.1.2 *Tap Water Test Fluid Preparation*—Tap water shall have a pH in the range from 6.5 to 8.0 and contain the necessary free-chlorine to maintain an ORP of 825 ± 30 mV, see Note 5.

NOTE 5—At the time this test method was originally approved, several test laboratories had existing experimental data developed under varying test conditions, not necessarily in strict accordance with this test method.

It is suggested that future testing be conducted at conditions that are as aggressive, or more aggressive than plumbing piping might encounter in actual service; specifically, with a test fluid having a pH of 7 or lower and a free-chlorine concentration of 3 PPM or higher. Test data developed with a less aggressive test fluid having a pH higher than 7 or free-chlorine content less than 3 PPM, or both, or prepared from locally available tap-water, may provide higher extrapolated values. However, such higher values may not necessarily be representative of better performance. It is important to be aware of and consider the specific test conditions when comparing data from different materials or laboratories.