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An American National Standard

Standard Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[1]

This standard is issued under the fixed designation D 1598; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This test method covers the determination of the time-to-failure of both thermoplastic and reinforced thermosetting/resin pipe under constant internal pressure.

1.2 This test method provides a method of characterizing plastics in the form of pipe under the conditions prescribed.

1.3 The values stated in inch-pound units are to be regarded as 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[2]

D 2837 Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[2]

D 2992 Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass'' (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[2]

D 3517 Specification for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pressure Pipe[2]

D 3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[2]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *failure*—any continuous loss of pressure with or without the transmission of the test fluid through the body of the specimen under test shall constitute failure. Failure may be by one or a combination of the following modes:

3.1.2 *ballooning*—any localized expansion of a pipe specimen while under internal pressure. This is sometimes referred to as ductile failure.

NOTE 1—Overall distention which results from creep caused by long-term stress is not considered to be a ballooning failure.

3.1.3 *free (unrestrained) end closure*—a pipe specimen end closure (cap) that seals the end of the pipe against loss of internal fluid and pressure, and is fastened to the pipe specimen.

3.1.4 *restrained end closure*—a pipe specimen end closure (cap) that seals the end of the specimen against loss of internal fluid and pressure, but is not fastened to the pipe specimen. Restrained end closures rely on tie-rod(s) through the pipe specimen or on external structure to resist internal pressure end thrust.

3.1.5 *rupture*—a break in the pipe wall with immediate loss of test fluid and continued loss at essentially no pressure. If rupture is not preceded by some yielding, this may be termed a non-ductile failure.

3.1.6 *seepage or weeping*—water or fluid passing through microscopic breaks in the pipe wall. A reduction in pressure will frequently enable the pipe to carry fluid without evidence of loss of the liquid.

4. Summary of Test Method

4.1 This test method consists of exposing specimens of pipe to a constant internal pressure while in a controlled environment.

[1] This test method is under the jurisdiction of ASTM Committee F~~-~~17 on Plastic Piping Systems and is the direct responsibility of Subcommittee F17.40 on Test Methods.

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

Such a controlled environment may be accomplished by, but is not limited to, immersing the specimens in a controlled temperature water or air bath. The time-to-failure is measured.

NOTE 2—Dimensional changes should be measured on specimens undergoing long-term strength tests. Measurements using circumferential tapes, strain gages, or mechanical extensometers provide useful information.

5. Significance and Use

5.1 The data obtained by this test method are useful for establishing stress versus failure time relationships in a controlled environment from which the hydrostatic design basis for plastic pipe materials can be computed. (Refer to Test Method D 2837 and Practice D 2992.)

5.2 In order to determine how plastics will perform as pipe, it is necessary to establish the stress-failure time relationships for pipe over 2 or more logarithmic decades of time (hours) in a controlled environment. Because of the nature of the test and specimens employed, no single line can adequately represent the data, and therefore the confidence limits should be established.

NOTE 3—Some materials may exhibit a nonlinear relationship between log-stress and log-failure time, usually at short failure times. In such cases, the 10^5-hour stress value computed on the basis of short-term test data may be significantly different than the value obtained when a distribution of data points in accordance with Test Method D 2837 is evaluated. However, these data may still be useful for quality control or other applications, provided correlation with long-term data has been established.

5.3 The factors that affect creep and long-term strength behavior of plastic pipe are not completely known at this time. This procedure takes into account those factors that are known to have important influences and provides a tool for investigating others.

5.4 Creep, or nonrecoverable deformation for pipe made of some plastics, is as important as actual leakage in deciding whether or not a pipe has failed. Specimens that exhibit localized ballooning, however, may lead to erroneous interpretation of the creep results unless a method of determining creep is established that precludes such a possibility. Circumferential measurements at two or three selected positions on a specimen may not be adequate.

5.5 Great care must be used to ensure that specimens are representative of the pipe under evaluation. Departure from this assumption may introduce discrepancies as great as, if not greater than, those due to departure from details of procedure outlined in this test method.

6. Apparatus

6.1 *Constant-Temperature System*—A water bath or other fluid bath equipped so that uniform temperature is maintained throughout the bath. This may require agitation. If an air or other gaseous environment is used, provision shall be made for adequate circulation. The test may be conducted at 23°C (73°F) or other selected temperatures as required and the temperature tolerance requirements shall be ±2°C (±3.6°F).

6.2 *Pressurizing System*—Any device that is capable of continuously applying constant internal pressure on the specimen may be used. The device shall be capable of reaching the test pressure without exceeding it and of holding the pressure within the tolerance shown in 6.6 for the duration of the test.

6.3 *Pressure Gage*—A pressure gage having an accuracy sufficient to meet the pressure tolerance requirements of 6.6 is required.

6.4 *Timing Device*—A time meter connected to the pressurized fluid side of the system through a pressure or flow switch, or both. The timing device and pressure or flow switch, or both, together shall be capable of measuring the time when the specimen is at 98 % or more of test pressure with sufficient accuracy to meet the tolerance requirements of 6.6.

6.5 *Specimen End Closures*—Either free-end or restrained-end closures that will withstand the maximum test pressures may be used. Closures shall be designed so that they do not cause failure of the specimen. Free-end closures shall be used for referee tests for thermoplastic pipe.

NOTE 4—Free-end closures fasten to the specimen so that internal pressure produces longitudinal tensile stress in addition to hoop. Compared to free end closure specimens, stresses in the wall of restrained-end closure specimens act in the hoop and radial directions only. Because of this difference in loading, the equivalent hoop stress in free-end closure specimens of solid wall thermoplastic pipe are approximately 11 % lower than in restrained-end closure specimens tested at the same pressure. The test results for each specimen and the LTHS will reflect this difference in test method.

6.6 *Time and Pressure Tolerance*—When added together, the tolerance for the timing device and the tolerance for the pressure gage shall not exceed ±2 %.

7. Test Specimens

7.1 *Pipe Specimen Length*—For pipe sizes of 6 in. (150 mm) or less, the specimen length between end closures shall be not less than five times the nominal outside diameter of the pipe, but in no case less than 12 in. (300 mm). The 12 in. (300 mm) minimum specimen length requirement shall not apply to molded specimens. For larger sizes of pipe, the minimum length between end closures shall be not less than three times the nominal outside diameter but in no case less than 30 in. (760 mm).

7.2 *Measurements*—Dimensions shall be determined in accordance with Test Method D 2122 or Practice D 3567.

8. Conditioning

8.1 Specimens to be tested at 23°C shall be conditioned at test temperatures in a liquid bath for a minimum of 1 h or in a gaseous medium for a minimum of 16 h before pressurizing.

8.2 When specimens are to be tested at higher temperatures, condition them in the elevated temperature environment until they have reached test temperature.

NOTE 5—Conditioning time is a function of pipe size wall thickness, temperature differential, the film heat transfer coefficient and whether the elevated temperature environment is applied to one or both sides of the specimen. One-hour conditioning of 1-in. and smaller pipe at 82°C (180°F) in a water environment has been found to be sufficient.

8.3 Unless otherwise agreed upon, the test temperature shall be 23 ± 2°C (73 ± 3.6°F) for thermoplastics. For thermosets test at 23 ± 2°C (73 ± 3.6°F) or at maximum rated temperature depending on intended service. While every effort should be made to meet the temperature tolerances listed, temporarily exceeding the (+) temperature tolerance does not necessarily require that all samples under test be abandoned. Data points from such samples may still be acceptable. Refer also to Test Method D 2837 or Practice D 2992 to determine the suitability of these data points.

9. Procedure

9.1 Attach end closures to the pipe test sections and fill each specimen completely with the test fluid conditioned to the test temperature. Attach the specimens to the pressuring device, making certain no gas is entrapped when using liquids. Completely immerse the test specimens in the conditioning medium.

9.2 Support specimens in such a way as to prevent bending or deflection by the weight of the pipe while under test. This support shall not constrain the specimen circumferentially or longitudinally.

9.3 After conditioning the specimens as specified in Section 8, adjust the pressure to produce the desired loading. Apply the pressure to the specimens and make sure the timing devices have started.

9.4 Record the time-to-failure of each specimen. The time-to-failure shall not include periods of time during which the specimen was under depleted pressure or under no pressure.

9.4.1 Any failure occurring within one pipe diameter of the end closure shall be examined carefully. If there is any reason to believe that the failure is attributable to the end closure, the value shall be discarded in computing averages or in plotting the data.

9.4.2 The failure value of a specimen that fails due to column buckling shall be discarded in computing averages or in plotting the data.

NOTE 6—For certain materials creep measurements should be made in accordance with Test Method D 2837. It describes the procedure for determining when "circumferential expansion" must be used as a criterion for establishing the hydrostatic design stress.

9.5 *Pressure Connections*—Each specimen may be pressured individually or through a manifold system. If a manifold system is utilized, each pressure connection should include a check valve to prevent pressure depletion of the system when one specimen fails. Where the system is designed to prevent one specimen failure from depressurizing the manifold, each specimen shall have its own timing device.

9.6 *Test Fluids*—While water is normally used inside the test specimens, any fluid may be used. However, if a gas is used special care must be taken because of the potential energy stored in any compressed gas.

NOTE 7—*Test Apparatus*—All the above components with some additional features can be acquired as assembled stress rupture testers. Some units utilize a liquid bath environment that can be adjusted from −20 to +150°C. Other units offer a single pressure source with as many as 40 manifolds that can each be set for a different pressure and 240 specimen positions. A list of manufacturers of stress rupture test equipment can be obtained from the ASTM Information Center.

10. Calculation

10.1 Hoop stress in the pipe specimens is calculated using equations (approximation) for the hoop stress, as follows:

$$S = P(D - t)/2t \tag{1}$$

or

$$S = \frac{P(DR - 1)}{2} \tag{2}$$

where:

S = hoop stress, psi (MPa),
P = internal pressure, psig (MPa),
D = measured average outside diameter, in. (mm). For reinforced thermosetting pipe, outside diameter shall not include nonreinforced covers,
t = measured minimum wall thickness, in. (mm). For reinforced thermosetting pipe use minimum reinforced wall thickness, and
DR = dimension ratio, $DR = D/t$.

NOTE 8—An alternative method for calculating the hoop stress of reinforced pipe is given in the Annex of Specification D 3517.

10.2 Internal pressure in the pipe specimens is calculated using equations (approximate) for the internal pressure as follows:

$$P = \frac{2\,St}{(D - t)} \tag{3}$$

or:

$$P = \frac{2S}{(DR - 1)} \tag{4}$$

where terms are as defined in 10.1.

11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of the specimens, including material type, manufacturer's name and code number, and previous history.

11.1.2 Pipe dimensions including nominal size, minimum wall thickness, average outside diameter, length of test specimen between end closures, and type of end closure. For reinforced thermosetting pipe, wall thicknesses and outside diameter shall be reinforced dimensions only. Unreinforced thicknesses shall also be reported.

11.1.3 Test temperature.

11.1.4 Test environment, including conditioning time.

11.1.5 Test fluid inside specimens.

11.1.6 Test pressure, calculated hoop stress, and time-to-failure for each specimen.

11.1.7 When pressure depletion is experienced, the time at which the pressure was depleted and time at which pressure was restored shall be reported. The failure time in this case shall be considered as the total time the specimen was under full test pressure as defined in 6.2.

11.1.8 Plot of hoop stress versus time-to-failure or computer print-out showing the stress regression line intercepts and the lower confidence limit.

11.1.9 Failure mode and any unusual effects of prolonged exposure and type of failure.

11.1.10 Date test was started and reporting date.

11.1.11 Name of test laboratory and supervisor of this test.

11.1.12 When testing assemblies identify pipe, fitting, and joint. Describe in detail the location and mode of failure.

12. Precision and Bias [3]

12.1 *Precision*—Based on a mini laboratory round-robin conducted on 2-in. medium density polyethylene pipe, the precision (one standard deviation) of this test method for medium density polyethylene pipe is as follows:

12.1.1 *Slit Failure Mode*:

12.1.1.1 Within-laboratory, ±37 % (repeatability).

12.1.1.2 Between-laboratory, ±39 % (reproducibility).

12.1.2 *Ductile Failure Mode*:

12.1.2.1 Within-laboratory, ±50 % (repeatability).

12.1.2.2 Between-laboratory, ±100 % (reproducibility).

12.2 *Bias*—Data obtained using this standard test method are believed to be reliable since accepted techniques of analysis are used. However, since no referee method is available, no bias statement can be made.

13. Keywords

13.1 internal pressure; plastic pipe; time-to-failure

[3] Interlaboratory test data and calculations are available from ASTM Headquarters. Request RR: F 17-1037.