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Standard Practice for Obtaining Hydrostatic or Pressure Design Basis for "Fiberglass" (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings[1]

This standard is issued under the fixed designation D2992; 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 establishes two procedures, Procedure A (cyclic) and Procedure B (static), for obtaining a hydrostatic design basis (HDB) or a pressure design basis (PDB) for fiberglass piping products, by evaluating strength-regression data derived from testing pipe or fittings, or both, of the same materials and construction, either separately or in assemblies. Both glass-fiber-reinforced thermosetting-resin pipe (RTRP) and glass-fiber-reinforced polymer mortar pipe (RPMP) are fiberglass pipe.

NOTE 1—For the purposes of this standard, polymer does not include natural polymers.

1.2 This practice can be used for the HDB determination for fiberglass pipe where the ratio of outside diameter to wall thickness is 10:1 or more.

~~NOTE 2—This limitation, based on thin-wall pipe design theory, serves further to limit the application of this practice to internal pressures which, by the hoop-stress equation, are approximately 20 % of the derived hydrostatic design stress (HDS). For example, if HDS is 5000 psi (34 500 kPa), the pipe is limited to about 1000-psig (6900-kPa) internal pressure, regardless of diameter.~~

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NOTE 3—Where long (continuous) glass fibers are intentionally placed to resist the planned pressure load case (that is, free end pressure testing and 654.7° fiberglass windings) the results from this practice may be overly conservative in predicting long term fiberglass pipe performance when the same pipe is operated at lower (non-damaging) stresses typical in normal pipeline applications.

NOTE 4—All data points in the analysis shall be of the same failure mode. Where plastic creep of the resin leading to pipe failure is precluded by unintended resin matrix cracking or other unanticipated modes of failure, this practice may not accurately represent the pipe's life expectancy.

1.3 This practice provides a PDB for complex-shaped products or systems where complex stress fields seriously inhibit the use of hoop stress.

1.4 Specimen end closures in the underlying test methods may be either restrained or free, leading to certain limitations.

1.4.1 *Restrained Ends*—Specimens are stressed by internal pressure only in the hoop direction, and the HDB is applicable for stresses developed only in the hoop direction.

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.23 on Reinforced ~~Plastic~~ Thermosetting Resin Piping Systems and Chemical Equipment.

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

1.4.2 *Free Ends*—Specimens are stressed by internal pressure in both hoop and longitudinal directions, such that the hoop stress is twice as large as the longitudinal stress. This practice may not be applicable for evaluating stresses induced by loadings where the longitudinal stress exceeds 50 % of the HDS.

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

NOTE 5—There is no known ISO equivalent to this standard.

1.6 *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.*

1.7 *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]

D618 Practice for Conditioning Plastics for Testing
D883 Terminology Relating to Plastics
D1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure
D1599 Test Method for Resistance to Short-Time Hydraulic Pressure of Plastic Pipe, Tubing, and Fittings
D1600 Terminology for Abbreviated Terms Relating to Plastics
D2143 Test Method for Cyclic Pressure Strength of Reinforced, Thermosetting Plastic Pipe
D3567 Practice for Determining Dimensions of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe and Fittings
F412 Terminology Relating to Plastic Piping Systems
F948 Test Method for Time-to-Failure of Plastic Piping Systems and Components Under Constant Internal Pressure With Flow (Withdrawn 2018)[3]

2.2 *ISO Standard:*

3 Preferred Numbers—Series of Preferred Numbers[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *General*—Definitions are in accordance with Terminologies D883 and F412, and abbreviations are in accordance with Terminology D1600, unless otherwise indicated.

3.1.2 *closure, free-end*—a sealing device or mechanism fastened to the end of the test specimen so that internal pressure produces longitudinal tensile stresses in addition to hoop and radial stresses in the test specimen.

3.1.3 *closure, restrained-end*—a sealing device or mechanism which relies on a rod through the test specimen or an external structure to resist the end thrust produced by internal pressure, thereby limiting the stresses in (straight) specimens to the hoop and radial directions only.

3.1.4 *failure*—the transmission of the test fluid through the body of the specimen in any manner, whether it be a wall fracture, localized leaking, or weeping at a distance greater than one diameter from the end closure.

NOTE 6—For this practice, specimens which have not failed may be included as failures under the specific conditions given in 6.3, 9.3, and 12.2.

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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 National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

3.1.5 *fiberglass pipe*—a tubular product containing glass fiber reinforcement embedded in or surrounded by cured thermosetting-resin; the composite structure may contain aggregate, granular or platelet fillers, thixotropic agents, pigments, or dyes; thermoplastic or thermosetting liners or coatings may be included.

3.1.6 *reinforced polymer mortar pipe (RPMP)*—a fiberglass pipe with aggregate.

3.1.7 *reinforced thermosetting resin pipe (RTRP)*—a fiberglass pipe without aggregate.

3.1.8 *hoop stress*—the tensile stress in the wall of the piping product in the circumferential direction due to internal pressure; hoop stress will be calculated by the ISO equation, as follows:

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

where:

S = hoop stress, psi (kPa),
D = average reinforced outside diameter, in. (mm),
P = internal pressure, psig (kPa), and
t_r = minimum reinforced wall thickness, in. (mm).

NOTE 7—Hoop stress should only be determined on straight hollow cylindrical specimens. Product evaluation of more complex shapes may be based on pressure.

3.1.9 *hydrostatic design basis (HDB)*—a hoop stress developed for fiberglass pipe by this practice and multiplied by a service design factor to obtain an HDS.

3.1.10 *hydrostatic design pressure (HDP)*—the estimated maximum internal hydrostatic pressure that can be applied cyclically (Procedure A) or continuously (Procedure B) to a piping component with a high degree of certainty that failure of the component will not occur.

3.1.11 *hydrostatic design stress (HDS)*—the estimated maximum tensile stress in the wall of the pipe in the hoop direction due to internal hydrostatic pressure that can be applied cyclically (Procedure A) or continuously (Procedure B) with a high degree of certainty that failure of the pipe will not occur.

3.1.12 *long-term hydrostatic strength (LTHS)*—the estimated tensile stress in the wall of the pipe in the hoop direction due to internal hydrostatic pressure that, when applied cyclically, will cause failure of the pipe after a specified number of cycles by Procedure A or a specified number of hours by Procedure B.

NOTE 8—The time for determination of LTHS or LTHP is specified by the product standard. Typically, the time is 150×10^6 or 657×10^6 cycles for Procedure A and 100 000 or 438 000 h for Procedure B.

3.1.13 *long-term hydrostatic pressure (LTHP)*—the estimated internal pressure of the piping product that, when applied cyclically, will cause failure of the product after a specified number of cycles by Procedure A or a specified number of hours by Procedure B.

3.1.14 *pressure design basis (PDB)*—an internal pressure developed for fiberglass piping product by this practice and multiplied by a service design factor to obtain an HDP.

3.1.15 *pressure rating (PR)*—the estimated maximum pressure in the pipe or fitting that can be exerted continuously with a high degree of certainty that failure of the piping component will not occur.

3.1.16 *service design factor*—a number equal to 1.00 or less that takes into consideration all the variables and degree of safety involved in a fiberglass piping installation so that when it is multiplied by the HDB, an HDS and corresponding pressure rating is obtained, or when it is multiplied by the PDB, a pressure rating is obtained directly, such that in either case a satisfactory and safe piping installation results when good quality components are used and the installation is made properly.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *average outside diameter*—a measurement obtained in accordance with Practice D3567 less any veil-reinforced and nonreinforced exterior coating thicknesses.

3.2.2 *minimum reinforced wall thickness*—a measurement obtained in accordance with Practice D3567, excluding veil-reinforced and nonreinforced coating and lining thicknesses; wall thickness of fittings is determined at the thinnest section of the fitting body.

4. Summary of Practice

4.1 Procedure A consists of exposing a minimum of 18 specimens of pipe or fittings, or both to cyclic internal pressures at a cycle rate of 25 cycles/min and at several different pressures. Elevated test temperatures are obtained by circulating a hot liquid through the specimens or by testing in an air environment where the temperature is controlled.

4.1.1 The cyclic LTHS or cyclic LTHP of a pipe or fitting is obtained by an extrapolation of a log-log plot of the linear regression line for hoop stress or internal pressure versus cycles to failure.

4.1.2 The experimental basis for Procedure A shall be in accordance with Test Method D2143, which forms a part of this practice. When any part of the procedure is not in agreement with Test Method D2143, the provisions of this practice shall be used.

4.1.3 Joints between pipe and fitting specimens shall be typical of those normally used for the kind of piping being tested.

4.2 Procedure B consists of exposing a minimum of 18 specimens of pipe or fittings, or both, to constant internal hydrostatic pressures at differing pressure levels in a controlled environment and measuring the time to failure for each pressure level. Test temperatures are obtained by immersing the specimens in a controlled-temperature water bath, by testing in an air environment where the temperature is controlled, or by circulating a temperature-controlled fluid through the specimen.

NOTE 9—Testing in a water bath precludes the detection of weeping failure, (see 3.1.4) by either visual or electronic means.

4.2.1 The static LTHS or static LTHP of a pipe or fitting is obtained by an extrapolation of a log-log linear regression line for hoop stress or internal pressure versus time to failure.

4.2.2 The experimental basis for Procedure B shall be in accordance with either Test Method D1598 or Test Method F948, or both, which form a part of this practice. When any part of this practice is not in agreement with the selected method, the provisions of this practice shall be used.

4.2.3 Joints between pipe and fitting specimens shall be typical of those normally used for the kind of piping being tested.

4.3 The HDB category is obtained by categorizing the LTHS in accordance with Section 7 or Section 10.

4.4 The PDB category is obtained by categorizing the LTHP in accordance with Section 8 or Section 11.

4.5 Hydrostatic design stresses for pipe are obtained by multiplying the HDB values by a service design factor.

4.6 *Reconfirmation of HDB or PDB for Altered Constructions*—When a product already has an HDB or PDB determined in accordance with this practice and a change of process or material is made, a reconfirmation of the original HDB or PDB shall be attempted in accordance with Section 12. At least six specimens must be tested and meet the specified criteria.

5. Significance and Use

5.1 This practice is useful for establishing the hoop stress or internal pressure versus time-to-failure relationships, under selected internal and external environments which simulate actual anticipated product end-use conditions, from which a design basis for specific piping products and materials can be obtained. This practice defines an HDB for material in straight, hollow cylindrical shapes where hoop stress can be easily calculated, and a PDB for fittings and joints where stresses are more complex.

5.1.1 An alternative design practice based on initial strain versus time-to-failure relationships employs a strain basis HDB instead of the stress basis HDB defined by this practice. The strain basis HDB is most often used for buried pipe designs with internal pressures ranging from 0 to 250 psig (1.72 MPa).

5.2 To characterize fiberglass piping products, it is necessary to establish the stress versus cycles or time to failure, or pressure versus cycles or time to failure relationships over three or more logarithmic decades of time (cycles or hours) within controlled environmental parameters. Because of the nature of the test and specimens employed, no single line can adequately represent the data. Therefore, the confidence limits shall be established.

5.3 Pressure ratings for piping of various dimensions at each temperature may be calculated using the HDS determined by testing one size of piping provided that the same specific process and material are used both for test specimens and the piping in question.

5.4 Pressure ratings at each temperature for components other than straight hollow shapes may be calculated using the HDP determined by testing one size of piping provided that (*1*) the specific materials and manufacturing process used for the test specimens are used for the components, (*2*) for joints, the joining materials and procedures used to prepare the test specimens are used for field joining, and (*3*) scaling of critical dimensions is related to diameter and pressure rating of the component.

NOTE 10—Scaling of fittings and joints should be further verified by short-time testing in accordance with Test Method D1599.

5.5 Results obtained at one set of environmental conditions shall not be used for other conditions, except that higher temperature data can be used for design basis assignment for lower application temperatures. The design basis shall be determined for each specific piping product. Design and processing can significantly affect the long-term performance of piping products, and therefore shall be taken into consideration during any evaluation.

5.6 This practice is valid for a given pipe or fitting only so long as the specimens are truly representative of that material and manufacturing process.

5.6.1 Changes in materials or manufacturing processes will necessitate a reevaluation as described in Section 12.

PROCEDURE A

6. Long-Term Cyclic Hydrostatic Strength or Long-Term Cyclic Hydrostatic Pressure

6.1 Select either free-end or restrained-end closures based on the tensile stresses induced by internal pressure and the type of joint in the intended piping system (see 1.4).

6.2 Obtain a minimum of 18 failure stress-cycle points for each selected temperature in accordance with Test Method D2143 except as follows:

6.2.1 Determine the average outside diameter and the minimum reinforced wall thickness in accordance with Practice D3567.

NOTE 11—Because of the need to cut the specimen, this determination may be made on the failed test specimen. A corrected hoop stress is then calculated for use in the analysis.

6.2.2 Elevated test temperatures are obtained by circulating a heated test liquid through the specimens or by testing in a hot air environment. In either case the test liquid shall be maintained within ±5°F (3°C) of the selected temperature.

NOTE 12—Where elevated test temperatures are maintained by applying heat to the circulating test liquid, work to date indicates that the ambient air temperature need not be controlled.

6.2.3 The stress or pressure values for test shall be selected to obtain a distribution of failure points as follows:

Cycles to Failure	Failure Points
1000 to 10 000	at least 3
10 000 to 100 000	at least 3
100 000 to 1 000 000	at least 3
1 000 000 to 10 000 000	at least 3
After 15 000 000	at least 1
Total	at least 18

6.3 Analyze the test results by using, for each specimen, the logarithm of the stress or pressure in Section 6 and the logarithm of the cycles to failure, as described in Annex A1.

NOTE 13—It is the custom of those testing fiberglass pipe to plot stress or pressure on the vertical (y) axis and time or cycles on the horizontal (x) axis.

6.3.1 A specimen which leaks within one diameter of an end closure may be: (*1*) included as a failure point if it lies above the 95 % lower confidence limit curve; (*2*) repaired and testing resumed provided the new leak is more than one diameter from a test joint, or (*3*) discarded and no data point recorded.

6.3.2 Those specimens that have not failed after more than 15 000 000 cycles may be included as failures in establishing the regression line. Use of such data points may result in a lower or higher cyclic LTHS or cyclic LTHP. In either case, the lower confidence value requirements of Section 6 must be satisfied.

NOTE 14—Non-failed specimens may be left under test and the regression line recalculated as failures are obtained.

6.3.3 Determine the final line for extrapolation by the method of least squares using the failure points along with those nonfailure points selected by the method described in 6.3.1 and 6.3.2. Do not use failure points for stresses or pressures that cause failure in less than 500 cycles on the average; determine these points by averaging the number of cycles-to-failure of tests made at the same stress or pressure level, that is, a stress within ±200 psi (1380 kPa) or a pressure within ±20 psig (138 kPa). Include in the report all failure points excluded from the calculation by this operation and identify them as being in this category.

NOTE 15—Since this procedure is for pipe or fittings, or both, it is recommended that the pipe specimen and fitting be tested at the same time as one specimen, using the normal joining procedures to join them together, with the fitting being at one end of the specimen. If the fitting fails first, it can be cut off, and the test can be continued using the unfailed pipe with a mechanical end closure replacing the fitting. Should the pipe fail first, it can be recorded and repaired and the test continued until the fitting fails. If this recommendation is followed, it may enable the tester to obtain failure points for both the pipe and the fitting while testing only one specimen.

7. Cyclic Hydrostatic Design Basis

7.1 Calculate the cyclic LTHS at the specified time (150×10^6 or 657×10^6 cycles) as described in Annex A1.

7.2 If $Sxy > 0$ (see A1.4) consider the data unsuitable.

7.3 Calculate r in accordance with A1.4.3. If r is less than the applicable minimum value given in Table A1.1, consider the data unsuitable.

7.4 If required, determine the cyclic HDB category in accordance with Table 1.

8. Cyclic Pressure Design Basis

8.1 Use the procedures in 7.1, 7.2, and 7.3, using pressure in place of stress.

8.2 If required, determine the cyclic PDB category in accordance with Table 2.

TABLE 1 Hydrostatic Design Basis Categories by Procedure A or Procedure B

Hydrostatic Design Basis Category		Range of Calculated Values	
psi[A]	(kPa)	psi	(kPa)
2500	(17 200)	2400 to 3010	(16 500 to 20 700)
3150	(21 700)	3020 to 3820	(20 800 to 26 300)
4000	(27 600)	3830 to 4790	(26 400 to 33 000)
5000	(34 500)	4800 to 5990	(33 100 to 40 900)
6300	(43 400)	6000 to 7590	(41 000 to 52 900)
8000	(55 200)	7600 to 9590	(53 000 to 65 900)
10 000	(68 900)	9600 to 11 990	(66 000 to 82 900)
12 500	(86 200)	12 000 to 15 290	(83 000 to 105 900)
16 000	(110 000)	15 300 to 18 990	(106 000 to 130 900)
20 000	(138 000)	19 000 to 23 990	(131 000 to 169 900)
25 000	(172 000)	24 000 to 29 990	(170 000 to 209 900)
31 500	(217 000)	30 000 to 37 990	(210 000 to 259 900)
40 000	(276 000)	38 000 to 47 000	(260 000 to 320 000)

[A] Standard stress levels chosen in accordance with ISO 3, Series R10.

TABLE 2 Pressure Design Basis Categories by Procedure A or Procedure B

Pressure Design Basis Category			Range of Calculated Values	
psi	(bar)[A]	(kPa)	psi	(kPa)
91	(6.3)	(630)	87 to 110	(605 to 760)
116	(8)	(800)	111 to 143	(765 to 990)
150	(10)	(1000)	144 to 172	(995 to 1180)
180	(12.5)	(1250)	173 to 220	(1190 to 1510)
230	(16)	(1600)	221 to 287	(1520 to 1980)
300	(20)	(2000)	288 to 345	(1990 to 2380)
360	(25)	(2500)	346 to 438	(2390 to 3020)
460	(31.5)	(3150)	439 to 556	(3030 to 3830)
580	(40)	(4000)	557 to 695	(3840 to 4790)
725	(50)	(5000)	696 to 876	(4800 to 6040)
910	(63)	(6300)	877 to 1110	(6050 to 7680)
1160	(80)	(8000)	1115 to 1380	(7690 to 9580)
1450	(100)	(10 000)	1390 to 1720	(9590 to 11 800)
1800	(125)	(12 500)	1730 to 2220	(11 900 to 15 300)

[A] Standard pressures chosen in accordance with ISO 3, Series R10.

PROCEDURE B

9. Long-Term Static Hydrostatic Strength

9.1 Select either free-end or restrained-end closures based on the tensile stresses induced by internal pressure and the type of joint in the intended piping system (see 1.4).

9.2 Obtain a minimum of 18 failure points for each selected temperature in accordance with Test Method D1598 or Test Method F948 except as follows:

9.2.1 Determine the average outside diameter and the minimum reinforced wall thickness in accordance with Practice D3567 (Note ~~9~~11).

9.2.2 The inside environment for the pipe or fitting, test specimens, or both, shall be water. The outside environment shall be air or a controlled temperature water bath (See ~~7~~9). Other media may be used, but the environment shall be given in the test report. The test liquid shall be maintained within ±5°F (3°C) of the test temperature (Note ~~10~~12).

9.2.3 The stress or pressure values for test shall be selected to obtain a distribution of failure points as follows: