Designation: D 2837 – 01a

An American National Standard

Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials[1]

This standard is issued under the fixed designation D 2837; 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 describes a procedure for obtaining a long-term hydrostatic strength category, referred to herein as the hydrostatic design basis (HDB), for thermoplastic pipe materials based on the material's long-term hydrostatic strength (LTHS). The LTHS is determined by analyzing stress versus time-to-rupture (that is, stress-rupture) test data that cover a testing period of not less than 10 000 h and that are derived from sustained pressure testing of pipe made from the subject material. The data are analyzed by linear regression to yield a best-fit log-stress versus log time-to-fail straight-line equation. Using this equation, the material's mean strength at the 100 000-h intercept (LTHS) is determined by extrapolation. The resultant value of the LTHS determines the HDB strength category to which the material is assigned. An HDB is one of a series of preferred long-term strength values. This test method is applicable to all known types of thermoplastic pipe materials, and for any practical temperature and medium that yields stress-rupture data that exhibit an essentially straight-line relationship when plotted on log stress (pound-force per square inch) versus log time-to-fail (hours) coordinates, and for which this straight-line relationship is expected to continue uninterrupted through at least 100 000 h.

1.2 Unless the experimentally obtained data approximate a straight line, when calculated using log-log coordinates, it is not possible to assign an HDB to the material. Data that exhibit high scatter or a "knee" (a downward shift, resulting in a subsequently steeper stress-rupture slope than indicated by the earlier data) but which meet the requirements of this test method tend to give a lower forecast of LTHS. In the case of data which exhibit excessive scatter or a pronounced "knee," the lower confidence limit requirements of this test method are not met and the data are classified as unsuitable for analysis.

1.3 A fundamental premise of this test method is that when the experimental data define a straight-line relationship in accordance with this test method's requirements, this straight line may be assumed to continue beyond the experimental period, through at least 100 000 h (the time intercept at which the material's LTHS is determined). In the case of polyethylene piping materials, this test method includes a supplemental requirement for the "validating" of this assumption. No such validation requirements are included for other materials (see Note 1). Therefore, in all these other cases, it is up to the user of this test method to determine based on outside information whether this test method is satisfactory for the forecasting of a material's LTHS for each particular combination of internal/external environments and temperature.

NOTE 1—Extensive long-term data that have been obtained on commercial pressure pipe grades of polyvinyl chloride (PVC), polybutlene (PB), and cross linked polyethlene (PEX) materials have shown that this assumption is appropriate for the establishing of HDB's for these materials for water and for ambient temperatures. Refer to Note 2 and Appendix X1 for additional information.

1.4 The experimental procedure to obtain individual data points shall be as described in Test Method D 1598, which forms a part of this test method. When any part of this test method is not in agreement with Test Method D 1598, the provisions of this test method shall prevail.

1.5 General references are included at the end of this test method.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only and are not considered the standard.

NOTE 2—Over 3000 sets of data, obtained with thermoplastic pipe and piping assemblies tested with water, natural gas, and compressed air, have been analyzed by the Plastic Pipe Institute's[2] (PPI) Hydrostatic Stress Board. None of the currently commercially offered compounds included in PPI TR-4, "PPI Listing of Hydrostatic Design Bases (HDB), Pressure Design Bases (PDB) and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe" exhibit knee-type plots at the listed temperature, that is, deviate from a straight line in such a manner

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

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[2] Plastic Pipe Institute, 1825 Connecticut Avenue N.W., Washington, DC 20009.

that a marked drop occurs in stress at some time when plotted on equiscalar log-log coordinates. Ambient temperature stress-rupture data that have been obtained on a number of the listed materials and that extend for test periods over 120 000 h give no indication of "knees." However, stress-rupture data which have been obtained on some thermoplastic compounds that are not suitable or recommended for piping compounds have been found to exhibit a downward trend at 23°C (73°F) in which the departure from linearity appears prior to this test method's minimum testing period of 10 000 h. In these cases, very low results are obtained or the data are found unsuitable for extrapolation when they are analyzed by this test method.

Extensive evaluation of stress-rupture data by PPI and others has also indicated that in the case of some materials and under certain test conditions, generally at higher test temperatures, a departure from linearity, or "down-turn", may occur beyond this test method's minimum required data collection period of 10 000 h. A PPI study has shown that in the case of polyethylene piping materials that are projected to exhibit a "down-turn" prior to 100 000 h at 73°F, the long-term field performance of these materials is prone to more problems than in the case of materials which have a projected "down-turn" that lies beyond the 100 000-h intercept. In response to these observations, a supplemental "validation" requirement for PE materials has been added to this test method in 1988. This requirement is designed to reject the use of this test method for the estimating of the long-term strength of any PE material for which supplemental elevated temperature testing fails to validate this test method's inherent assumption of continuing straight-line stress-rupture behavior through at least 100 000 h at 23°C (73°F).

When applying this test method to other materials, appropriate consideration should be given to the possibility that for the particular grade of material under evaluation and for the specific conditions of testing, particularly, when higher test temperatures and aggressive environments are involved, there may occur a substantial "down-turn" at some point beyond the data collection period. The ignoring of this possibility may lead to an overstatement by this test method of a material's actual LTHS. To obtain sufficient assurance that this test method's inherent assumption of continuing linearity through at least 100 000 h is appropriate, the user should consult and consider information outside this test method, including very long-term testing or extensive field experience with similar materials. In cases for which there is insufficient assurance of the continuance of the straight-line behavior that is defined by the experimental data, the use of other test methods for the forecasting of long-term strength should be considered (see Appendix X1).

2. Referenced Documents

2.1 *ASTM Standards:*

D 1243 Test Method for Dilute Solution Viscosity of Vinyl Chloride Polymers[3]

D 1598 Test Method for Time-to-Failure of Plastic Pipe Under Constant Internal Pressure[4]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[5]

2.2 *ISO/DIS Standard:*

ISO/DIS 9080 Plastic Piping and Ducting Systems, Determination of Long-Term Hydrostatic Strength of Thermoplastics Materials in Pipe Form by Extrapolation[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *failure*—bursting, cracking, splitting, or weeping (seepage of liquid) of the pipe during test.

3.1.2 *hoop stress*—the tensile stress in the wall of the pipe in the circumferential orientation due to internal hydrostatic pressure.

3.1.3 *hydrostatic design basis (HDB)*—one of a series of established stress values for a compound. It is obtained by categorizing the LTHS in accordance with Table 1.

3.1.4 *hydrostatic design stress (HDS)*—the estimated maximum tensile stress the material is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur. This stress is circumferential when internal hydrostatic water pressure is applied.

3.1.5 *long-term hydrostatic strength (LTHS)*—the estimated tensile stress in the wall of the pipe in the circumferential orientation that when applied continuously will cause failure of the pipe at 100 000 h. This is the intercept of the stress regression line with the 100 000-h coordinate.

3.1.6 *pressure*—the force per unit area exerted by the medium in the pipe.

3.1.7 *pressure rating (PR)*—the estimated maximum water pressure the pipe is capable of withstanding continuously with a high degree of certainty that failure of the pipe will not occur.

3.1.7.1 The PR and HDS are related by the equations given in 3.1.9.

3.1.8 *service (design) factor*—a number less than 1.00 (which takes into consideration all the variables and degree of safety involved in a thermoplastic pressure piping installation) which is multiplied by the HDB to give the HDS.

3.1.9 The following equations shall be used for the relation between stress and pressure:

$$S = P(D - t)/2t \text{ for outside diameter controlled pipe} \quad (1)$$

or

$$S = P(d + t)/2t \text{ for inside diameter controlled pipe} \quad (2)$$

TABLE 1 Hydrostatic Design Basis Categories

NOTE 1—The LTHS is determined to the nearest 10 psi. Rounding procedures in Practice E 29 should be followed.

Range of Calculated LTHS Values		Hydrostatic Design Basis	
psi	(MPa)	psi	(MPa)
190 to < 240	(1.31 to < 1.65)	200	(1.38)
240 to < 300	(1.65 to < 2.07)	250	(1.72)
300 to < 380	(2.07 to < 2.62)	315	(2.17)
380 to < 480	(2.62 to < 3.31)	400	(2.76)
480 to < 600	(3.31 to < 4.14)	500	(3.45)
600 to < 760	(4.14 to < 5.24)	630	(4.34)
760 to < 960	(5.24 to < 6.62)	800	(5.52)
960 to <1200	(6.62 to < 8.27)	1000	(6.89)
1200 to <1530	(8.27 to <10.55)	1250	(8.62)
1530 to <1920	(10.55 to <13.24)	1600	(11.03)
1920 to <2400	(13.24 to <16.55)	2000	(13.79)
2400 to <3020	(16.55 to <20.82)	2500	(17.24)
3020 to <3830	(20.82 to <26.41)	3150	(21.72)
3830 to <4800	(26.41 to <33.09)	4000	(27.58)
4800 to <6040	(33.09 to <41.62)	5000	(34.47)
6040 to <6810	(41.62 to <46.92)	6300	(43.41)
6810 to <7920	(46.92 to <54.62)	7100	(48.92)

[3] *Annual Book of ASTM Standards*, Vol 08.01.
[4] *Annual Book of ASTM Standards*, Vol 08.04.
[5] *Annual Book of ASTM Standards*, Vol 14.02.
[6] Available from American National Standards Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

where:
S = stress,
P = pressure,
D = average outside diameter,
d = average inside diameter, and
t = minimum wall thickness.

4. Significance and Use

4.1 The procedure for estimating long-term hydrostatic strength is essentially an extrapolation with respect to time of a stress-time regression line based on data obtained in accordance with Test Method D 1598. Stress-failure time plots are obtained for the selected temperature and environment: the extrapolation is made in such a manner that the long-term hydrostatic strength is estimated for these conditions.

NOTE 3—Test temperatures should preferably be selected from the following: 40°C; 50°C; 60°C; 80°C; 100°C. It is strongly recommended that data also be generated at 23°C for comparative purposes.

4.2 The hydrostatic design basis is determined by considering the following items and evaluating them in accordance with 5.4.

4.2.1 Long-term hydrostatic strength at 100 000 h,

4.2.2 Long-term hydrostatic strength at 50 years, and

4.2.3 Stress that will give 5 % expansion at 100 000 h.

4.2.4 The intent is to make allowance for the basic stress-strain characteristics of the material, as they relate to time.

4.3 Results obtained at one temperature cannot, with any certainty, be used to estimate values for other temperatures. Therefore, it is essential that hydrostatic design bases be determined for each specific kind and type of plastic compound and each temperature. Estimates of long-term strengths of materials can be made for a specific temperature provided that calculated values, based on experimental data, are available for temperatures both above and below the temperature of interest.

4.4 Hydrostatic design stresses are obtained by multiplying the hydrostatic design basis values by a service (design) factor.

4.5 Pressure ratings for pipe may be calculated from the hydrostatic design stress (HDS) value for the specific material used to make the pipe, and its dimensions using the equations in 3.1.9.

5. Procedure

5.1 *General*—Generated data in accordance with Test Method D 1598.

5.2 *Stress Rupture*—Obtain the data required for 4.2.1 and 4.2.2 as follows:

5.2.1 Obtain a minimum of 18 failure stress-time points for each environment. Distribute these data points as follows:

Hours	Failure Points
<1000	At least 6
10 to 1000	At least 3
1000 to 6000	At least 3
After 6000	At least 3
After 10 000	At least 1

NOTE 4—When the long-term stress regression line of a compound is known, this method may be used, using fewer points and shorter times, to confirm material characteristics, or to evaluate minor process or formulation changes. See also PPI TR3, Policies and Procedures for Developing Recommended Hydrostatic Design Stresses for Thermoplastic Pipe Materials.

5.2.2 Analyze the test results by using, for each specimen, the logarithm of the stress in psi and the logarithm of the time-to-failure in hours as described in Appendix X2 (Note 5). Calculate the strength at 100 000 h. Include as failures at the conclusion of the test those specimens which have not failed after being under test for more than 10 000 h if they increase the value of the extrapolated strength. Accomplish this by first obtaining the linear log-log regression equation for only the specimens that failed, by the method of least squares as described in Appendix X2. Then use the stress in psi for each specimen that has been under test for more than 10 000 h, and that has not failed, with this regression equation to calculate the time in hours. If this time is less than the hours the specimen has been under test, then use the point. Determine the final line for extrapolation by the method of least squares using the failure points along with those non-failure points selected by the method described above. Unless it can be demonstrated that they are part of the same regression line, do not use failure points for stresses that have failure times less than 10 h. Include failure points excluded from the calculation by this operation in the report, and identify them as being in this category.

NOTE 5—It should be noted that contrary to the custom in mathematics, it has been the practice of those testing plastics pipe to plot the independent variable (stress) on the vertical (y) axis and the dependent variable (time-to-failure) on the horizontal (x) axis. The procedure in Appendix X2 treats stress as an independent variable.

5.2.3 Determine the suitability of the data for use in determining the long-term hydrostatic strength and hydrostatic design basis of plastic pipe as follows:

5.2.3.1 Extrapolate the data by the method given in Appendix X2, to 100 000 h and 50 years, and record the extrapolated stress values (4.2.1 and 4.2.2), and

5.2.3.2 Calculate, by the method given in Appendix X3, the lower confidence value of stress at 100 000 h.

5.2.3.3 If the lower confidence value at 100 000 h differs from the extrapolated LTHS value by more than 15 % of the latter, or M in Appendix X3 is zero or negative, or b in the equation $h = a + bf$ in Appendix X2 is positive, consider the data unsuitable.

5.3 *Circumferential Expansion*—Obtain the data required for 4.2.3 as follows:

5.3.1 Initially test at least three specimens at a stress of 50 % of the long-term hydrostatic strength determined in 5.2.3.1 until the circumferential expansion exceeds 5 % or for 2000 h, whichever occurs first. Measure the expansion of the circumference in the center of that section of the pipe specimen that is under test to the nearest 0.02 mm (0.001 in.) periodically (Note 6) during the test, unless the expansion at some other point is greater, in which case measure the section with the maximum expansion. Calculate the changes in circumference for each specimen as a percentage of the initial outside circumference. Calculate the expansion at 100 000 h for each specimen by the method given in Appendix X4 or by the plotting technique described in 5.3.3. If the calculated expansion for one or more of the specimens tested exceeds 5 %, then use the hydrostatic stress as determined from circumferential expansion measurements as the stress value to be categorized to establish the hydrostatic design basis.

NOTE 6—It is suggested that these measurements be made once every 24 h during the first 5 days, once every 3 days during the next 6 days, and once a week thereafter. The periods shall be selected on the basis of past experience with the type of pipe so that they will be reasonably distributed to obtain a good plot.

5.3.2 The stresses and distribution of specimens used to determine hydrostatic stress from circumferential expansion measurements shall be as follows:

Approximate Percent of Long-Term Hydrostatic Strength (see 5.2)	Minimum Number of Specimens
20	3
30	3
40	3
50	3
60	3

Subject the specimens to test until the circumferential expansion exceeds 5 % or for 2000 h, whichever occurs first.

5.3.3 The results may be calculated by the methods given in Appendix X4 and Appendix X5 or plotted by the following procedures. Plot the percent changes in circumference against time in hours on log-log graph paper. Draw a straight line by the method of least squares, with time as the independent variable as described in Appendix X4. Calculate the expansion of the circumference in percent at 100 000 h for each specimen by the equation from Appendix X4:

$$c = a' + 5.00\, b' \tag{3}$$

Do not use extrapolations of curves for specimens that expand more than 5 % in less than 1000 h. Plot the corresponding expansion-stress points from the 100 000 h intercept on log-log graph paper and draw a line representative of these points by the method of least squares with stress as the independent variable as described in Appendix X5.

5.3.4 Calculate the stress corresponding to a circumferential expansion of 5.00 % in accordance with 5.3.3 and Appendix X5. The stress is the antilog of r in the equation $c = a'' + b'' r$ in Appendix X5. Use the values for a'' and b'' as calculated in Appendix X5 and 0.6990 for c. This stress may be obtained by calculation or read from the circumferential expansion-stress plot obtained in 5.3.3. In cases of disagreement, use the calculation procedure.

5.4 *Hydrostatic Design Basis*—The procedure for determining the HDB shall be as follows (see also Appendix X8):

5.4.1 Calculate the hydrostatic strength at 100 000 h (LTHS) in accordance with 5.2.

5.4.2 Calculate the hydrostatic strength at 50 years in accordance with 5.2.3.1.

5.4.3 Estimate the long-term hydrostatic strength using expansion test data and in accordance with 5.3.

NOTE 7—For all the presently used stress rated thermoplastic pipe materials in North America, the 5 % expansion strengths are not the limiting factor. Therefore, this measurement is not required for such materials.

5.4.4 Determine the hydrostatic design basis (HDB) by categorizing, in accordance with Table 1, the applicable hydrostatic strength value as specified below:

5.4.4.1 Use the LTHS value (5.4.1) if it is less than 125 % of the 50-year value (5.4.2), and less than the expansion strength value (5.4.3).

5.4.4.2 Use the 50-year value if it is less than 80 % of the LTHS value, and less than the expansion strength value.

5.4.4.3 Use the expansion strength value if it is less than the LTHS and 50-year values.

5.5 *Hydrostatic Design Stress*—Obtain the hydrostatic design stress by multiplying the hydrostatic design basis by a service (design) factor selected for the application on the basis of two general groups of conditions. The first group considers the manufacturing and testing variables, specifically normal variations in the material, manufacture, dimensions, good handling techniques, and in the evaluation procedures in this test method and in Test Method D 1598 (Note 8). The second group considers the application or use, specifically installation, environment, temperature, hazard involved, life expectancy desired, and the degree of reliability selected (Note 9). Select the service factor so that the hydrostatic design stress obtained provides a service life for an indefinite period beyond the actual test period.

NOTE 8—Experience to date, based on data submitted to PPI, indicates that variation due to this group of conditions are usually within ±10 %, for any specific compound.

NOTE 9—It is not the intent of this standard to give service (design) factors. The service (design) factor should be selected by the design engineer after evaluating fully the service conditions and the engineering properties of the specific plastics under consideration. Alternatively, it may be specified by the authority having jurisdiction.

It is recommended that numbers selected from ANSI Standard Z17.1-1973 for Preferred Numbers, in the R10 series (25 % increments) be used, namely, 0.80, 0.63, 0.50, 0.40, 0.32, 0.25, 0.20, 0.16, 0.12, or 0.10. If smaller steps seem necessary it is recommended that the R20 series (12 % increments) be used, namely, 0.90, 0.80, 0.71, 0.63, 0.56, 0.50, 0.45, 0.40, 0.36, 0.32, 0.28, 0.25, 0.22, 0.20, 0.18, 0.16, 0.14, 0.12, 0.112, or 0.10.

5.6 *Determination or Validation of the HDB for Polyethylene Materials, or Both*—Apply either of the following procedures to PE material to validate its HDB at any temperature. When an elevated temperature HDB is validated, all lower temperature HDB's are considered validated for that material. If a brittle failure occurs before 10 000 h when testing in accordance with 5.2, the Standard Method (Procedure II) is not applicable and the Alternate Method (Procedure I) shall be used. Procedure I is also used to determine the HDB at elevated temperatures for some PE materials.

5.6.1 *Alternate Method Procedure I*:

5.6.1.1 Develop stress rupture data in accordance with 5.2 for the temperature at which an HDB is desired. Using only the ductile failures, determine the linear regression equation. The failure point data must be spread over at least two log decades. The stress intercept at 100 000-h using this equation is the "ductile" LTHS.

5.6.1.2 To determine the brittle failure performance, solve for the three coefficients of the rate process method equation as follows:

(a) Select an elevated temperature appropriate for the polyethylene material. The maximum temperature chosen should not be greater than 95°C (203°F).

(b) Select a stress at this temperature at which all failures occur in the brittle mode (a crack through the pipe wall with no visible evidence of material deformation). This set of temperature and stress is called Condition I. Test at least six pipe

TABLE 2 Validation of 73°F (23°C) HDB

HDB to be Validated (psi)	193°F (90°C) Test Temperature / 176°F (80°C) Test Temperature			
	Stress (psi)	Time (h)	Stress (psi)	Time (h)
1600	735	70	825	200
1250	575	70	645	200
1000	460	70	515	200
800	365	70	415	200
630	290	70	325	200
500	230	70	260	200

TABLE 3 Validation of 100°F (38°C) HDB

HDB to be Validated (psi)	193°F (90°C) Test Temperature / 176°F (80°C) Test Temperature			
	Stress (psi)	Time (h)	Stress (psi)	Time (h)
1600	850	300	960	1000
1250	670	300	750	1000
1000	600	300	600	1000
800	535	300	480	1000
630	340	300	380	1000
500	265	300	300	1000

TABLE 4 Validation of 120°F (49°C) HDB

HDB to be Validated (psi)	193°F(90°C) Test Temperature / 176°F(80°C) Test Temperature			
	Stress (psi)	Time (h)	Stress (psi)	Time (h)
1600	970	1100	1090	3400
1250	760	1100	850	3400
1000	610	1100	685	3400
800	490	1100	545	3400
630	385	1100	430	3400
500	305	1100	345	3400

TABLE 5 Validation of 140°F (60°C) HDB

HDB to be Validated (psi)	193°F(90°C) Test Temperature / 176°F(80°C) Test Temperature			
	Stress (psi)	Time (h)	Stress (psi)	Time (h)
1250	860	3800	970	11300
1000	690	3800	775	11300
800	550	3800	620	11300
630	435	3800	490	11300
500	345	3800	390	11300
400	275	3800	310	11300

TABLE 6 Validation of 160°F (71°C) HDB

HDB to be Validated (psi)	193°F(90°C) Test Temperature / 176°F(80°C) Test Temperature			
	Stress (psi)	Time (h)	Stress (psi)	Time (h)
1250	975	12600	1100	37500
1000	780	12600	885	37500
800	625	12600	705	37500
630	495	12600	550	37500
500	390	12600	440	37500
400	315	12600	350	37500

specimens at this Condition I until failure.

(c) At the same temperature, select another stress about 75 to 150 psi lower than for Condition I. Test at least six pipe specimens at this Condition II until failure.

(d) Select a temperature 10°C (18°F) to 20°C (36°F) lower than the one in Condition I and use the same stress as Condition I. This is Condition III. Test at least six pipe specimens at this Condition III until failure.

(e) Using all these brittle failure data points from Conditions I, II, and III, calculate the A, B, and C coefficients for the following three-coefficient rate process method equation:

$$\log t = A + \frac{B}{T} + \frac{C \log S}{T} \tag{4}$$

where:

t = time, h,
T = absolute temperature, °K (K = C + 273),
S = hoop stress, psi, and
A, B, C = constants.

(f) Using this model, calculate the stress intercept value at 100 000 h for the temperature at which the HDB is desired. This resulting stress intercept is the "brittle" LTHS.

NOTE 10—The ISO TR/9080[7] four coefficient model may be used if it has a better statistical fit to the data.

5.6.1.3 Use the lower value of the ductile failure LTHS (see 5.6.1.1) or the brittle failure LTHS (see 5.6.1.2) to determine the HDB category per Table 1 for this PE material. The HDB determined by this procedure is considered validated.

5.6.1.4 Using this model, calculate the mean estimated failure time for Condition III. When the average time (log basis) for the six specimens tested at Condition III has reached this time, the extrapolation to 100 000 h to obtain the LTHS at 23°C (73°F) has been validated. (Examples are shown in Appendix X9.)

5.6.2 *Standard Method (Procedure II)*—The HDB for a PE material at a desired temperature is validated when the following criterion is met:

5.6.2.1 Develop stress rupture data in accordance with 5.2 for the temperature at which an HDB is desired. Analyze the data to determine the linear regression equation. Extrapolate this equation to 100 000 h to determine the LTHS. Use Table 1 to determine the HDB category at this temperature.

5.6.2.2 Use Tables 2-6 to define the time and stress requirements needed to validate this HDB. Test at least six specimens at the stress level determined by the tables. These specimens must have a minimum log average time exceeding the value shown in the table to validate the HDB. For example, to validate an HDB of 1000 psi at 140°F, this required time is 3800 h at 193°F (90°C)/690 psi or 11 300 h at 176°F (80°C)/775 psi.

5.6.2.3 If a temperature/stress condition in the tables results in a premature ductile failure for a particular PE material, the stress at that temperature may be lowered by 15 %. The corresponding required time for this lowered stress is then six times the value in the table. For example, when validating an HDB of 1600 psi at 73°F, if testing at 80°C/825 psi results in ductile failures, lower the stress to 700 psi and retest. The required time to validate using this condition is now 1200 h. If ductile failures still occur, the stress may be lowered to 595 psi and the corresponding time is increased to 7200 h.

5.7 *Pressure Rating*—Calculate the pressure rating for each diameter and wall thickness of pipe from the hydrostatic design stress (hydrostatic design basis × service factor) for the specific material in the pipe by means of the equations in 3.1.9.

[7] For additional information contact the Plastic Pipe Institute Hydrostatic Stress Board Chairman, 1801 K St., NW, Suite 600 K, Washington, DC 20006.

6. Report

6.1 The report shall include the following:

6.1.1 Complete identification of the sample, including material type, source, manufacturer's name and code number, and previous significant history, if any,

6.1.2 Pipe dimensions including nominal size, average and minimum wall thickness, and average outside diameter,

6.1.3 Test temperature,

6.1.4 Test environment inside and outside of the pipe,

6.1.5 A table of the stresses in pounds-force per square inch and the time-to-failure in hours for all the specimens tested (specimens that are designated as failures after they have been under stress for more than 10 000 h shall be indicated),

6.1.6 The estimated long-term hydrostatic strength (Note 11),

6.1.7 The estimated stress at 50 years,

6.1.8 A table of the percent circumferential expansion versus time data and the estimated stress at 5.00 % expansion. This item need not be reported if previous test results show that the stress calculated for 5 % expansion is significantly greater than that reported in 6.1.6 or 6.1.7.

6.1.9 The hydrostatic design basis

6.1.10 The nature of the failures in accordance with 3.4,

6.1.11 Any unusual behavior observed in the tests,

6.1.12 If the material is polyethylene, the results of the validation in accordance with 5.6,

6.1.13 Dates of test, and

6.1.14 Name of laboratory and supervisor of the tests.

NOTE 11—The outside environment of the pipe test specimen shall be placed after the values reported.

7. Precision and Bias

7.1 No statement is made about either the precision or the bias of Test Method D 2837 for measuring the hydrostatic design basis since the result merely states whether there is conformance to the criteria for success specified in the procedure.

APPENDIXES

(Nonmandatory Information)

X1. METHODOLOGY FOR THE FORECASTING OF THE LONGER-TERM HYDROSTATIC STRENGTH OF THERMOPLASTIC PIPING MATERIALS IN CONSIDERATION OF THE NATURE OF THEIR STRESS-RUPTURE BEHAVIOR

X1.1 Similar to what has been observed for metals at higher temperatures, the stress-rupture data obtained on thermoplastics piping materials generally yields a relatively straight line when plotted on log stress versus log time-to-fail coordinates. By means of regression analysis, such straight-line behavior can readily be represented by a mathematical equation. Using this equation, the long-term strength of a material for a time under load much beyond the longest time over which the data were obtained can be determined by extrapolation. This straight-line behavior has been observed to hold true for nearly all plastic piping materials, provided failures always occur by the same mechanism. However, it has also been observed that when the cause of failure transitions from one mechanism to another, that is, from failure caused by excessive ductile deformation to a failure resulting by the initiation and growth of a crack, this may result in a significant downward shift (that is a gradual "downturn," or a relatively sharp "knee") in the slope of the initially defined stress-rupture line. In such cases, the stress-rupture data can best be characterized by means of two straight lines: an initial line of fairly flat slope; followed by a second line of steeper slope. The change in slope from the first to the second line can be minimal, in which case the stress rupture behavior is generally sufficiently well-characterized by a single average line; or, the change can be significant, in which case, it is more accurately represented by two straight lines, each with a different slope (see Fig. X1.1). Should there occur a significant downward trend in slope, the extrapolation of the trend solely defined by the earlier stage of stress-rupture behavior may result in an excessive overestimation of a material's actual LTHS. For a more accurate forecast, it should be made based on the trend exhibited by the second straight line, a trend that may not always be evidenced by the data collected during the minimum testing period of 10 000 h, as required by this test method.

X1.2 Studies[8] conducted on polyolefin pipes indicate that, exclusive of potential effects of polymer chemical degradation, or aging, that may occur in consequence of the effects of environments that are aggressive to the polymer, stress-rupture failures can occur over two stages. In the first stage, failures are of a ductile nature, but, in the second, they are the consequence of the initiation and slow growth of small cracks or faults. The schematic in Fig. X1.1 depicts this two-stage behavior. Other materials have also been found to exhibit such two-stage failure behavior; however, different failure mechanisms may be involved. As is also illustrated by Fig. X1.1, increasing the test temperature decidedly shifts to earlier times the point at which there occurs a transition in failure mechanism. Studies show that the shift, or accelerating effect, caused by increasing temperature follows established chemical and physical rate-process principles[9,10]. The significance of this finding is that shorter-time observations of stress-rupture behavior at higher

[8] M. Ifwarson and H. Leijstrom, What Controls The Lifetime of Plastic Pipes and How Can the Lifetime be Extrapolated, a paper presented at Plastic Pipes VIII, Koningshof, The Netherlands.

[9] Bartenev, G.M., and Xuyev, V.S., "Strength and Failure of Viscoelastic Materials," 1st English Publication, 1968.

[10] Bragaw, C. G., "Service Rating of Polyethylene Piping Systems by The Rate Process Method," *Eighth Plastic Fuel Gas Pipe Symposium*, New Orleans, LA, Nov. 29–30–Dec. 1, 1983.