Designation: D 2444 – 99

Standard Test Method for
Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)[1]

This standard is issued under the fixed designation D 2444; 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 impact resistance of thermoplastic pipe and fittings under specified conditions of impact by means of a tup (falling weight). Three interchangeable striking noses are used on the tup, differing in geometrical configuration. Two specimen holders are described.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*
D 618 Practice for Conditioning Plastics for Testing[2]
D 2122 Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[3]
F 725 Practice for Drafting Impact Test Requirements in Thermoplastic Pipe and Fitting Standards[3]

3. Significance and Use

3.1 The impact resistance of thermoplastic pipe and fittings relates to suitability for service and to quality of processing. Impact resistance may also provide a relative measure of a material's resistance to breakage during handling and installation and, for non-buried applications, to in-service breakage. See Appendix X4 for guidelines for selecting testing combinations.

3.2 Results obtained by use of this test method can be used in three ways:

3.2.1 As the basis for establishing impact test requirements in product standards,

3.2.2 To measure the effect of changes in materials or processing, and

3.2.3 To measure the effect of the environment.

4. Apparatus

4.1 *General*—One type of impact tester is illustrated in Fig. 1.

4.2 *Tup*:

4.2.1 The tup nose shall be as shown in Fig. 2. When used with the 0.50-in. (12.7-mm) radius nose, it is designated as Tup A. When used with the 2.00-in. (51-mm) radius nose, it is designated as Tup B. When used with the 0.25-in. (6.3-mm)
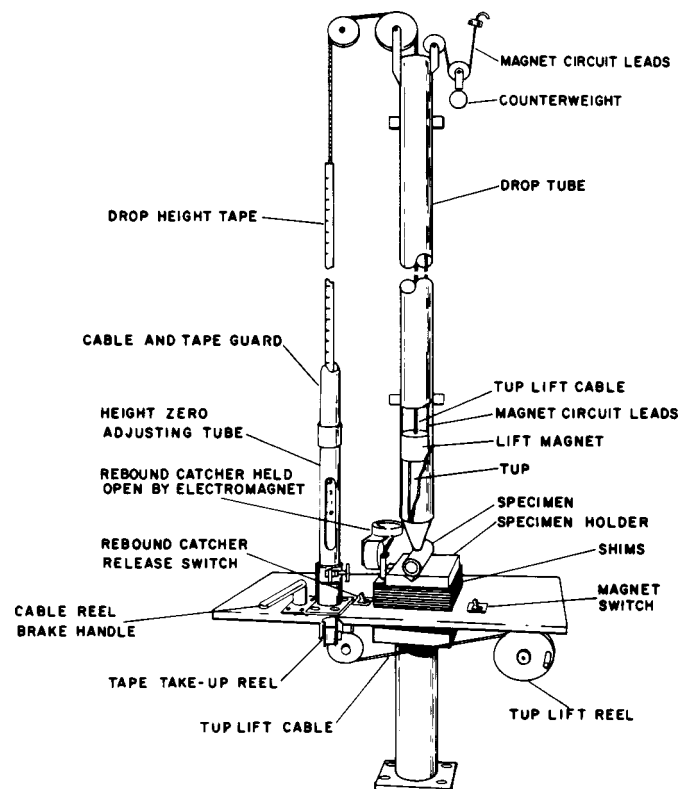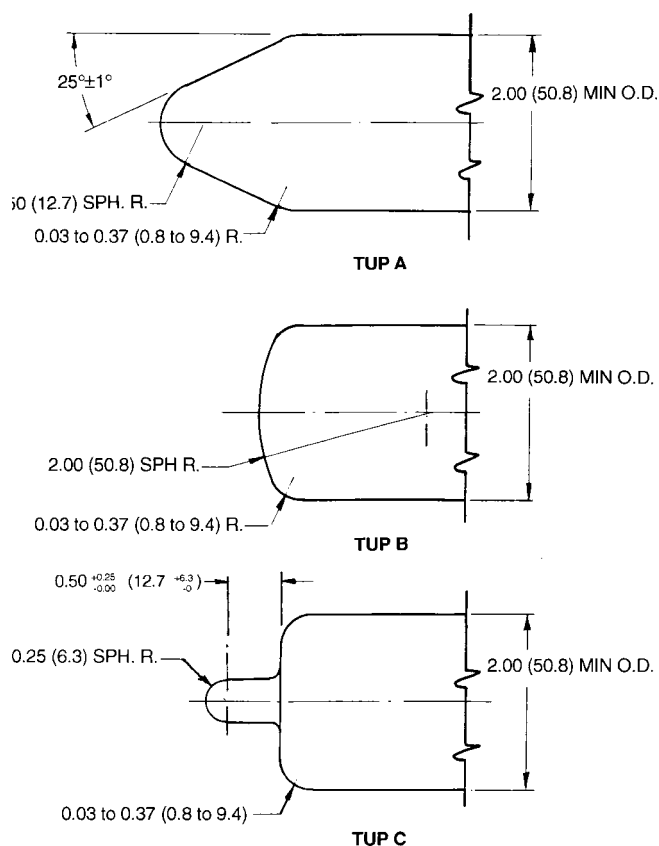

FIG. 1 One Type of Tup Impact Tester

NOTE 1—Dimensions are in inches (millimetres).
FIG. 2 Tup Nose Detail

radius nose, it is designated as Tup C.

NOTE 1—It is suggested that tups be made of scratch-resistant steel to reduce damage to the nose. Badly scarred noses may affect test results.

4.2.2 The mass of the tup shall be 6, 12, 20, or 30 lb (2.7, 5.4, 9.1, or 13.6 kg).

4.3 *Drop Tube*:

4.3.1 The drop tube shall be of sufficient length (approximately 12 ft (3.7 m)) to provide for a fall of at least 10 ft (3.0 m) and shall be mounted so that the lengthwise direction is vertical as measured with a plumb bob or a spirit level at least 2 ft (610 mm) in length.

4.3.2 Care must be taken to ensure that the tup falls freely; it must not "chatter" down the tube.

NOTE 2—No material for the drop tube is specified. However, a colddrawn seamless steel tubing with an inside diameter of 2.563 ± 0.003 in. (65.10 ± 0.08 mm), or acrylonitrile-butadiene-styrene (ABS) or poly(vinyl chloride) (PVC) plastic pipe, 2½ in. nominal pipe size, with a standard dimension ratio (SDR) of 21, have been found to be satisfactory.

NOTE 3—Provided equivalent results are obtained, the tup may be dropped without a drop tube or guided by other means. The drop tube is used to reduce the hazard to operators and property that may occur when the tup rebounds. It also helps guide and center the tup so that it will be more likely to strike the top of the test specimen. It may also be necessary to provide a protective barrier around the specimen, particularly for larger sizes of pipe and fittings, to protect the operator from flying broken pieces.

NOTE 4—The tup may not fall freely if the clearance between the tup and tube is too large or too small, or if it is restrained by a partial vacuum above the tup, such as can be caused by the hold and release device.

4.3.3 Means shall be provided (*1*) to hold the tup at steps of 2 in. (50.8 mm) for a distance of 2 to 10 ft (610 mm to 3.0 m) above the specimen holder, (*2*) to release the tup in a reproducible manner, (*3*) to allow the tup to fall freely, and (*4*) to catch the tup on the first rebound. Refer to Fig. 1.

4.4 *Specimen Holder*—Two specimen holders are described. The V-block (Holder A) is usually used with Tups A and C; the flat plate (Holder B) is often used with Tup B or for testing fittings.

4.4.1 The V-block holder shall be at least as long as the specimen being tested and shall have a 90-deg included angle. It may be fabricated or of solid construction. The side supports shall be of sufficient depth to support the specimen in the V and not on the top edges of the V-block.

NOTE 5—Both aluminum and steel have been found suitable for the holders.

4.4.2 The flat-plate holder shall consist of a plate approximately 8 by 12 by 1 in. (203 by 305 by 25.4 mm) in which a groove to position the pipe specimen shall be cut. This groove shall be about 0.12 in. (3 mm) in depth with the edges rounded to a radius of about 0.06 in. (1.5 mm). Fittings that do not contact the plate directly under the point of impact shall be supported at this point by a flat steel plate or shim. The specimen holder shall be mounted on a rigid base fastened to a concrete slab. Means shall be provided to center the specimens under the drop tube. A bar or rod placed inside the specimen and retained by a light spring may be employed if difficulty is encountered in holding the specimen in position.

5. Test Specimens

5.1 The pipe specimens shall be equal in length to the nominal outside diameter but not less than 6 in. (152 mm) in length. Burrs shall be removed.

5.2 Fittings shall be tested either unassembled or assembled to pieces of pipe each 6 in. in length.

6. Number of Test Specimens

6.1 A minimum of 20 specimens are required for preliminary tests.

6.2 A minimum of 100 specimens are required for final tests, and 50 additional specimens may be required.

7. Conditioning

7.1 Condition the test specimens at 40 h, 23°C, 50 % RH and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

7.2 *Test Conditions*—Conduct the test in a room maintained at the test temperature or, if the test is made in an atmosphere or at a temperature other than that at which the specimens are conditioned, conduct the test as soon as possible after removal from the conditioning atmosphere, but in any case within 15 s. In case of disagreement, conduct the tests in a room maintained at the test temperature.

8. Procedure—General

8.1 Measure the dimensions of the test specimens in accordance with Test Method D 2122.

8.2 The point of impact for all specimens shall be at the top of the vertical diameter.

8.3 Test unsymmetrical fittings with the specimen lying on its side.

8.4 Position the pipe specimens at random angular orientations.

8.5 Impact each specimen only once.

9. Procedure—Details

9.1 Impact one of the sets using an energy estimated to cause 15 % of the specimens to fail; impact the second set at an energy estimated to cause 85 % to fail. Record the actual percentage that fail and plot on normal probability graph paper.

9.2 *Preliminary Tests*:

9.2.1 The purpose of the preliminary tests is to identify the optimum tup mass and to determine the drop heights to be used for the final tests.

Note 6—The use of this preliminary procedure is optional. Trial and error, previous experience with the material, or guesswork may serve as well. Also, see Appendix X3.

Note 7—The chief source of problems in conducting impact tests is the ratio of the standard deviation to the mean strength. Use of Tup C with pipe specimens will reduce the size of the problem.

9.2.2 Select a tup estimated to cause failure of some specimens when dropped from a height of 5 ft (1.5 m) and use it to test four specimens.

9.2.2.1 If at least one but not all four specimens fail with the first tup selected, continue the test as described in 9.2.3.

9.2.2.2 If all four specimens fail, test four more specimens with a lighter tup.

9.2.2.3 If all four specimens pass, test the same specimens with a heavier tup, at a drop height of 5 ft (1.5 m).

9.2.2.4 Once a weight has been used that results in the failure of some, but not all, specimens at a height of 5 ft (1.5 m), continue the test as described in 9.2.3. If no failures occur with the heaviest tup at a drop height of 5 ft (1.5 m), test at the maximum drop height. If no failures occur with the maximum weight at the maximum drop height, test a total of 50 specimens at this drop height, record the results, and discontinue testing. If one or more of the preliminary test specimens passes with the maximum weight at the maximum drop height, proceed to 9.2.3.

9.2.3 After the optimum tup weight has been determined, divide the remaining group of preliminary test specimens into two equal lots. Each group shall contain at least eight specimens. Test one lot at a lesser drop height so that substantially less than 50 % failures result. Test the second lot at a greater drop height so that substantially more than 50 % failures result. Plot these results on probability graph paper to serve as the basis for estimating the proper drop heights for the final test.

9.2.4 If the 6-lb (2.7-kg) tup produces 100 % failures at 5 ft (1.5 m), use lesser drop heights for the procedures outlined in 9.2.3.

Note 8—Because there must be both failures and nonfailures in this test, conditions that result in 100 % failures or 100 % passes are of limited value in the development of information. When all specimens pass, the problem can be helped by (*1*) changing from the flat-plate holder to the V-block holder (in the case of pipe specimens), (*2*) changing from Tup B to Tup A, and finally to Tup C, and (*3*) lowering the test temperature.

When all specimens fail, the sequence is reversed.

9.3 *Final Test*:

9.3.1 Divide 100 test specimens into two equal sets.

9.3.2 On the basis of the preliminary test, trial and error, or judgment, estimate the drop height at which 85 % of the specimens will pass and test the first set of 50 specimens at this height. Record the value of the mass, the drop height, and the number of passes.

9.3.3 Estimate the drop height at which 85 % of the specimens will fail and, if it is 10 ft (3.0 m) or more, use this height. Test 50 specimens and record the number of passes and the drop height.

9.3.4 *Acceptable Data*:

9.3.4.1 To be acceptable, there must be at least one pass and at least one fail in each set of data; one set of data should list less than 50 % failures; the number of passes in the two sets should differ by at least 20.

9.3.4.2 If the requirements of 9.3.4.1 have not been met, test 50 additional specimens at a drop height chosen to rectify the deficiency.

9.3.5 Construct a straight-line plot of the test results on normal probability paper. Preliminary tests which were conducted at the same drop height as the final tests shall be used to compute the percent passing at that height. All other preliminary test results are ignored for purposes of obtaining the final plot.

9.3.6 The intercept of the plot with the 50 % pass/fail line is the average impact resistance of the set as measured by the test.

9.3.7 The intercept of the plot at the 16 % or the 84 % pass/fail line differs from the average strength by (for practical purposes) one standard deviation.

10. Definition of Failure

10.1 Failure in the test specimens shall be shattering or any crack or split created by the impact and that can be seen by the naked eye. Lighting devices may be used to assist in examining the specimens. A crease visible on the surface shall not be construed as failure. If criteria of failure other than those cited here are used, they shall be listed in the report.

11. Report

11.1 The report shall include the following:

11.1.1 Complete identification of pipe or fittings tested, including type of plastic, source, manufacturer's code, size, average dimensions and minimum wall thickness, and history,

11.1.2 In the case of fittings, the dimensions of pipe used to prepare the specimens, how joints were made, and the position of the weld mark in relation to the point of impact,

11.1.3 Test temperature and conditioning procedure,

11.1.4 Tup used,

11.1.5 Holder used,

11.1.6 The mass of the tup, lb (kg),

11.1.7 Point of impact for fittings,

11.1.8 Types of failure and any deformation observed,

11.1.9 Date of test, and

11.1.10 Copy of probability plot, including number of specimens tested at each drop height.

12. Precision and Bias

12.1 This test method is neither precise nor accurate within the limits usually associated with those terms unless larger numbers of test specimens are employed. Therefore, no statement of bias can be made.

NOTE 9—A brief treatment of the subject of precision and accuracy for binomial tests is provided in Appendix X1.

13. Keywords

13.1 fittings; impact resistance; pipe; thermoplastic; tup (falling weight)

APPENDIXES

(Nonmandatory Information)

X1. GUIDELINES FOR DETERMINING PRECISION AND ACCURACY BY APPLYING BINOMIAL PROBABILITY TECHNIQUES

X1.1 Tests that have only two possible results (pass or fail, heads or tails, black or white) are governed by the rules of probability.

X1.2 The most elementary application of the rules occurs when the true probability of success is known. When a fair coin is tossed, for example, the probability for "heads" is known to be exactly 0.5 chance out of 1.

X1.3 The probability, $_rP_n$, for exactly r successes in n tries when the probability for success, p, is known for each try, is given by the equation

$$_rP_n = \frac{n!}{r! \, (n - r)!}(p^r) \, (1 - p)^{n - r} \qquad (X1.1)$$

Example— The chance that one will obtain exactly 25 heads when a fair coin is tossed 50 times is equal to

$$\frac{50!}{25! \, (50 - 25)!} \, (0.5^{25}) \; or \; 0.112 \qquad (X1.2)$$

The factorial of zero (0) is one (1).

X1.4 The total of the probabilities for all possible results is equal to 1. The equation is mathematically exact.

X1.5 A complication exists when the true probability of success is not known, but must be deduced on the basis of binomial test data. This is the case when thermoplastic pipe and fittings are subjected to impact testing as outlined in this test method.

X1.6 The binomial probability equation can be employed to define the likely limits of error for binomial test data. It will be simpler to refer to a statistics text or to use the approximate equation as follows:

$$s = \sqrt{\frac{p(1 - p)}{N}} \qquad (X1.3)$$

where:
s = standard error,
N = number of specimens tested, and
p = measured rate of success.

Example—50 specimens are tested and 32 pass. Then the best estimate for p (true probability of success) is 0.64, and the standard error equals:

$$\sqrt{\frac{0.64 \, (1 - 0.64)}{50}} = 0.07 \qquad (X1.4)$$

The confidence level is 68.27 % (note the similarity to plus and minus one standard deviation); the true probability of success is in the range 0.64 ± 0.07, or from 0.57 to 0.71.

X1.7 The 90 % confidence interval is equal to the experimental value p plus and minus 1.65 standard errors, and the 95 % confidence interval is equal to the experimental value plus and minus 1.96 standard errors. Note that the foregoing deals with error due to probability only and does not take account of error caused by equipment or experimental technique.

X1.8 Charts defining the confidence limits for binomial test data are listed in many reference works. Dixon and Massey[4] provide charts for 80, 90, 95, and 99 % confidence coefficients.

X1.8.1 *Use of Fig. X1.1*—If 100 specimens are tested, and 24 pass, calculate $p = 0.24$. Find the ordinate labeled 0.24 at the bottom of the chart and read up. At the intersection with the first curved line labeled "100", move to the left-hand side of the chart and read $p' = 0.16$. Return to the ordinate labeled 0.24 and find the intersection with the upper curved line labeled "100" and read "0.33" at the left-hand side of the chart. The probability of success (p') is identified as 0.16 to 0.33, to a 95 % confidence level.

X1.9 *Improving Accuracy:*

X1.9.1 This test method provides less accuracy than may be required for some purposes.

X1.9.2 Analysis of the material represented by Fig. X1.1 reveals that accuracy is related to the square root of the number of specimens subjected to test. To reduce the size of error by a factor of 2 requires that four times as many specimens be tested. Note, also, that when the failure rate is close to zero (0 %) or one (100 %), then it requires more testing than when the failure rate is somewhat removed from these points.

[4] Dixon, D. W., and Massey, Jr., F. J., "Introduction to Statistical Analysis," 3rd ed., McGraw Hill Book Co., Inc. New York, NY, 1969, pp. 501–504.
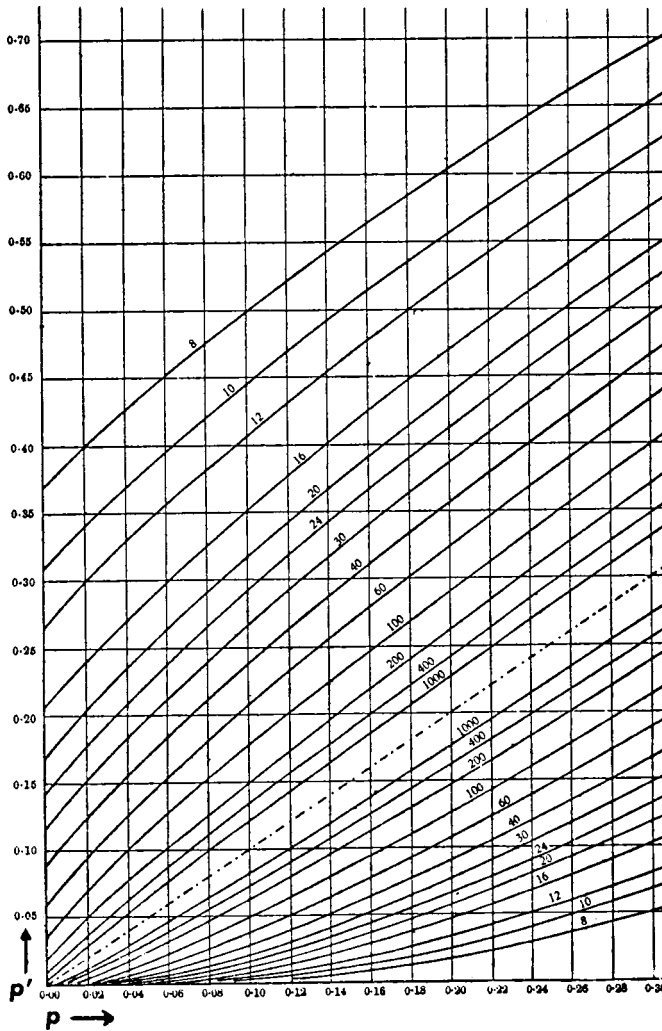
NOTE 1—Reproduced by permission of the Biometrika Trust.

NOTE 2—This figure provides confidence limits for p' in binomial sampling, given a sample fraction. Confidence coefficient = 0.95. The numbers printed along the curves indicate the sample size n. If for a given value of the abscissa, P_A and P_B are the ordinates read from (or interpolated between) the appropriate lower and upper curves, then $Pr \{p_A \leq p' \leq p_B\} \geq 0.95$.

FIG. X1.1 95 % Confidence Limits for Binomial Test Data

X1.9.3 The use of only two data points presumes that the distribution of attributes is normal. When good information is required at some specific point (for example, the place where 90 % of all specimens should pass), then the two-point plot can be used to define the new test level most likely to be correct,

and a third series of tests run at that level to check the accuracy of the preliminary plot at that point.

X1.9.4 Finally, a series of tests can be conducted at different energy levels when it is desired to define the true distribution of attributes over the range $p = 0$ to $p = 1$.

X2.   PROBABILITY GRAPH PAPER

X2.1   Probability graph paper is available in a variety of forms. One of the most common is illustrated in Fig. X2.1.

X2.2   The vertical grid is evenly spaced, whereas the horizontal grid spacing expands in both directions from the line labeled "50". The spacing is such that when statistical data are plotted, and when the distribution of attributes is normal, the plot will be a straight line. Numbers printed on the sides of the graph will typically read "0.01, 0.1, 0.2, 0.5, 1, 2, ... 40, 50, 60,

... 99, 99.9, 99.99." These numbers refer to the percent passing or failing at a given test level. The user labels the vertical lines. Ordinarily, equal increments will be used to label these lines. If it is known, for example, that all data of interest will fall in the region encompassed by 60 ft·lbf and 160 ft·lbf, the lines would be labeled "60, 70, 80, 90, ... 150, and 160." Two data points suffice to define the plot if the distribution is normal. Note that if the two data points are close to each other (for example, 40 and 52 % passing), then errors in either will affect the slope of
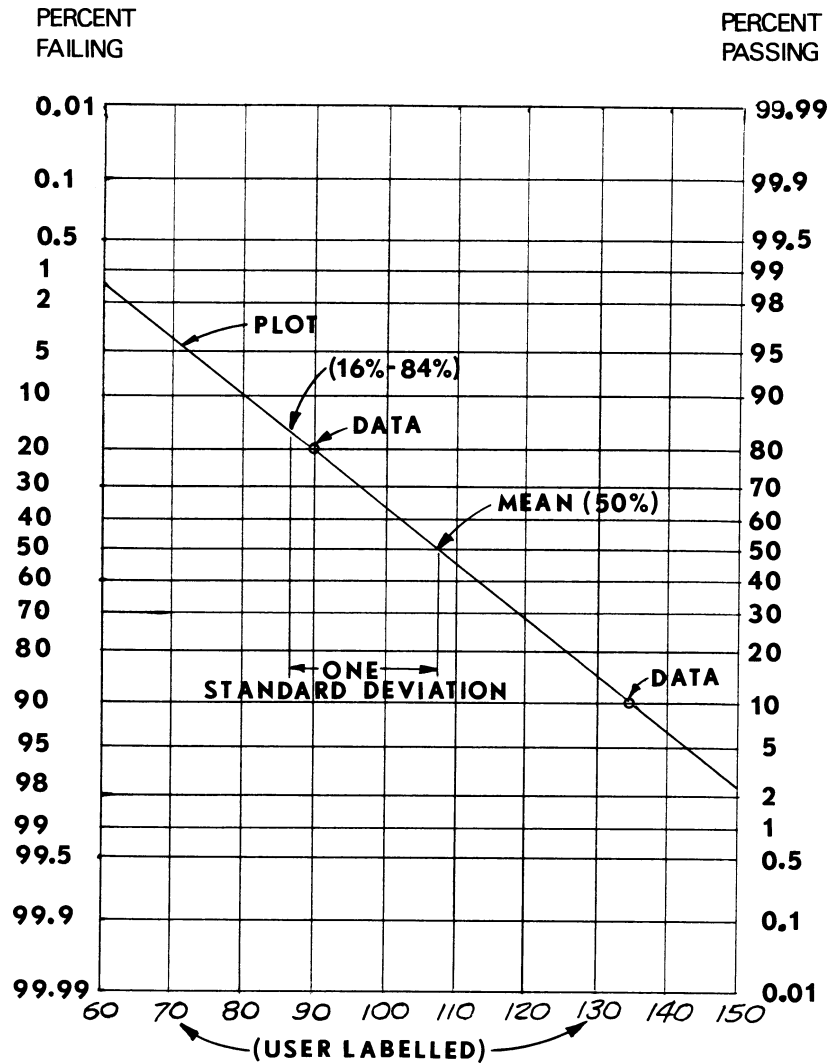
PERCENT
FAILING

PERCENT
PASSING

FIG. X2.1 Probability Graph

the plot seriously. This is the reason for the requirements listed in 9.3.4.1. The mean impact resistance of the lot is defined by the intersection of the plot with the line labeled "50 %." To find the standard deviation, locate the intersection of the plot with the line for 16 % or for 84 %. The difference between either of these points and the 50 % point is equal to one standard deviation. Since there is no assurance that the properties will be distributed completely normally (particularly true for yard-aged pipe exposed to differing amounts of ultraviolet light), the reliability will fall off in the regions where few pass or few fail. The plot suffices, nevertheless, to give a good general description of the properties of the pipe.

X3. "UP/DOWN" TEST PROCEDURE TO DEFINE THE MEAN IMPACT RESISTANCE

X3.1 Number of Test Specimens

X3.1.1 *Determination of Median Value*:

X3.1.1.1 Six or more specimens shall be used to determine the approximate starting point of the test. Once this is done for a specific size and type of pipe, it may not be necessary to repeat this preliminary step.

X3.1.1.2 The median impact resistance shall be determined with 20 test specimens of each sample. The specimens shall be labeled from 1 to 20 and the order of testing determined by a set of random numbers.

X3.1.2 For specification purposes, the number of specimens tested shall be in accordance with Section X3.5.

X3.2 Conditioning

X3.2.1 *Conditioning*—Condition the test specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required.

X3.2.2 *Test Conditions*—Tests at lower or elevated temperatures shall be made in a room maintained at the test

temperature, or if the test is made in an atmosphere at a temperature other than that at which the specimens are conditioned, the test shall be made as soon as possible on removal from the conditioning atmosphere, but in any case within 15 s after removal from the conditioning atmosphere. In case of disagreement, the tests shall be conducted in a room maintained at the test temperature.

X3.3 Procedure—General

X3.3.1 Measure the dimensions of the test specimens in accordance with Test Method D 2122. Note the position of the thinnest wall of each specimen.

X3.3.2 Mount the first test specimen with the thinnest wall section on top so that the tup strikes this area. Mount the second specimen so that the point of impact is 18° from the thinnest wall, the third 36°, etc.

X3.3.3 Test unsymmetrical fittings by laying the specimen on its side and impacting the other side. Strike six specimens on one side and six on the other.

X3.3.4 The point of impact for all specimens shall be at the top of the vertical diameter.

X3.3.5 Determine the impact resistance (energy) by the" Up and Down" (hereafter called UD) method.[5] In this method the energy required to break the specimens is bracketed by making the tests at different heights of drop in a systematic manner. No specimen is tested more than once in this method.

X3.4 Procedure—Details

X3.4.1 The weight (mass) of the tup shall be 6, 12, 20, or 30 lb (2.7, 5.4, 9.1, or 13.6 kg).

X3.4.2 Make preliminary tests to determine the approximate height of fall of the tup required to produce failure in the pipe or fittings made of the particular material and in the particular dimensions to be tested.

NOTE X3.1—It has been found desirable to use increments of at least 6 in. (152 mm) for this initial testing.

X3.4.3 Test the first specimen, chosen by a set of random numbers as indicated in X3.1.2, by dropping the tup onto it from the 2-in. (50.8-mm) or 6-in. (152-mm) increment immediately below the approximate height determined in X3.4.2. If this specimen ruptures or cracks, test the second specimen at the next lower increment. If the first specimen does not fail, test the second one at the next higher increment. In a similar manner, determine the height of fall of the tup to test each specimen from the results observed with the specimen tested immediately prior.

X3.5 Procedure—Specification Requirement

X3.5.1 For use in determining whether or not a sample meets the impact requirement in pipe or fitting specifications, it

is recommended that specimens be tested on a "go, no-go" basis. The tup, the weight, and the height from which the tup is dropped shall be specified in the product specification.

X3.5.2 For pipe or symmetrical fittings, ten specimens shall be tested. When two or more specimens fail, the product does not meet the impact requirement. Nine nonfailures out of ten specimens tested shall be acceptable.

X3.5.3 For unsymmetrical fittings, six specimens shall be struck on one side and six on the other. When two or more of the specimens fail, the product does not meet the specified impact requirement. Eleven nonfailures out of twelve specimens tested shall be acceptable.

X3.6 Definition of Failure

X3.6.1 Failure in the test specimens shall be shattering or any crack or split on the inside or outside created by the impact and that can be seen by the naked eye. Lighting devices shall be used to assist in examining for cracks and splits in the walls of the pipe or fittings specimens. Any permanent deformation of the specimens shall be reported with a short description of the deformation. If other criteria of failure than those cited here are used they shall be given in the report.

X3.7 Calculations

X3.7.1 Calculate the median height of fall (h) and standard deviation (s) from the test data obtained as follows:

$$h = h_o + d\,[\,(A/N) \pm (1/2)]\qquad(\text{X3.1})$$

$$s = 1.620d\left(\frac{NB - A^2}{N^2} + 0.029\right)\qquad(\text{X3.2})$$

where:
h = median height of fall, ft (m),
d = increment in height of drop, ft or m, (⅙ for 2-in. or ½ for 6-in. (50.8 or 152 mm) increment),
s = standard deviation for h,
N = lesser number, either failures or nonfailure,
h_0 = lowest height at which any one of N occurs, ft (m),
A = $\displaystyle\sum_{i=0}^{k} i\,n_i$

where h_0, h_1, h_2, h_3, etc. are the heights in progressive order of magnitude in the range of heights where N occurs: i is the subscript of h, and n_i is the number of failures or nonfailures, whichever is pertinent, at the level of i, and

B = $\displaystyle\sum_{i=0}^{k} i^2 n_i.$

X3.7.2 The negative sign is used in the parentheses to calculate h when N refers to failures, and the positive sign when N is the number of nonfailures. Calculate the median impact resistance by multiplying h by the weight used in pounds. Calculate the standard deviation by multiplying s by the weight used in pounds.

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[5] This system of testing, nomenclature, and calculations is described by Dixon, W. J., and Massey, F. J., Jr., *Introduction to Statistical Analysis*, Chapter 19, Third Edition 1969, McGraw Hill Book Co. Inc., New York, NY.

X4. GUIDELINES FOR SELECTION OF TESTING COMBINATIONS

X4.1 It is recognized that the impact resistance of thermoplastic pipe and fittings is a function of the material in the product, of the quality of the extrusion or molding, of the geometry and dimensions of the test specimen and of the testing variables used (temperature, tup nose geometry, tup weight, specimen support, and height of drop). Because all these factors and their interrelations affect the test results, impact tests are useful mainly for quality control and comparative purposes, not as simulated service tests. The combinations of test variables should be selected so that the test can be easily run with little or no hazard to personnel and the results obtained are reasonably reproducible. To achieve this end, the following guidelines for selection of the testing variables are suggested:

X4.1.1 Use the tup which will give the best reproducibility.

X4.1.2 Use the tup which is most representative of the service concerned.

X4.1.3 Use the tup and weight combination which will produce failure within a drop height between 2 and 10 ft (0.6 and 3.0 m).

X4.1.4 If no combination of tup-weight-height-support is available that will give satisfactory results because of high-impact resistance, lower the test temperature of the test specimen by use of an ice-water mixture or by an air-conditioned environment to an even lower temperature.

X4.1.5 The impact resistance of a specimen increases when (*a*) the temperature is increased; (*b*) the tup nose geometry changes in order to C, A, B; (*c*) the specimen support is changed from the V-block to a flat plate; (*d*) the tup weight is decreased; and (*e*) the height drop is decreased.