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Standard Practice for Drafting Impact Test Requirements In Thermoplastic Pipe And Fittings Standards[1]

This standard is issued under the fixed designation F725; 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 describes a procedure for setting up impact test requirements on the basis of test data obtained by Test Method D2444.

1.2 This practice is applicable to thermoplastic pipe and fittings.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered 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:*[2]

D2444 Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *binomial probability equation*—the equation that defines the chance for exactly r specimens to pass, when n are tested, given p, the chance that a single specimen chosen at random will pass. It is expressed as follows:

$$ {}_{r}P_{n} = \frac{n!}{r!(n-r)!} p^{r}(1-p)^{n-r} \quad (1) $$

NOTE 1—The factorial of zero is one.

3.1.2 *binomial test*—a test that has only two possible results (for example, pass or fail, heads or tails, true or false).

3.1.3 *mean strength*—the average strength of the total population (see Note 2).

3.1.4 *OC curve (operating characteristic curve)*— a graph that illustrates the chance of success or failure when a given specification format is employed, given any quality level from 0 to 1 (0 to 100 % passing in the lot from which test specimens are selected).

3.1.5 *probability graph paper*—commercially available graph paper that provides straight-line plots when the distribution of attributes is normal. For a discussion on the use of proability graph paper, see Test Method D2444 Appendix X2.

3.1.6 *specification format*—the rules set forth by the test requirement, including the number of specimens to be tested and the minimum acceptable number of passes.

3.1.7 *standard deviation*—a statistical term that relates to the size of the expected variation in test results.

NOTE 2—The terms "mean," "normal distribution," and "standard deviation" are dealt with in elementary statistics textbooks.

4. Summary of Practice

4.1 Round-robin tests of representative pipe and fittings specimens are performed to identify the energy levels at which 90 % or more of the specimens in acceptable lots will pass. A preferred test format is listed. The B-tup and the V-block holder, and room-temperature conditioning and tests are preferred choices.

5. Significance and Use

5.1 This practice is used for drafting impact test specification requirements, and it presupposes no special familiarity with statistical methods. It provides for specification values that will pass acceptable lots with a high degree of certainty. The impact test requirement is intended to discriminate between acceptable materials and manufacturing methods and those which are not; it is not a simulated service test.

6. Procedure

6.1 Test thermoplastic pipe or fittings specimens in accordance with Test Method D2444, and plot the test results on probability graph paper.

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

6.2 It will be clear, from the probability paper plot, that the energy level where 98 % or 99 % of all specimens would pass will be low. On the one hand, when the test format requires that five of five, or six of six, or nine or ten of ten tested shall pass, or the lot rejected, then the specified energy levels must correspond to these levels (see Fig. 1, the operating characteristic (OC) curve for the "nine or ten of ten" test format). On the other hand, five of five, six of six, and nine or ten of ten tests at low energy levels will not screen marginal or poor lots effectively. (See Fig. 1 again).

6.3 A format which will accept reliably when 90 % or more of the specimens in acceptable lots would pass, and reject reliably when 60 % or fewer would pass, is as follows:

6.3.1 "X.X Test ten specimens. When nine or ten pass, accept the lot. When six or fewer pass, reject the lot. When seven or eight pass, test ten additional specimens. When 17 or more of 20 pass, accept the lot. When 13 or fewer of 20 pass, reject the lot. When 14, 15, or 16 pass, test 20 additional specimens. When 32 or more of 40 pass, accept the lot. When 31 or fewer pass, reject the lot."

6.3.2 The OC curve for this format is illustrated in Fig. 2.

6.4 *Specimen Length*—The pipe specimen length should be 6 in. (150 mm) ± ¼ in. (6mm).

6.5 *Choice of Tup and Holder*—The B tup is preferred. It provides a good compromise between energy concentration in the specimen (and therefore reduced test energy levels), and resistance to damage in service. The V-block holder is preferred for pipe specimens; it provides for greater energy concentration, and for failures in a range of thin-walled specimens which would merely flatten on the flat-plate holder.

6.6 *Test Conditions*—Room-temperature tests are preferred. They can be performed by the manufacturer on a timely basis, so that the size of questionable or defective inventories is minimized. Binomial tests are relatively crude, unless large numbers of specimens are subjected to test. The expense and inconvenience of low-temperature conditioning render it a poor choice (study Fig. 1 together with a data plot performed in accordance with Test Method D2444 to fully grasp the merits of this statement).

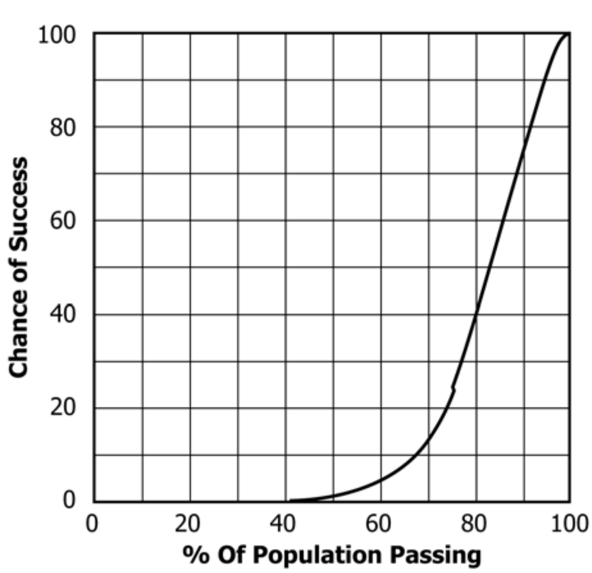

FIG. 1 O.C. Curve for Nine or Ten of Ten

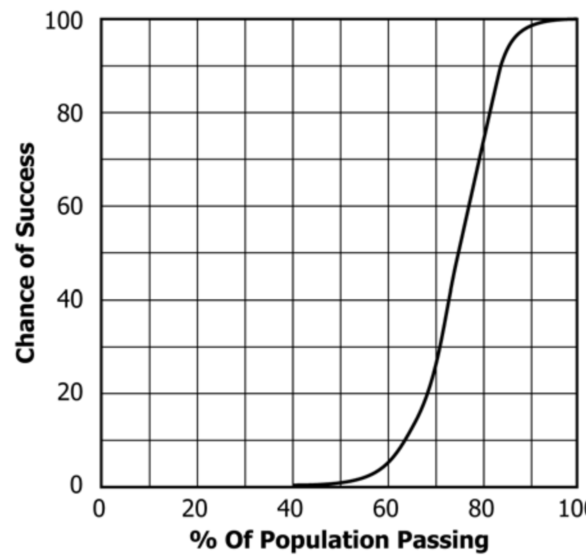

FIG. 2 O.C. Curve for Section 6.3

7. Multiple-Product Standards

7.1 Many thermoplastic pipe and fittings specifications list large numbers of products. Test Method D2444 requires that at least 100 test specimens shall be employed for each single test run in order that the impact properties can be measured with useful accuracy. The cost of round-robin tests on each size of the products in the standard may approach or exceed the value of the information to be obtained.

7.2 Testing costs can be significantly reduced by performing preliminary tests on the largest sizes listed, to determine whether or not a cut-off point exists above which all specimens will pass at an energy level of 300 ft·lbf (407 J) (ordinarily the highest test energy level listed in a thermoplastic pipe or fittings impact test requirement).

7.2.1 Following these tests, a limited number of representative sizes can be selected, and round-robin testing performed.

7.2.2 The results of these tests are analyzed. List the energy levels where the failure level was 10 % for each size tested, and divide the energy levels by the specimen volumes in cubic inches. Plot the results against the specimen outside diameters, and label the points if it is a multiple SDR specification. In a specification which included 25 sizes of pipe, and seven SDR series, for example, three sizes each of three different SDR series of pipe might be tested preliminarily. The points for each SDR series would be connected with a curve, and from the plots the appropriate trial energy levels for six untested sizes and SDR's calculated.

7.3 One hundred test specimens of each of the six untested sizes would be prepared, and subjected to test. If 85 to 95 specimens in each lot passed, the degree of correlation would be good.

7.4 Depending upon the degree of correlation obtained, proceed to calculate the test energy levels for each untested size, factor all energy levels back by an appropriate amount and draft the test specification proposal, or else conduct additional tests.

7.5 The tup weight and style listed in the proposal should be the same as that used for the preliminary tests.

8. Special Considerations

8.1 *Fittings*—The flat-plate holder is employed for fittings impact tests. Shims may be required, depending on fittings configuration. Fittings should be impacted on a horizontal surface, as close to the center of mass as is practical. Ordinarily, the specification will require that half the fittings be impacted on one side, and half on the other.

8.2 *Thin-Walled Pipe*—Thin-walled pipe may undergo complete closure without failure (particularly if the flat-plate holder is employed). Impact testing may still serve a useful purpose, however, since the energy levels required to flatten acceptable specimens may result in failure of improperly manufactured specimens.

8.3 *Yard-Aged Pipe*—The impact test is not ordinarily specified on yard-aged pipe since many thermoplastic pipe materials are subject to reduction in impact strength as the result of exposure to ultraviolet rays.

9. Keywords

9.1 drafting impact; drafting impact requirements; impact; plastic pipe; plastic tubing; thermoplastic pipe; thermoplastic tubing

APPENDIXES

(Nonmandatory Information)

X1. THE OPERATING CHARACTERISTIC (OC) CURVE

X1.1 *Purpose*—The OC curve gives an accurate picture of the impact-test relationship between a particular test sample and the total population. Specifically, the curve provides the chance of success of a sample when given testing regimen is employed. This relationship is ordinarily too complex to be arrived at on the basis of guesswork.

X1.2 *Constructing the OC Curve*—Start by listing the number of ways in which success can be achieved (For example, in a "7 or more out of 10" specification format, the lot is accepted when 7, 8, 9, or 10 out of 10 specimens pass.) Use the binomial probability equation to obtain an expression for the chance that each of these events will occur. (See example.) Evaluate the chances, substituting values for p ranging from 0 to 1. Sum the chances of success, for each chosen value of p. Plot the results (chance of success, against p) to obtain the curve.

*Example:*OC Curve for a "7 or more out of 10" specification format. The chance that 7 out of 10 will pass equals,

$$\frac{10!}{7!(3)!}p^7(1-p)^3 \text{ or } 120\,p^7(1-p)^3 \qquad \text{(X1.1)}$$

Substitute values ranging from 0.1 to 0.9 for p, and tabulate the results:

p	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
${}_7P_{10}$	0.000	0.001	0.009	0.042	0.117	0.215	0.267	0.201	0.057

In like manner, tabulate the chance that 8, 9, or 10 will pass.

p		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Odds of:	7	0.000	0.001	0.009	0.042	0.117	0.215	0.267	0.201	0.057
	8	0.000	0.000	0.001	0.011	0.044	0.121	0.233	0.302	0.194
	9	0.000	0.000	0.000	0.002	0.010	0.040	0.121	0.268	0.387
	10	0.000	0.000	0.000	0.000	0.001	0.006	0.028	0.107	0.349
Totals:		0.000	0.001	0.010	0.055	0.172	0.382	0.649	0.878	0.987

When the totals are plotted against p, the OC curve results. Note that calculation increments smaller than 0.1 will provide more accuracy. A spreadsheet is useful in evaluating the binomial probability equation.

X2. MEASURING CONFORMANCE TO EXISTING TEST REQUIREMENTS

X2.1 A variety of impact test specification formats are in current use. The information provided in the OC curve for each of them can be expressed in mathematical terms. To identify the chance that a given manufacturing process will pass the test requirement, select at least 100 test specimens, and subject them to the impact test listed. Express the decimal percent passing as p, and substitute in the appropriate equation: For a 5 out of 5 test requirement, $P_{success} = p^5$

For a 6 out of 6 test requirement, $P_{success} = p^6$

For a 10 out of 10 test requirement, $P_{success} = p^{10}$

For a 12 out of 12 test requirement, $P_{success} = p^{12}$

For a 5 of 5 or 9 of 10 test, $P_{success} = p^5 (1 + 5 p^4 - 5p^5)$

For a 6 of 6 or 11 of 12 test, $P_{success} = p^6 (1 + 6 p^5 - 6p^6)$

For a 9 or more out of 10 test, $P_{success} = p^9 (10 - 9p)$

For a 7 or more out of 10 test, $P_{success} = 120 p^7 - 315p^8 + 280p^9 - 84p^{10}$

For the procedure listed in 6.3, the formula is: $3\,225p^{36} (1 - p)^4 + 75\,300p^{35} (1 - p)^5 + 828\,750p^{34}(1 - p)^6 + 5\,728\,500p^{33} (1 - p)^7 + 62\,312\,400p^{32} (1 - p)^8 + 570p^{17} (1 - p)^3 + 45p^{18} (1 - p)^2 + 10p^9 (1 - p) + p^{10}$

X2.2 The results from a 100-specimen test may not correlate accurately with the quality level in the population. The standard error for a 100-specimen test is approximately 0.05 (68 % of the time the measured results will not be in error by more than 0.05, and 95.5 % of the time they will not be in error by more than 0.10). If better accuracy is required then more specimens should be tested. The approximate equation for the standard error is $(P(1 - P)/N)^{1/2}$.