Designation: D 4356 – 84 (Reapproved 2002)

An American National Standard

Standard Practice for Establishing Consistent Test Method Tolerances[1]

This standard is issued under the fixed designation D 4356; 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 should be used in the development of any test method in which the determination value is calculated from measurement values by means of an equation. The practice is not applicable to such determination values as those calculated from counts of nonconformities, ratios of successes to failures, gradings, or ratings.

1.2 The purpose of this practice is to provide guidance in the specifying of realistic and consistent tolerances for making measurements and for reporting the results of testing.

1.3 This practice can be used as a guide for obtaining the minimum test result tolerance that should be specified with a particular set of specified measurement tolerances, the maximum permissible measurement tolerances which should be specified to achieve a specified test result tolerance, and more consistent specified measurement tolerances.

1.4 These measurement and test result tolerances are not statistically determined tolerances that are obtained by using the test method but are the tolerances specified in the test method.

1.5 In the process of selecting test method tolerances, the task group developing or revising a test method must evaluate not only the consistency of the selected tolerances but also the technical and economical feasibility of the measurement tolerances and the suitability of the test result tolerance for the purposes for which the test method will be used. This practice provides guidance only for establishing the consistency of the test method tolerances.

1.6 This practice is presented in the following sections:

1.7 *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 123 Terminology Relating to Textiles[2]

D 2905 Practice for Statements on Number of Specimens for Textiles[2]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[3]

E 456 Terminology Relating to Quality and Statistics[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *determination process*, *n*—the act of carrying out the series of operations specified in the test method whereby a single value is obtained. (Syn. *determination.* See Section 4.)

3.1.1.1 *Discussion*—A determination process may involve several measurements of the same type or different types, as well as an equation by which the determination value is calculated from the measurement values observed.

3.1.2 *determination tolerance*, *n—as specified in a test method*, the exactness with which a determination value is to be calculated and recorded.

3.1.2.1 *Discussion*—In this practice, the determination tolerance also serves as the bridge between the test result tolerance and the measurement tolerances. The value of the determination tolerance calculated from the specified test result tolerance is compared with the value calculated from the specified measurement tolerances.

[1] This practice is under the jurisdiction of ASTM Committee E11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.20on Test Method Evaluation and Quality Control.

Current edition approved March 30, 1984. Published August 1984.

[2] *Annual Book of ASTM Standards*, Vol 07.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

3.1.3 *determination value*, *n*—the numerical quantity calculated by means of the test method equation from the measurement values obtained as directed in a test method. (Syn. *determination.* See Section 4.)

3.1.4 *measurement process*, *n*—the act of quantifying a property or dimension. (Syn. *measurement.* See Section 4.)

3.1.4.1 *Discussion*—One test method determination may involve several different kinds of measurement.

3.1.5 *measurement tolerance, n—as specified in a test method*, the exactness with which a measurement is to be made and recorded.

3.1.6 *measurement tolerance propagation equation*, *n*—the mathematical formula, derived from the test method equation, which shows the dependence of the determination tolerance on the measurement tolerances. (Syn. *propagation equation*.)

3.1.6.1 *Discussion*—Propagation equations and the propagation of errors are discussed in Annex A1.

3.1.7 *measurement value*, *n*—the numerical result of quantifying a particular property or dimension. (Syn. *measurement.* See Section 4.)

3.1.7.1 *Discussion*—Measurement values in test methods are of two general types: those whose magnitude is specified in the test method, such as the dimensions of a specimen, and those whose magnitude is found by testing, such as the measured mass of a specimen.

3.1.8 *propagation equation*, *n*—Synonym of *measurement tolerance propagation equation.*

3.1.9 *test method equation*, *n*—the mathematical formula specified in a test method, whereby the determination value is calculated from measurement values.

3.1.10 *test method tolerances*, *n—as specified in a test method*, the measurement tolerances, the determination tolerance, and the test result tolerance.

3.1.11 *test result*, *n*—a value obtained by applying a given test method, expressed either as a single determination or a specified combination of a number of determinations.

3.1.11.1 *Discussion*—In this practice the test result is the average of the number of determination values specified in the test method.

3.1.12 *test result tolerance*, *n—as specified in a test method*, the exactness with which a test result is to be recorded and reported.

3.1.13 *tolerance terms*, *n*—the individual members of a measurement tolerance propagation equation in which each member contains only one test method tolerance.

3.1.14 For the definitions of other terms used in this practice, refer to Terminology D 123 and Terminology E 456.

4. Discussion of Terms

4.1 *Test Results, Determinations, and Measurements*:

4.1.1 A test result is always a value (numerical quantity), but *measurement* and *determination* are often used as referring to general concepts, processes or values—the context indicating which meaning is intended. In this practice it is necessary to make these distinctions explicit by means of the terms given in Section 3.

4.1.2 The necessary distinctions can be illustrated by a test method for obtaining the mass per unit area of a fabric. Two kinds of measurement are required for each test specimen, length and mass. Two different length measurements are made, the length and the width of the specimen. One determination value of the mass per unit area is calculated by dividing the mass measurement value by the product of the length measurement value and the width measurement value from one specimen.

4.1.3 If the test method directs that mass per unit area determinations are to be made on three test specimens, the test result is the average of the three determination values, each obtained as directed in 4.1.2.

4.2 *Test Method Tolerances*:

4.2.1 The specified measurement tolerances tell the operator how closely observations are to be made and recorded. "Weigh the specimen to the nearest 0.01 g" and "Measure the length of the specimen to the nearest 0.02 in." are examples of typical measurement tolerance specifications in a test method.

4.2.2 The specified determination and test result tolerances tell the operator how many significant digits should be recorded in the determination value and in the test result, respectively.

5. Expressing Test Method Tolerances

5.1 Tolerances in test methods are commonly specified in one of four ways which are combinations of two general distinctions. A test method tolerance may be absolute or relative and may be expressed either as a range having an upper and a lower limit or as the result of rounding-off. These distinctions are illustrated by the following equivalent instructions that are possible in weighing a 5.00 g test specimen:

	Absolute	Relative
Upper and Lower Limit	within ±0.005 g	within ±0.1 %
Rounding-off	to the nearest 0.01 g	to the nearest 0.2 %

5.2 Within one method, state all test method tolerances in either the rounding-off mode or the upper and lower limit mode. The rounding-off mode is preferred for all test methods. Use a series of absolute tolerances for successive levels of a measurement or determination in preference to a relative tolerance.

5.3 The numerical value of a tolerance expressed in terms of rounding-off is twice that for the same tolerance expressed as an upper and lower limit. A discussion of rounding-off appears in Section 3 of Practice E 29 and in Chapter 4 of Ref **(1)**[4]. Numbers are usually rounded-off to the nearest 1, 2, or 5 units in the last place.

6. Tolerance Symbols

6.1 An absolute tolerance is symbolized by a capital delta, Δ, followed by a capital letter designating a measurement value, a determination value or a test result. Thus, ΔA.

6.2 A relative tolerance is symbolized by the absolute tolerance, ΔA, divided by the corresponding measurement value, determination value, or test result, A. Thus, $\Delta A/A$.

6.3 Relative tolerances are expressed as percentages by $100\Delta A/A$. All relative tolerances for a specific test method must be expressed in the same way throughout, either as fractions or as percentages.

[4] The boldface numbers in parentheses refer to the list of references at the end of this standard.

SUMMARY AND USES

7. Summary of Practice

7.1 A specific measurement tolerance propagation equation relating the determination tolerance to the measurement tolerances is derived by applying an adaptation of the law of error propagation to the test method equation. In this measurement tolerance propagation equation, the determination tolerance term should equal the sum of individual measurement tolerance terms.

7.2 Tentative measurement and determination tolerance values are substituted in the propagation equation terms, and the consistency of the selected test method tolerances is judged by the relative magnitudes of the tolerance terms.

7.3 Successive adjustments in the selected test method tolerance values are made until a consistent set of test method tolerances is established.

8. Significance and Use

8.1 In any test method, every direction to measure a property of a material should be accompanied by a measurement tolerance. Likewise, determination and test result tolerances should be specified. This practice provides a method for evaluating the consistency of the test method tolerances specified.

8.2 This practice should be used both in the development of new test methods and in evaluating old test methods which are being revised.

8.3 The test result tolerance obtained using this practice is not a substitute for a precision statement based on interlaboratory testing. However, the measurement tolerances selected by means of this practice will be an important part of the test method conditions affecting the precision of the test method.

MATHEMATICAL RELATIONSHIPS

9. Propagation Equations

9.1 The test method equations by which determination values are calculated from measurement values in textile testing usually involve simple sums or differences, products or ratios, or combinations of these. Measurement tolerance propagation equations for each of these types of relationships are derived in Annex A2 by applying the general measurement tolerance propagation equation, developed in Annex A1, to each of the typical test method equations. Propagation equations for a number of textile test method equations are given in Table A2.1.

9.2 In the following discussion, the determination of mass per unit area is used to illustrate the principles involved in obtaining consistent tolerances.

9.2.1 Eq 1 is a typical mass per unit area equation.

$$W = KM/DE \tag{1}$$

where:

W = the mass per unit area,
K = a constant to change W from one set of units to another,
M = the specimen mass,
D = the specimen width, and
E = the specimen length.

9.2.2 The corresponding propagation equation is Eq 2, derived in A2.4.1.

$$(\Delta W/W)^2/2 = (\Delta M/M)^2 + (\Delta D/D)^2 + (\Delta E/E)^2 \tag{2}$$

where:

$(\Delta W/W)^2/2$ = the mass per unit area determination tolerance term,
$(\Delta M/M)^2$ = the mass measurement tolerance term,
$(\Delta D/D)^2$ = the width measurement tolerance term, and
$(\Delta E/E)^2$ = the length measurement tolerance term.

10. Tolerance Terms

10.1 As shown in Annex A2, every propagation equation can be expressed in the form of $r = a + b + c$ . . ., in which each of the terms of this equation contains only one test method tolerance. The r term contains the determination tolerance, ΔR, and the other terms contain such measurement tolerances as ΔA, ΔB, and ΔC. The terms r, a, b, and c are tolerance terms.

10.1.1 For the mass per unit area example $r = (\Delta W/W)^2/2$, $a = (\Delta M/M)^2$, $b = (\Delta D/D)^2$, and $c = (\Delta E/E)^2$, as can be seen from Eq 2.

NOTE 1—The number of measurement tolerance terms is not restricted to 3, of course, but matches the number of measurements, q, for which tolerances are specified.

10.2 The key to this practice is the recognition that there are two ways of calculating the determination tolerance term:

10.2.1 The determination tolerance term, r, can be calculated from a specified value of ΔR using the expression for r given in the propagation equation. For example, in Eq 2 $r = (\Delta W/W)^2/2$. By substituting a typical value for W and a specified value for ΔW, a value of r is obtained.

10.2.2 The determination tolerance term can also be calculated as the sum of the measurement tolerance terms a, b, c, etc., which have been calculated from specified values of ΔA, ΔB, ΔC, etc. For the mass per unit area example, an estimate of the value of r may be obtained from values of a, b, and c found by substituting values of ΔM, M, ΔD, D, ΔE, and E in the tolerance term expressions $(\Delta M/M)^2$, $(\Delta D/D)^2$ and $(\Delta E/E)^2$.

10.3 These two ways of calculating the determination tolerance term usually produce different results, often radically different. In order to deal with this inconsistency, the second way of calculating the determination tolerance term is labelled u, which equals $a + b + c + \ldots$.

10.3.1 Therefore, in the following sections, r is the determination tolerance term value calculated from the specified determination tolerance by means of the expression for r supplied in the propagation equation, and u is the determination tolerance term value calculated from the specified measurement tolerances by means of the expressions for the measurement tolerance terms, a, b, c, etc., supplied in the propagation equation.

10.3.2 The term, r, is the specified determination tolerance term and u is the effective determination tolerance term.

11. Determination Tolerances

11.1 The propagation equation relates the determination tolerance to the specified measurement tolerances. However, in