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An American National Standard

Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[1]

This standard is issued under the fixed designation E29; 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 U.S. Department of Defense.

1. Scope

1.1 This practice is intended to assist the various technical committees in the use of uniform methods of indicating the number of digits which are to be considered significant in specification limits, for example, specified maximum values and specified minimum values. Its aim is to outline methods which should aid in clarifying the intended meaning of specification limits with which observed values or calculated test results are compared in determining conformance with specifications.

1.2 This practice is intended to be used in determining conformance with specifications when the applicable ASTM specifications or standards make direct reference to this practice.

1.3 Reference to this practice is valid only when a choice of method has been indicated, that is, either *absolute method or rounding method*.

1.4 The system of units for this practice is not specified. Dimensional quantities in the practice are presented only as illustrations of calculation methods. The examples are not binding on products or test methods treated.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E456 Terminology Relating to Quality and Statistics

E2282 Guide for Defining the Test Result of a Test Method

IEEE/ASTM SI 10 ~~Standard for Use of the International System of Units (SI): The Modern Metric System~~American National Standard for Metric Practice

[1] This practice is under the jurisdiction of ASTM Committee E11 on Quality and Statistics and is the direct responsibility of Subcommittee E11.30 on Statistical Quality Control.

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

3. Terminology

3.1 *Definitions*—Terminology E456 provides a more extensive list of terms in E11 standards.

3.1.1 *observed value, n*—the value obtained by making an observation. **E2282**

3.1.2 *repeatability conditions, n*—conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time. **E177**

3.1.3 *repeatability standard deviation (s_r), n*—the standard deviation of test results obtained under repeatability conditions. **E177**

3.1.4 *significant digit*—any of the figures 0 through 9 that is used with its place value to denote a numerical quantity to some desired approximation, excepting all leading zeros and some trailing zeros in numbers not represented with a decimal point.

3.1.4.1 *Discussion*—
This definition of significant digits relates to how the number is represented as a decimal. It should not be inferred that a measurement value is precise to the number of significant digits used to represent it.

3.1.4.2 *Discussion*—
The digit zero may either indicate a specific value or indicate place only. Zeros leading the first nonzero digit of a number indicate order of magnitude only and are not significant digits. For example, the number 0.0034 has two significant digits. Zeros trailing the last nonzero digit for numbers represented with a decimal point are significant digits. For example, the numbers 1270. and 32.00 each have four significant digits. The significance of trailing zeros for numbers represented without use of a decimal point can only be identified from knowledge of the source of the value. For example, a modulus strength, stated as 140 000 Pa, may have as few as two or as many as six significant digits.

3.1.4.3 *Discussion*—
To eliminate ambiguity, the exponential notation may be used. Thus, 1.40×10^5 indicates that the modulus is reported to the nearest 0.01×10^5 or 1000 Pa.

3.1.4.4 *Discussion*—
Use of appropriate SI prefixes is recommended for metric units to reduce the need for trailing zeros of uncertain significance. Thus, 140 kPa (without the decimal point) indicates that the modulus is reported either to the nearest 10 or 1 kPa, which is ambiguous with respect to the number of significant digits. However, 0.140 MPa clearly indicates that the modulus is reported to the nearest 1 kPa, and 0.14 MPa clearly indicates that the modulus is reported to the nearest 10 kPa.

3.1.5 *test result, n*—the value of a characteristic obtained by carrying out a specified test method. **E2282**

4. Significance and Use

4.1 A test result is compared to specification limits to determine conformance with the specification. The test result may be an observed value, calculated from two or more property measurements, or a summary value of multiple test determinations as defined in the test method.

4.2 The unqualified statement of a numerical limit, such as "2.50 in. max," cannot, in view of different established practices and customs, be regarded as carrying a definite operational meaning concerning the number of digits to be retained in an observed or a calculated value for purposes of determining conformance with specifications.

4.3 This practice describes two commonly accepted methods ~~of rounding data,~~ to evaluate conformance of a numerical value to specification, identified as the Absolute Method and the Rounding Method. In the applications of this practice to a specific material or materials it is essential to specify which method is intended to apply. ~~In the absence of such specification, reference to this practice, which expresses no preference as to which method should apply, would be meaningless.~~ The choice of method depends upon the current practice of the particular branch of industry or technology concerned, and should therefore be specified in the prime publication.

~~4.1.1 The unqualified statement of a numerical limit, such as "2.50 in. max," cannot, in view of different established practices and customs, be regarded as carrying a definite operational meaning concerning the number of digits to be retained in an observed or a calculated value for purposes of determining conformance with specifications.~~

4.3.1 *Absolute Method*—In some fields, specification limits of 2.5 in. max, 2.50 in. max, and 2.500 in. max are all taken to imply the same absolute limit of exactly two and a half inches and for purposes of determining conformance with specifications, an

observed value or a calculated value is to be compared directly with the specified limit. Thus, any deviation, however small, outside the specification limit signifies nonconformance with the specifications. This will be referred to as the *absolute method*, which is discussed in Section ~~5~~6.

4.3.2 *Rounding Method*—In other fields, specification limits of 2.5 in. max, 2.50 in. max, and 2.500 in. max are taken to imply that, for the purposes of determining conformance with specifications, an observed value or a calculated value should be rounded to the nearest 0.1 in., 0.01 in., 0.001 in., respectively, and then compared with the specification limit. This will be referred to as the *rounding method*, which is discussed in Section ~~6~~7.

4.4 Section ~~7~~8 of this practice gives guidelines for use in recording, calculating, and reporting the final result for test data.

5. Treatment of Test Results

5.1 Bias adjustments to be applied and criteria for acceptability of the test data should be specified in the test method.

5.2 Unless permitted by the specification or agreed by supplier and receiver, the observed or calculated value for comparison to limits shall not be modified in consideration of measurement uncertainty prior to or subsequent to use of the absolute or rounding method in this standard. When adjustments to the observed or calculated value for comparison to specification based on measurement uncertainty are permitted, the non-adjusted value, adjusted value, and adjustment method shall be reported.

5.3 Unless part of a retest that is compliant with applicable guidelines and is permitted by the specification, test method, or a laboratory procedure, the test result for comparison to specifications shall not be selected among multiple test results of equal validity or repeat testing until a passing value is obtained.

6. Absolute Method

6.1 *Where Applicable*—The absolute method applies where it is the intent that all digits in an observed value or a calculated value are to be considered significant for purposes of determining conformance with specifications. Under these conditions, the specified limits are referred to as absolute limits.

6.2 *How Applied*—With the absolute method, an observed value or a calculated value is not to be rounded, but is to be compared directly with the specified limiting value. Conformance or nonconformance with the specification is based on this comparison.

6.3 *How Expressed*—This intent may be expressed in the standard in one of the following forms:

6.3.1 If the absolute method is to apply to all specified limits in the standard, this may be indicated by including the following sentence in the standard:

> For purposes of determining conformance with these specifications, all specified limits in this standard are absolute limits, as defined in ASTM Practice E29, for Using Significant Digits in Test Data to Determine Conformance with Specifications.

6.3.2 If the absolute method is to apply to all specified limits of some general type in the standard (such as dimensional tolerance limits), this may be indicated by including the following sentence in the standard:

> For purposes of determining conformance with these specifications, all specified (dimensional tolerance) limits are absolute limits, as defined in ASTM Practice E29, for Using Significant Digits in Test Data to Determine Conformance with Specifications.

6.3.3 If the absolute method is to apply to all specified limits given in a table, this may be indicated by including a footnote with the table as follows:

Capacity mL	Volumetric Tolerance[A] ± mL
10	0.02
25	0.03
50	0.05
100	0.10

[A] Tolerance limits specified are absolute limits as defined in Practice E29, for Using Significant Digits in Test Data to Determine Conformance with Specifications.

7. Rounding Method

7.1 *Where Applicable*—The rounding method applies where it is the intent that a limited number of digits in an observed value or a calculated value are to be considered significant for purposes of determining conformance with specifications.

7.2 *How Applied*—With the rounding method, an observed value or a calculated value ~~should be~~ is rounded by the procedure prescribed in ~~4.1.3~~7.4 to the nearest unit in the designated place of figures stated in the ~~standard, as, for example, "to the nearest kPa," "to the nearest 10 ohms," "to the nearest 0.1 percent," etc.~~ standard. The rounded value ~~should then be~~ is compared with the specified limit, and conformance or nonconformance with the specification based on this comparison.

7.2.1 The value as rounded to the decimal places of the specification is not required to be the reported value. Additional figures may be provided to preserve information, and the rounding left implicit (see 8.1). For example, report passing observed or calculated values 0.012 or 0.0003 rather than 0.01 or 0.00 for specification "not more than 0.01," or values 98.65 % or 99.97 % rather than 99 % or 100 % for specification ≥99 %. A test method may also specify the decimals in values to be reported.

7.3 *How Expressed*—This intent may be expressed in the standard in one of the following forms:

7.3.1 If the rounding method is to apply to all specified limits in the standard, and if all digits expressed in the specification limit are to be considered significant, this may be indicated by including the following statement in the standard:

> The following applies to all specified limits in this standard: For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded "to the nearest unit" in the last right-hand digit used in expressing the specification limit, in accordance with the rounding method of ASTM Practice E29, for Using Significant Digits in Test Data to Determine Conformance with Specifications.

7.3.2 If the rounding method is to apply only to the specified limits for certain selected requirements, this may be indicated by including the following statement in the standard:

> The following applies to specified limits for requirements on (tensile strength), (elongation), and (...) given in ..., (applicable section number and title) and (...) of this standard: For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded to the nearest 1 kPa for (tensile strength), to the nearest (1 percent) for (elongation), and to the nearest (...) for (...) in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

7.3.3 If the rounding method is to apply to all specified limits in a table, this may be indicated by a note in the manner shown in the following examples:

7.3.3.1 *Example 1*—Same significant digits for all items:

	Chemical Composition, % mass
Copper	4.5 ± 0.5
Iron	1.0 max
Silicon	2.5 ± 0.5
Other constituents (magnesium + zinc + manganese)	0.5 max
Aluminum	remainder

For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded to the nearest 0.1 percent, in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

7.3.3.2 *Example 2*—Significant digits not the same for all items; similar requirements:

	Chemical Composition, % mass	
	min	max
Nickel	57	...
Chromium	14	18
Manganese	...	3
Silicon	...	0.40
Carbon	...	0.25
Sulfur	...	0.03
Iron	remainder	

For purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded "to the nearest unit" in the last right-hand significant digit used in expressing the limiting value, in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

7.3.3.3 *Example 3*—Significant digits not the same for all items; dissimilar requirements:

	Tensile Requirements
Tensile strength, psi	60 000 to 72 000
Yield point, min, psi	33 000
Elongation in 2 in., min %	22

For purposes of determination of conformance with these specifications, an observed value or a calculated value shall be rounded to the nearest 1000 psi for tensile strength and yield point and to the nearest 1 percent for elongation, in accordance with the rounding method of ASTM Practice E29 Using Significant Digits in Test Data to Determine Conformance with Specifications.

7.4 *Rounding Procedure*—The actual rounding procedure[3] shall be as follows:

7.4.1 When the digit next beyond the last place to be retained is less than 5, retain unchanged the digit in the last place retained.

7.4.2 When the digit next beyond the last place to be retained is greater than 5, increase by 1 the digit in the last place retained.

7.4.3 When the digit next beyond the last place to be retained is 5, and there are no digits beyond this 5, or only zeros, increase by 1 the digit in the last place retained if it is odd, leave the digit unchanged if it is even. Increase by 1 the digit in the last place retained, if there are non-zero digits beyond this 5.

NOTE 1—This method for rounding 5's is not universally used by software packages. For calculations carried out to high numerical precision, the effect is negligible and need not be considered.

7.4.4 This rounding procedure may be restated simply as follows: When rounding a number to one having a specified number of significant digits, choose that which is nearest. If two choices are possible, as when the digits dropped are exactly a 5 or a 5 followed only by zeros, choose that ending in an even digit. Table 1 gives examples of applying this rounding procedure.

7.5 The rounded value should be obtained in one step by direct rounding of the most precise value available and not in two or more successive roundings. For example: 89 490 rounded to the nearest 1000 is at once 89 000; it would be incorrect to round first to the nearest 100, giving 89 500 and then to the nearest 1000, giving 90 000.

[3] The rounding procedure given in this practice is the same as the one given in the *ASTM Manual 7 on Presentation of Data and Control Chart Analysis*.