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Standard Practice for Calculating Precision Data on Refractories (C08) from Interlaboratory Test Results[1]

This standard is issued under the fixed designation C 1095; 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.

ε1 NOTE—Table 1 was corrected editorially in October 1997.

1. Scope

1.1 This practice covers the procedures for calculating the results of an interlaboratory study in order to arrive at a statistical precision statement on refractories.

1.2 The purpose of these calculations is to focus attention on unusual features of the data such as high variability within cells or laboratories and discrepant or unusual results.

1.3 *This standard does not purport to address the safety problems, 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:*

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials[2]

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[3]

E 178 Practice for Dealing with Outlying Observations[3]

E 456 Terminology Relating to Quality and Statistics[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

3. Terminology

3.1 *Symbols*—The symbols in this procedure conform to Practice E 691. The symbols used are as follows:

n = number of test results.
p = number of laboratories.
x = individual test results.
$\bar{x}$ = cell average.
$\dot{x}$ = average of cell averages.
s = cell standard deviation.
d = deviation from average (cell deviation).
S_x = standard deviation of cell averages.
S_r = repeatability standard deviation.
S_R = reproducibility standard deviation.
h = between laboratory deviation.
k = within laboratory deviation.
V_r = coefficient of variation within laboratories.
V_R = coefficient of variation between laboratories.
r = repeatability interval.
R = reproducibility interval.
$\% r$ = relative repeatability interval.
$\% R$ = relative reproducibility interval.

4. Summary of Practice

4.1 This practice presents the statistical calculations needed to obtain a meaningful precision statement from an interlaboratory study.

5. Significance and Use

5.1 Every ASTM test method must have a precision statement which states the level of expected variability of the test method both within a laboratory and between laboratories.

5.2 The practice does not describe how to conduct an interlaboratory study. For details on conducting a test program, refer to Practice E 691.

5.3 This procedure is useful for assessing the quality of the data provided by an interlaboratory study.

5.4 Statistical calculations provide evidence of outliers in the data which are useful in either eliminating data or the recommendation for retests.

5.5 The resultant precision statement is only as good as the parameters and conditions of the interlaboratory protocol. The value of these calculations and procedures is to provide a precision statement based upon statistical evidence.

5.6 The repeatability and reproducibility intervals are specified for a comparison between two test results as defined in Practice E 691.

6. Analysis of Data

6.1 Table 1 shows the necessary calculations representing six laboratories, p, on a single material, q, with the number of replicates $n = 2$. This format lends itself to a simple personal computer (PC) spreadsheet. The steps in this section can also be simply done with a handheld calculator. Examination of these data may lead to reanalysis after elimination of detectable outliers or retests conducted by a laboratory due to an assignable cause.

6.2 *Step 1:*

Calculate the average of each laboratory:

$$\bar{x} = \Sigma x/n \text{ (cell average)}$$

$$\dot{x} = \Sigma \bar{x}/p \text{ (average of cell averages)}$$

[1] This practice is under the jurisdiction of ASTM Committee C-8 on Refractories and is the direct responsibility of Subcommittee C08.93 on Ruggedness and Precision.

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

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

TABLE 1 Precision Calculations for ASTM Committee C-8 Test Methods[A]

Material A (—Thermal Conductivity at 200°C—W/m·K)						
Laboratory	Test Results, x	Cell Average, $\bar{x}$	Cell Standard Deviation, s	Deviation from Average, d	Within Lab Deviations, k	Between Lab Deviations, h
1	12.178 12.167	12.1725	0.0078	−0.2532	0.0203	−0.1208
2	9.788 10.493	10.1405	0.4985	−2.2852	1.3008	−1.0901
3	14.773 13.939	14.3560	0.5897	1.9302	1.5388	0.9207
4	15.086 15.664	15.3750	0.4087	2.9492	1.0665	1.4068
5	12.282 11.975	12.1285	0.2171	−0.2973	0.5664	−0.1418
6	10.570 10.194	10.3820	0.2659	−2.0437	0.6938	−0.9749

[A] Grand average, $\bar{\bar{x}}$ = 12.4258.
Standard deviation from average, S_x = 2.0965.
Repeatability standard deviation within lab, S_r = 0.3832.
Between lab variability – S_R = 2.1139.
Repeatability interval, r = 1.07.
Reproducibility interval, R = 5.92.
Coefficient of variation within labs, V_r = 3.08.
Coefficient of variation between labs, V_R = 17.01.
Relative repeatability interval, % r = 8.64.
Relative reproducibility interval, % R = 47.63.

6.3 *Step 2:*

Calculate the standard deviation:

$$s = [\Sigma (x - \bar{x})^2/n - 1]^{0.5}$$

6.4 *Step 3:*

Calculate the deviation from average:

$$d = \bar{x} - \bar{\bar{x}}$$

6.5 *Step 4:*

Calculate the standard deviation of cell average:

$$S_x = [\Sigma d^2/p - 1]^{0.5}$$

6.6 *Step 5:*

Calculate the repeatability standard deviation:

$$S_r = [\Sigma s^2/p]^{0.5}$$

6.7 *Step 6:*

Calculate the reproducibility standard deviation:

$$S_R = [S_x^2 + S_r^2 (n - 1)/n]^{0.5}$$

6.8 *Step 7:*

Calculate the within laboratory deviation (consistency statistic):

$$k = s/S_r$$

6.9 *Step 8:*

Calculate the between laboratory deviation (consistency statistic):

$$h = d/S_x$$

6.10 *Step 9:*

Calculate the repeatability interval at the 95 % limit:

$$r = 2.8\ S_r$$

6.11 *Step 10:*

Calculate the reproducibility interval at the 95 % limit:

$$R = 2.8\ S_R$$

6.12 *Step 11:*

Calculate the coefficient of variation within laboratories:

$$V_r = (S_r/\bar{\bar{x}})\cdot 100$$

6.13 *Step 12:*

Calculate the coefficient of variation between laboratories:

$$V_R = (S_R/\bar{\bar{x}})\cdot 100$$

6.14 *Step 13:*

Calculate the relative repeatability interval:

$$\%\ r = (r/\bar{\bar{x}})\cdot 100$$

6.15 *Step 14:*

Calculate the relative reproducibility interval:

$$\%\ R = (R/\bar{\bar{x}})\cdot 100$$

7. Outliers

7.1 Table 2 represents a tabulation of critical values, k and h for p laboratories and n number of replicates. Any calculated k or h values that exceed these critical values in Table 2 are at the probability of ~0.5 % as a result of chance alone.

7.2 The values h and k are used to flag unusual cells or data which should lead to an investigation to locate an assignable cause. The results of such an investigation decide whether to retain the unusual data, request a retest, or to delete some data.

7.3 The graphs h and k (see Figs. 1 and 2) are useful in examining such data.

7.3.1 Figure 1 reflects k values (within laboratory consistency), showing that the within-laboratory variability of laboratory three stands out.

7.3.2 Figure 2 shows h values (between laboratory consistency) and clearly shows variability is a function of test temperature.

7.4 Any changes made on the test results due to 7.2 must then recalculate new h and k values.