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Standard Guide for Calculating and Reporting Measures of Precision Using Data from Interlaboratory Wear or Erosion Tests[1]

This standard is issued under the fixed designation G117; 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 guide covers and offers direction on the handling of data from interlaboratory tests for wear or erosion. It describes a format for entering data and for subsequently reporting results on measures of precision in a Committee G02 standard. It indicates methods for calculation of the needed statistical quantities.

1.2 This guide offers guidance based on a Committee G02 consensus, and exists for the purpose of emphasizing the need to use established statistical practices, and to introduce more uniformity in reporting interlaboratory test results in Committee G02 standards.

1.3 An example of how the methods described in this guide may be applied is available in personal computer format (DOS type system) on floppy disk as a spreadsheet (LOTUS, rel. 4) file. The purpose is to facilitate use of the methods in this guide. The example file contains all needed equations in the recommended format and can be edited to accept new data. ASTM Headquarters or the Chairman of G02 should be contacted for a copy of that computer file. The user must have spreadsheet software (for example, LOTUS or compatible) available.

1.4 The methods used in this document are consistent with Practices E691 and E177, and with ADJE0691, Conducting an Interlaboratory Study to Determine the Precision of a Test Method.[2]

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G65 Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus

G76 Test Method for Conducting Erosion Tests by Solid Particle Impingement Using Gas Jets

G77 Test Method for Ranking Resistance of Materials to Sliding Wear Using Block-on-Ring Wear Test

3. Summary of Guide

3.1 Use of this guide in preparation of interlaboratory test results for inclusion in G02 standards involves a sequence of steps. First the raw data from the individual laboratories are entered into a table of any suitable form that permits calculation of average values and standard deviations for each laboratory. Then those two measures are entered, for each laboratory, into a table such as that shown in Fig. 1. Then the steps described in this guide are carried out, leading to calculation of the precision measures that are to be used in the standard being prepared.

4. Significance and Use

4.1 This guide is intended to assist in developing statements of precision and supporting data that will be used in Committee G02 standards. The methods and approach are drawn from Practice E177 and E691. It was felt that preparation of this guide and its use in Committee G02 would lead to appropriate statistical analyses and more uniformity in G02 standards regarding reporting of interlaboratory results and precision. The guide is not meant to substitute for possible use of Practices E177 or E691 in developing committee standards.

5. Procedure

5.1 An example of interlaboratory data analyzed and presented in the recommended format is shown in Fig. 1. The data were obtained from an interlaboratory series of solid particle erosion tests carried out in connection with Practice G76. This table format can be used with either PC spreadsheet calculation or hand calculation.

5.2 Data tabulation and calculation can be carried out by use of a PC and numeric spreadsheet software (for example,

[1] This guide is under the jurisdiction of ASTM Committee G02 on Wear and Erosion and is the direct responsibility of Subcommittee G02.20 on Data Acquisition in Tribosystems.

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[2] Available from ASTM International Headquarters. Order Adjunct No. ADJE0691. Original adjunct produced in 1990.

[3] 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.

	A	B	C	D	E	F	G	H
1	ASTM G-2 INTERLABORATORY TEST DATA - STATISTICAL ANALYSIS (G117_93 ver.2)							
2								
3								
4					WITHIN-LAB	REPEATABILIT'	BETWEEN-LAB	REPRODUCIBILITY
5	TEST	LAB	NUMBER OF	AVERAGE	STD DEV	k STATISTIC	DEV FROM AVG	h STATISTIC
6	CONDITIONS	#	REPLICATES	(units)	(units)		(units)	
7		----	----------	-------	------		------	
8	List key	1	3	9.800	0.500	1.100	1.100	0.434
9	information,..	2	3	10.500	0.100	0.220	1.800	0.710
10	.....	3	3	5.800	0.600	1.320	-2.900	1.144
11								
12		------	------	------	------		------	
13		3	3	8.700	0.455		2.563	
14		NUMBER	AVERAGE	AVERAGE	WITHIN-LAB		BETWEEN-LAB	
15					STD DEV		STD DEV (PROV)	
16								
17				C.O.V. (%) =	5.2		29.5	
18								
19				95 % LIMITS=	1.27		7.18	
20	** USE THE LARGER OF THE **				WITHIN-LAB		BETWEEN-LAB	
21	** 95% LIMITS FOR THE FINAL VALUE **							
22					k crit =	1.67	h crit =	1.15
23								
24					k and h values greater than k crit and h crit			
25	18-Nov-97				suggest those data should be examined for 'outliers'.			
26								
27								
28	*Recommended statement of precision:*				The average test value was 8.70(units)			
29					with a 95% repeatability limit (within-lab) of 1.27(units)			
30					and a 95% reproducibility limit (between-labs) of 7.18(units) .			
31								
32								

NOTE 1—Column and row labels A, B, . . . and 1, 2, . . . are not required.

FIG. 1 Example of Recommended Format for Data Analysis

LOTUS), as described in Table 1, or by any other appropriate means such as hand calculation (Table 2). The formulae were obtained from Practices E177 or E691 or from statistical analysis texts. Formulae that are used for calculation are given in Table 1 for spreadsheet calculation (for example, LOTUS) and in Table 2 for hand calculation.

5.3 The sequence of steps in assembling and handling the data is as follows (refer to the designated columns in Fig. 1):

5.3.1 Calculate the *average* value of the data for each of *N* laboratories. (Column D)

5.3.2 Calculate the *average* value *Q* of all the laboratory averages. (Cell D13)

TABLE 1 Formulae Used in PC Spreadsheet Shown in Fig. 1, in Notation Appropriate to Spreadsheet Software (for example, LOTUS)[A]

B13:	@COUNT(B8..B11)
C13:	@AVG(C8..C11)
D13:	@AVG(D8..D11)
E13:	@SQRT((@SUM(K8 . . K11))/B13)
G13:	@SQRT((@SUM(L8..L11))/(B13-1) + E13*E13*(C13-1)/C13)
	where:
	F8: +E8/ E13 — H8: @ABS(+G8/ L13)
	K8: +E8*E8 — L8: +G8*G8
	and so forth — and so forth
L13:	@SQRT((@SUM(L8..L11))/(B13-1)
E17:	100*E13/D13
G17:	100*G13/ D13
E19:	2.8*E13
G19:	2.8*G13

[A] *N* is used as the divisor in (E12) to obtain the mean value of the variance, while *N*-1 is used as the divisor in calculating individual standard deviations (E7..E9) since they are estimates of population values. Practice E691 should be consulted for further explanation.

TABLE 2 Formulae Used in Calculating Quantities for Fig. 1, Given in Usual Mathematical Notation

B13:	$N = \sum n$	Number of laboratories
C13:	$R = (1/N)\cdot\sum r$	Average number of replicates
D13:	$Q = (1/N)\cdot\sum q$	Average of the quantity measured
E13:	$W = [(1/N)\cdot\sum s^2]^{0.5}$	Within-laboratory standard deviation
G13:	$B = [(1/(N-1))\cdot\sum(q-Q)^2 + (1/N)\cdot\sum s^2\cdot(R-1)/R]^{0.5}$	
F8:	s/W	*h*-statistic
H8:	d/s_x	*k*-statistic
K8:	s^2	cell standard deviation
L8:	d^2	cell deviation squared
L13:	$[(1/(N-1)\cdot\sum(q-Q)^2]^{0.5}$	standard deviation of cell averages
		Provisional between-laboratory standard deviation
E17:	100·W/Q	Percent coefficient of variation, within-laboratory
G17:	100·B/Q	Percent coefficient of variation, between-laboratory
E19:	2.8·W	95 % confidence limits, within-laboratory
G19:	2.8·B	95 % confidence limits, between-laboratory

5.3.3 Calculate the *standard deviation* values for each laboratory. Note that the quantity $(r - 1)$ is used as the divisor where *r* is the number of replicate results for each laboratory. (Column E)

5.3.4 Calculate the *within-laboratory standard deviation* value *W*. Note that this is the root-mean-square value of the laboratory standard deviations, using *N* as the divisor. This quantity is also called the repeatability standard deviation. (Cell E13)

5.3.5 Calculate the *within-laboratory coefficient of variation* in percent. (Cell E17)

5.3.6 Calculate the *k*-statistic values for each laboratory, by dividing each laboratory standard deviation by the within-laboratory standard deviation. (Column F)

5.3.7 Calculate the *deviation* of the average for each laboratory from the average for all laboratories. (Column G)

5.3.8 Calculate the *between-laboratory standard deviation* value *B*. Note that this is the square root of the sum of the mean-square value of the deviations from the average, using $N - 1$ as the divisor, and the square of the within-laboratory standard deviation multiplied by the quantity $(r - 1)/r$. This is also called the provisional reproducibility standard deviation. (Cell G13)

NOTE 1—It is termed provisional since the final reproducibility standard deviation will be the larger of the two calculated measures, the repeatability and the reproducibility standard deviations.

5.3.9 Calculate the *between-laboratory coefficient of variation* in percent. (Cell G17)

5.3.10 Calculate the *h*-statistic values for each laboratory, by dividing each laboratory deviation from average by the between-laboratory standard deviation. (Column H)

5.3.11 Select the larger of the two quantities calculated in 5.3.4 and 5.3.8 for the (final) reproducibility standard deviation. An example is shown at the bottom of Fig. 1.

5.3.12 Calculate the *95 % limits of repeatability and reproducibility* by multiplying the within-laboratory standard deviation and the (final) between-laboratory standard deviation, respectively, by the factor, 2.8×. (Cells E19 and G19)

NOTE 2—These limits are the maximum differences between two test results that can be expected to occur in 95 % of the cases.

5.3.13 Refer to Practice E691, Table 12, and determine critical values of *k* and *h* for the number of laboratories and replicates involved. Examine the values in the *k*-statistic and *h*-statistic columns. Any values greater than the respective critical values indicate data outliers for that laboratory which should be inspected for validity. (Cells F22 and H22)

6. Report

6.1 Examples of the recommended tabular format for the results of the calculations are shown in Fig. 2 for three standards from Committee G02.

6.2 A recommended version of a statement of precision, drawn from Practice E177, is as follows for the example shown in Fig. 1:

Average Test Value:	8.70 mm^3/g
95 % repeatability limit (within-lab)	1.27 mm^3/g
95 % reproducibility limit (between-labs)	7.18 mm^3/g

7. Keywords

7.1 erosion; precision; repeatability; reproducibility; wear