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IPC-TM-650
TEST METHODS MANUAL

Number **1.8**	
Subject **Measurement Precision Estimation for Binary Data**	
Date **01/03**	Revision **A**
Originating Task Group **Measurement Precision Task Group (7-11a)**	

1 Scope Tests performed on presumably identical samples under seemingly identical conditions do not always yield identical results. This is due to errors inherent in every measurement or evaluation. During the development of a new test procedure or use of an existing test procedure, this variability must be understood and precautions taken to ensure that it is controlled to within necessary limits. Performance of this test method will help to estimate measurement error and troubleshoot causes of measurement variability. Use of this test method will provide some evidence that a new test procedure is suitable for use when submitted for review, or an existing test procedure is capable of measuring the applicable parameter.

This method provides a standard procedure for determining the precision of a test method involving binary data or tests that result in two outcomes. These include evaluations where the results are recorded as pass/fail or go/no-go. Examples include solderability tests and visual inspections. This method helps to estimate how often the disposition is performed correctly.

This method is not useful for measurements which result in variables data, or where more than three repeated measurements or more than ten testers are used. These situations are covered under other methods (see 6.1).

1.1 Definitions

Accuracy – The difference between an observed measurement and the true (but perhaps unknown) value being measured.

Precision – The closeness to each other of repeated measurements of the same quantity.

Binary Data – Inspections or tests in which parts are placed in one of two classes. This includes pass/fail, go/no-go tests and inspections.

2 Applicable Documents The test procedure under evaluation.

3 Test Specimens The test specimens used will be as specified in the test procedure under investigation.

The number and types of test materials to be used will depend on the range of levels in the class of materials to be tested. If it is known that precision is worse at one end of the range, evaluation could be limited to that end of the range. In general, evaluations are generally advisable for all combinations of materials, levels, set-ups, and conditions. If resources are limited, begin the study with those combinations deemed to be the most critical, or where measurement error is likely to be greatest.

The number of samples will also depend on the difficulty involved in obtaining, processing, and distributing the test specimens, the difficulty, length of time required for, and expense of performing the test, and other prior known information.

This test method will assume that evaluations can be repeated on the same samples. For situations where this is not possible or the sample is consumed during the test, other methods may be better suited (see 6.1).

4 Apparatus The apparatus used will be as specified by the test procedure under investigation.

5 Procedure

5.1 Planning Evaluation Keep the evaluation as simple as possible to obtain data that is free of unintended secondary effects.

Prepare a procedure that is complete and describes the test parameters as well as recommended techniques for assessing the outcome. Include known best practices and draw extensively on the experience of test users.

The method used in this procedure allows for up to 10 test conditions. Solicit participants from among the community of facilities with the proper equipment, competent operators and familiarity with the test. In order to obtain representative precision estimates, do not select only from a small group of users who are considered exceptionally qualified. Be sure to specify any special calibration procedures or material preparation requirements.

The analysis method used in this procedure allows for up to 10 repeated evaluations per sample. Carefully evaluate the materials to determine the appropriate classification or disposition before the study. Choose material representing a likely range of conditions normally encountered during routine tests or inspections. Randomize the samples prior to dividing into test groups. Prepare more than the material required to ensure an adequate amount is available for the study in case of lost or damaged specimens, errors, test set-up, etc.

Carefully package and label the material. Assign serial numbers, if possible. Identify the version of the test procedure. Specify care and handling procedures. Provide a data sheet, and describe any documentation required. Require a test log, and insist that observations of any unusual events be recorded.

5.2 Conducting the Evaluation Ensure the samples are inspected on receipt. Send replacement material if damaged or tests are performed improperly.

Inspect the data sheets when returned. Review the test logs for unusual events. Review the results. Question unusual dispositions or comments. Incorrect dispositions and typos must be fixed prior to analysis.

5.3 Analyzing the Data Analysis may be performed on the data sheet or on the Excel spreadsheet (see 6.2).

The basic techniques involve beginning with a set of parts or materials for which the classification has been previously determined. Several inspectors or testers then examine and classify the parts and the results are compared with the known standard classification.

The effectiveness of the test is the number of correct determinations divided by the total number of classification opportunities (number of parts times the number of inspectors).

$$E = \frac{\text{Number of correct dispositions}}{\text{Number of parts x Number of testers}} \quad (1)$$

The probability of a false reject and the probability of a false accept can be defined as follows:

$$P(FR) = \frac{\text{Number of dispositions where good parts were rejected}}{\text{Number of good parts x Number of testers}} \quad (2)$$

$$P(FA) = \frac{\text{Number of dispositions where bad parts were accepted}}{\text{Number of bad parts x Number of testers}} \quad (3)$$

5.4 Preparing Analysis Conclusions Goals for measurement precision should be established before the study begins. The goals should be established using knowledge of the anticipated levels of product variability (or process capability), specifications, customer needs and the possible impact of dispositioning test samples improperly. As a rule of thumb, the guidelines shown in Table 1 have been extensively applied.

Table 1 Recommended evaluation criteria

Metric	Acceptable	Marginal	Inadequate
E	>0.9	0.8 to 0.9	<0.8
P(FR)	<0.05	0.05 to 0.10	>0.10
P(FA)	<0.02	0.02 to 0.05	>0.05

If the test effectiveness is inadequate, then steps should be taken to diagnose and improve the causes of the deficiency. The probabilities of false acceptance and false rejection should help in this diagnosis. Marginal tests should also be improved.

An acceptable test effectiveness rating (E) indicates that the test method dispositions the products with reasonable correctness.

The results of this evaluation should be compared to the test efficiency goals for this inspection. The rules of thumb noted above have been found to be useful. These goals could be amended, depending on the criticality of the inspection, and the impact of incorrect disposition.

6 Notes

6.1 Methods for Analyzing Repeatability and Reproducibility This test method covers situations where the measurements result in binary data, such as go and no-go, or pass and fail tests. The precision of the test is determined by calculating the consistency and correctness of the sample dispositions.

Measurements that result in variables data can be analyzed using IPC Test Method IPC-TM-1.9.

In some cases, the measurement cannot be repeated more than once on the same sample. This is common where the sample is consumed during the test, such as chemical analysis, or changed during testing, such as solderability evaluations. In these cases, the analysis using a modified average and range method is possible. This method is under development.

6.2 References

a. ISO 5725-1 Accuracy (trueness and precision) of measurement methods and results (parts 1 to 6), 1998(E), International Organization for Standardization, Geneva, Switzerland (www.iso.org).

b. Measurement Systems Analysis, 2nd edition, June 1998, Automotive Industry Action Group (AIAG), 26200 Lahser Road, Southfield, MI 48034 (www.aiag.org).

c. Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method, E691-99, ASTM, Philadelphia, PA (www.astm.org).

d. Concepts for R&R Studies, Larry B. Barrentine, (ISBN 0-87389-108-2), ASQC Press, Milwaukee, WI ((www.qualitypress.asq.org).

e. Basic Statistics, 4th Edition, Mark J. Kiemele, Stephen R. Schmidt, Ronald Berdine, Air Academy Press, 1997, ISBN 1-880156-06-7, pages 9-71 to 9-77

f. ''Is 100% Test 100% Effective,'' W. Russell, 1998 IPC EXPO, San Jose, CA (gives methods for calculating the likely outcomes on product test for differing levels of measurement precision.)

6.3 Software Measurement precision studies are greatly facilitated by use of software to perform the calculations. Below are just a few of the many software packages which can be used for this purpose. Reference (a) is an Excel spreadsheet written to perform the calculations in this procedure.

a. Measurement Precision Calculator For Binary Data, Excel spreadsheet, available at http://www.ipc.org/html/testmethods.htm, free of charge.

b. Statgraphics Plus, Manugistics Corp, 2115 East Jefferson Street, Rockville, MD, 20852-4999 (www.statgraphics.com).

c. SPC XL, Air Academy Press, 1155 Kelly Johnson Blvd, Colorado Springs, CO 80920 (www.airacad.com).

d. Minitab, Minitab. Inc., 3081 Enterprise Dr, State College, PA 16801 (www.minitab.com).

e. Interlaboratory Data Analysis Software for E691, ASTM, 100 Barr Harbor Dr, West Conshohocken, PA 19428 (www.astm.org).

Measurement Precision Study – Binary Data

Table 1: Data Entry Form

Enter test results into the table below.

Tester	Samples									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
True Standard										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

Calculations

Table 2: Samples Dispositioned Correctly

Score a "1" where disposition in Table 1 above matched the true standard.
Score a "0" where disposition did not match the true standard.
Note these scores for each of the testers in the table below.

Tester	Samples										Total
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
True Standard											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Table 3: Good Parts That Were Rejected

Score a ''1'' where good parts were rejected in Table 1 above.
Score a ''0'' everywhere else.
Note the scores for each tester in the table below.

	Samples										
Tester	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
True Standard											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Table 4: Bad Parts That Were Accepted

Score a ''1'' where bad parts were accepted in Table 1 above.
Score a ''0'' everywhere else.

	Samples										
Tester	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
True Standard											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Table 5: Measurement System Scorecard

	Tester										
Results	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Total**
Disposed correctly											
Good and rejected											
Bad and accepted											

Total tests		Number of testers times the number of parts.
Acceptable parts		Count acceptable parts in the True Standard line of the data input table.
Rejectable parts		Count rejectable parts in the True Standard line of the data input table.
# of testers		Count the number of participants.

Table 6: Measurement System Effectiveness

Metric	Calculation	Result	Acceptable	Needs Improvement
Test effectiveness (%)	$\frac{\text{Total parts dispositioned correctly}}{\text{Total parts tested}} \times 100$		>90	<80
Probability of false rejects (%)	$\frac{\text{Total good and rejected parts}}{\text{(No. of testers) x (Good parts)}} \times 100$		<5	>10
Probability of false acceptance (%)	$\frac{\text{Total bad and accepted parts}}{\text{(No. of testers\} x (Bad parts)}} \times 100$		<2	>5