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Standard ~~Test Method~~ Guide of Variables Sampling of Metallic and Inorganic Coatings[1]

This standard is issued under the fixed designation B762; 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 ~~test method~~ guide provides sampling plans that are intended for use in the inspection of metallic and inorganic coatings on products for the purpose of deciding whether submitted lots of coated products comply with the specifications applicable to the coating.

1.2 The sampling plans are variables plans. In plans of this type, several articles of product are drawn from a production lot. A characteristic of the coating on the drawn articles is measured. The values obtained are used to estimate the number of articles in the lot that do not conform to a numerical limit, for example a minimum thickness. The number is compared to a maximum allowable.

1.3 Variables plans can only be used when the characteristic of interest is measurable, the test method gives a numerical measure of the characteristic, and the specification places a numerical limit on the measured value. It is also necessary that the variation of the characteristic from article to article in a production lot be normally distributed (see Appendix X2). Each article must be tested in the same way (for example, coating thickness must be measured at the same location, see X2.7) so that the values from article to article are comparable. If one or more of these conditions are not met, a variables plan cannot be used. Instead, an attributes plan must be used. These are given in ~~Test Method~~ Guide B602 and Guide B697.

1.4 *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~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *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]

B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

B697 Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings

2.2 *ANSI Standards:*[3]

ANSI/ASQC Z1.9-1979 Sampling Procedures and Tables for Inspection by Variables for Percent Non-Conformance

ANSI/ASQC Z1.4-1981 Sampling Procedures and Tables for Inspection by Attributes

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[1] This ~~test method~~ guide is under the jurisdiction of ASTM Committee B08 on Metallic and Inorganic Coatings and is the direct responsibility of Subcommittee B08.10 on Test Methods.

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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] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

2.3 *Military Standards:*[4]
MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-414 Sampling Procedures and Tables for Inspection by Variables for Percent Defective

3. ~~Definitions~~ Terminology

3.1 *destructive ~~test~~ test, n*—test that destroys the tested article or makes it nonconforming to a requirement.

~~3.2 *nondestructive test*—test that neither destroys the tested article nor makes it nonconforming to a requirement.~~

3.2 *inspection ~~lot~~ lot, n*—collection of articles of the same kind that is submitted to inspection for acceptance or rejection as a group.

3.3 *nondestructive test, n*—test that neither destroys the tested article nor makes it nonconforming to a requirement.

3.4 *~~sample~~ sample, n*—articles randomly selected from an inspection lot whose quality is used to decide whether or not the inspection lot is of acceptable quality.

3.5 *standard ~~deviation~~ deviation, n*—measure of dispersion equal to the square root of the mean of the squares of the deviations from the arithmetic mean of the distribution (see 9.2.6).

4. Summary of ~~Test Method~~Guide

4.1 The plans in this ~~test method~~ guide provide the same protection as the attributes plans in Tables 1, 2, and 3 of ~~Test Method~~ Guide B602 and are interchangeable with them when the conditions necessary for variables sampling exist. This method has no plan comparable to Table 4 of ~~Test Method~~ Guide B602, because variables plans are subject to an excessive probability of error when the number of nonconforming articles in a lot is expected to be approximately 1 % or less as it is for the Table 4 plan. Also for this reason, comparable variables plans are not given for the smallest lot sizes of Tables 1 and 2 of ~~Test Method~~ Guide B602. The plans of Table 4, and Tables 1 and 2 in ~~Test Method~~ Guide B602 are described as Level I, Level II, and Level III, respectively. For consistency, Table 1 and Table 2 of this ~~method~~guide are described as Level II since they are comparable to Table 1 of ~~Test Method~~ Guide B602, and Table 3 and Table 4 are described as Level III.

4.2 The main advantage of a variables sampling plan over an attributes plan is that fewer articles need to be inspected to obtain the same protection. For example, a sample of 12 using variables can give the same protection as a sample of 50 using attributes. On the other hand, more expensive test methods may be required to yield the measurements required by variables sampling.

TABLE 1 Level II—Sampling Plans for Nondestructive Tests, Standard Deviation Known[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point	AOQL
91 through 280	7	1.664	1.1	12	4.8	2.4
281 through 500	12	1.649	1.7	10	5.0	2.6
501 through 1 200	16	1.712	1.7	8.2	4.4	2.3
1 201 through 3 200	25	1.704	2.1	7.4	4.4	2.5
3 201 through 10 000	36	1.778	2.0	5.9	3.8	2.2
10 001 through 35 000	52	1.829	2.0	4.9	3.4	2.1
Over 35 000	82	1.893	1.9	4.0	2.9	1.9

[A] The AQL, LQL, 50/50 Point, and AOQL are in percent.

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

TABLE 2 Level II—Sampling Plans for Nondestructive Tests, Standard Deviation Unknown[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point	AOQL
91 through 280	16	1.663	1.0	12	4.8	2.4
281 through 500	29	1.649	1.7	10	5.0	2.6
501 through 1 200	40	1.713	1.7	8.2	4.3	2.2
1 201 through 3 200	61	1.704	2.1	7.4	4.4	2.5
3 201 through 10 000	92	1.778	2.0	5.9	3.8	2.2
10 001 through 35 000	137	1.825	2.0	4.9	3.4	2.0
Over 35 000	223	1.893	1.9	4.0	3.0	1.9

[A] The AQL, LQL, 50/50 Point, and AOQL are in percent.

TABLE 3 Level III—Sampling Plans for Nondestructive Tests, Standard Deviation Known[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point	AOQL
51 through 150	6	1.432	1.8	18	7.6	3.8
151 through 280	10	1.411	2.7	16	7.9	4.1
281 through 500	14	1.470	2.8	13	7.1	3.5
501 through 1 200	23	1.492	3.3	11	6.8	3.8
1 201 through 3 200	30	1.551	3.2	9.4	6.0	3.5
3 201 through 16 000	44	1.618	3.1	7.7	5.3	3.2
16 001 through 35 000	66	1.680	3.0	6.4	4.6	3.0
Over 35 000	103	1.719	3.0	5.6	4.4	2.9

[A] The AQL, LQL, 50/50 Point, and AOQL are in percent.

TABLE 4 Level III—Sampling Plans for Nondestructive Tests, Standard Deviation Unknown[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point	AOQL
51 through 150	12	1.433	1.7	19	7.6	3.8
151 through 280	19	1.410	2.6	16	7.9	3.7
281 through 500	29	1.470	2.8	13	7.1	3.8
501 through 1 200	48	1.494	3.3	11	6.7	3.8
1 201 through 3 200	66	1.551	3.2	9.4	6.0	3.5
3 201 through 16 000	102	1.618	3.1	7.7	5.3	3.2
16 001 through 35 000	159	1.680	3.0	6.4	4.6	3.0
Over 35 000	248	1.717	3.0	5.6	4.3	2.9

[A] The AQL, LQL, 50/50 Point, and AOQL are in percent.

4.3 Generally, thickness is the only characteristic of a coating that meets the conditions of a variables plan given in 1.3. For that reason, the plans in this method are designed to be used when the specification for the characteristic in question is a minimum value, which is the usual case for coating thickness. Variables plans can be used when the limit is a maximum and when there are both a minimum and a maximum. Plans for these cases are given in the references.

4.4 The sampling plans in Tables 1 and 2 of this ~~test method~~ guide are considered to be standard for nondestructive testing and will be used unless the buyer specifies otherwise. Tables 5 and 6 will be used for destructive testing; these plans use smaller samples to reduce the cost of inspection with a resultant reduction of the ability to distinguish between conforming and nonconforming lots.

4.5 Additional variables plans are given in Appendix X3. Also found there are instructions for the calculation of plans for needs that are not covered.

5. Significance and Use

5.1 Sampling inspection permits the estimation of the overall quality of a group of product articles through the inspection of a relatively small number of product articles drawn from the group.

5.2 The specification of a sampling plan provides purchasers and sellers a means of identifying the minimum quality level that is considered to be satisfactory.

5.3 Because sampling plans yield estimates of the quality of a product, the results of the inspection are subject to error. Through the selection of a sampling plan, the potential error is known and controlled.

5.4 Sampling inspection is used when a decision must be made about what to do with a quantity of articles. This quantity may be a shipment from a supplier, articles that are ready for a subsequent manufacturing operation, or articles ready for shipment to a customer.

5.5 In sampling inspection, a relatively small number of articles (the sample) is selected randomly from a larger number of articles (the inspection lot); the sample is inspected for conformance to the requirements placed on the articles. Based on the results, a decision is made whether or not the lot conforms to the requirements.

5.6 Since only a portion of a production lot is inspected, the quality of the uninspected articles is not known. The possibility exists that some of the uninspected articles are nonconforming. Therefore, basic to any sampling inspection plan is the willingness of the buyer to accept lots that contain some nonconforming articles. The number of nonconforming articles in accepted lots is controlled by the size of the sample and the criteria of acceptance that are placed on the sample.

5.7 Acceptance sampling plans are used for the following reasons:

5.7.1 When the cost of inspection is high and the consequences of accepting a nonconforming article are not serious.

5.7.2 When 100 % inspection is fatiguing and boring and, therefore, likely to result in errors.

5.7.3 When inspection requires a destructive test, sampling inspection must be used.

5.8 In acceptance sampling by variables, the coating characteristic of each article in the sample is measured. Using the arithmetic mean of these values, the standard deviation of the process, and the factor *k* that is found in the Tables, a number is calculated (see 9.3). If this number equals or exceeds the specified minimum, the inspection lot conforms to the requirements. If it is less, the lot does not conform. If the standard deviation of the process is not known, the standard deviation of the sample is calculated and used.

TABLE 5 Sampling Plans for Destructive Tests, Standard Deviation Known[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point
26 through 1 200	5	1.262	2.3	25	10
1 201 through 35 000	10	1.411	2.7	16	7.9
Over 35 000	14	1.519	2.5	12	6.5

[A] The AQL, LQL, and 50/50 Point are in percent.

TABLE 6 Sampling Plans for Destructive Tests, Standard Deviation Unknown[A]

Inspection Lot Size	*n*	*k*	AQL	LQL	50/50 Point
26 through 1 200	9	1.181	2.8	27	12
1 201 through 35 000	19	1.412	2.5	16	7.9
Over 35 000	34	1.497	2.8	12	6.7

[A] The AQL, LQL, and 50/50 Point are in percent.

5.9 The use of a sampling plan involves the balancing of the costs of inspection against the consequences of accepting an undesirable number of nonconforming articles. There is always a risk that a random sample will not describe correctly the characteristics of the lot from which it is drawn, and that an unacceptable lot will be accepted or an acceptable lot will be rejected. The larger the sample, the smaller this risk but the larger the cost of inspection.

5.10 To understand the risks, consider that if every article in an inspection lot conforms to its requirements, every article in the sample will conform also. Such lots will be accepted (Note 1). If only a few articles in an inspection lot are nonconforming, the sample probably will indicate that the lot is acceptable; but there is a small probability that the sample will indicate that the lot is unacceptable. The larger the proportion of nonconforming articles in an inspection lot, the more likely it will be that the sample will indicate that the lot is unacceptable. If every article in an inspection lot is nonconforming, a sample will always indicate that the lot is unacceptable.

NOTE 1—Throughout this method, it is assumed that no mistakes are made in sampling, measurement, and calculation.

5.11 The probability of accepting an inspection lot that contains nonconforming items is often described in terms of the Acceptable Quality Level (AQL) and the Limiting Quality Level (LQL). The AQL is the quality level that is considered to be acceptable. The LQL is a quality level that is considered to be barely tolerable. A sampling plan is selected that has a high probability of accepting lots of AQL quality and of rejecting lots of LQL quality. In this method, the AQL given for a sampling plan is the quality level of lots (expressed as the percentage of nonconforming articles) that have a 95 % probability of being accepted. The LQL is the quality level of lots that have a 10 % probability of being accepted or, in other words, a 90 % probability of being rejected. The tables in this method give the AQL and LQL of each plan. They also give the 50/50 point, the quality level of a lot that is just as likely to be accepted as rejected.

5.12 The disposition of nonconforming inspection lots is beyond the scope of this method because, depending on the circumstances, lots may be returned to the supplier, kept and used, put to a different use, scrapped, reworked, or dealt with in some other way. An alternative is rectifying inspection in which rejected lots are screened and used.

5.13 In rectifying inspection, when an inspection lot is rejected, all of the articles in the lot are inspected and nonconforming ones are removed. They may be replaced with conforming articles. The now 100 % conforming lot is accepted. With this practice, the average quality level for a series of lots taken as a whole will be better because of the addition of the 100 % conforming lots. When the incoming lots are of a good quality level, the average quality level of a series of lots will be even better when the rejected lots are screened and resubmitted. When incoming lots are of a poor quality level, the average quality of a series of accepted lots will again be good because many of the incoming lots will be rejected and upgraded. At intermediate quality levels of incoming lots, the average quality level of a series of accepted lots will again be improved, but it will not be improved as much as in either of the above cases; and there will be an intermediate quality level where the degree of improvement is the least. This improved quality level is called the Average Outgoing Quality Limit (AOQL). It is the worst condition that can occur under rectifying inspection. The tables give the AOQL for each plan. There is no AOQL for the plans used with destructive tests because destructive tests cannot be used to screen rejected lots.

NOTE 2—The AOQLs given in the tables are strictly correct only when the sample is small with respect to the lot. If this is not the case, the correct AOQL will be smaller than the tabulated value. The correct values are obtained by multiplying the tabulated values by the following equation:

$$1 - \text{sample size/lot size} \quad (1)$$

5.14 Rectifying inspection will substantially increase the cost of inspection if the incoming lots are much worse than AQL quality.

5.15 Rectifying inspection is used only when required by the purchaser.

6. Ordering Information

6.1 Unless otherwise specified by the purchaser, the sampling plans given in Tables 1 and 2 will be used for nondestructive testing, and the plans given in Tables 5 and 6 for destructive testing.

6.2 When either a nondestructive or a destructive test can be used to inspect an article for conformance to a particular requirement, the purchaser should specify which test is to be used. When a test is neither clearly nondestructive nor destructive, the purchaser should specify which it is considered to be.

NOTE 3—The nature of a destructive test can be such that the tested article can be reclaimed, for example by stripping and reapplying the coating. Other tests can destroy the coating in nonessential locations, in which case the article can still be functional. In these instances, the purchaser needs to decide and state whether the tests are to be considered destructive or nondestructive.

6.3 Rectifying inspection will be used only when specified by the purchaser. When rectifying inspection is used, nonconforming articles will be replaced with conforming ones only when specified by the purchaser.

7. Formation of Inspection Lot

7.1 An inspection lot shall be formed from articles that are of the same kind, that have been produced to the same specification, and that have been coated by a single supplier at one time or at approximately the same time under essentially identical conditions.

NOTE 4—These requirements are intended to ensure that the lot is homogeneous and that variations between articles in the lot are the result only of the inherent variation of the production process (see Appendix X1).

8. Sampling

8.1 *General*—A sample shall be selected randomly from the inspection lot. If the test method to be used is nondestructive, the sample size shall be that directed in 8.2. If the test method is destructive, the sample size shall be that directed in 8.3.

8.2 *Nondestructive Tests*—For nondestructive testing, the size of the sample shall be that specified for the sampling plan level that is required by the purchaser. The sampling plans are given for Level II in Tables 1 and 2 and for Level III in Tables 3 and 4. If the purchaser does not specify the level, Level II shall be used. The plans in Table 1 and Table 3 shall be used when the standard deviation of the coating process is known. Tables 1 and 2 plans shall be used when the standard deviation is not known and must be estimated from the sample values.

8.3 *Destructive Tests*—For destructive testing, the size of the sample shall be that specified in Table 5 when the standard deviation of the process is known and Table 6 when it is not known.

8.4 The sample shall be drawn randomly from the inspection lot, that is, in a manner that ensures each article an equal chance of being selected regardless of other considerations such as location in the inspection lot, appearance, quality, location on a fixture during coating, and chronological relationship to the other articles. Random sampling procedures are given in the Appendixes.

9. Calculations

9.1 Calculate the arithmetic mean of the measured characteristic by adding the values obtained for the articles and dividing the number of articles that were tested using the following equation:

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n} \tag{2}$$

where:

$\bar{X}$ = arithmetic mean of the measured values,
X_i = measured value,
$\sum_{i=1}^{n} X_i$ = sum of the measured values, and

n = number of articles tested.

9.2 If the standard deviation of the coating process is known, continue the calculations as directed in 9.3. The symbol for the standard deviation for the process is σ. If the standard deviation for the process is not known, calculate an estimated value from the measurements obtained from the sample as directed in 9.2.1 through 9.2.6. The symbol for this estimated standard deviation is s.

9.2.1 Subtract the arithmetic mean from the first measured value using the following equation:

$$X_1 - \bar{X} \tag{3}$$

9.2.2 Calculate the square of the difference obtained in 9.2.1 using the following equation:

$$\left(X_1 - \bar{X}\right)^2 \tag{4}$$

9.2.3 Repeat 9.2.1 and 9.2.2 for each measured value.

9.2.4 Add all of the squares obtained in 9.2.2 and 9.2.3 using the following equation:

$$\left(X_1 - \bar{X}\right)^2 + \left(X_2 - \bar{X}\right)^2 + \ldots + \left(X_n - \bar{X}\right)^2 = \sum_{i=1}^{n} \left(X_1 - \bar{X}\right)^2 \tag{5}$$

9.2.5 Divide the sum obtained in 9.2.4 by one less than the number of articles that were tested using the following equation:

$$\frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1} \tag{6}$$

9.2.6 Calculate the square root of the value obtained in 9.2.5 using Eq 6. This is standard deviation, s.

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)^2}{n-1}} \tag{7}$$

NOTE 5—The following equation can also be used:

$$s = \sqrt{\frac{\sum X_i^{\,2} - \frac{\left(\sum X_i\right)^2}{n}}{n-1}} \tag{8}$$

9.3 Using the k that is in the table and the standard deviation from 9.2, calculate the following number when the standard deviation is known:

$$\bar{X} - k\sigma \tag{9}$$

or, calculate the following when the standard deviation is not known:

$$\bar{X} - ks \tag{10}$$

10. Inspection and Lot Classification

10.1 *Inspection*—Each article in the sample shall be inspected as directed in the applicable coating standard.

10.2 *Lot Classification:*

10.2.1 The number calculated in 9.3 shall be compared to the minimum number stated in the coating specification. If the number in 9.3 equals or exceeds the specified minimum, the lot conforms to the requirements. If it is less than the specified minimum, the lot does not conform.