Designation: B697 – 88 (Reapproved 2005)

Standard Guide for Selection of Sampling Plans for Inspection of Electrodeposited Metallic and Inorganic Coatings[1]

This standard is issued under the fixed designation B697; 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 gives guidance in the selection of sampling plans to be used in the inspection of electrodeposited and related coatings on products for the purpose of deciding whether submitted lots of coated products comply with the specifications applicable to the coatings. This supplements Test Method B602 by giving more information on sampling inspection and by providing additional sampling plans for the user who finds the limited choice of plans in Test Method B602 to be inadequate.

1.2 When using a sampling plan, a relatively small part of the articles in an inspection lot is selected and inspected. Based on the results, a decision is made that the inspection lot either does or does not satisfactorily conform to the specification.

1.3 This guide also contains several sampling plans. The plans are attribute plans, that is, in the application of the plans each inspected article is classified as either conforming or nonconforming to each of the coating requirements. The number of nonconforming articles is compared to a maximum allowable number. The plans are simple and relatively few. Additional plans and more complex plans that cover more situations are given in the Refs (**1-7**) at the end of this guide and in MIL-STD 105.

1.4 Acceptance sampling plans are used:

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

1.4.2 When 100 % inspection is fatiguing and boring and, therefore, likely to result in errors. In these cases a sampling plan may provide greater protection than 100 % inspection.

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

1.5 Another general type of acceptance sampling plan that is not covered in these guidelines is the variables plan in which measured values of characteristics are analyzed by statistical procedures. Such plans, when applicable, can reduce inspection cost and increase quality protection. Information on variables plans is given in Test Method B762, MIL-STD-414, ANSI/ASQC Z1.9-1979, and Refs (**1-2**).

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B602 Test Method for Attribute Sampling of Metallic and Inorganic Coatings

B762 Test Method of Variables Sampling of Metallic and Inorganic Coatings

2.2 *ANSI Standard:*[3]

ANSI/ASQC Z1.9–1979 Sampling Procedures and Tables for Inspection by Variables for Percent Nonconformance

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. General

3.1 *Procedure*—The use of acceptance sampling consists of a series of decisions and actions. These are listed in order below and are discussed in this standard.

3.1.1 Select characteristics to be inspected,

3.1.2 Select type of sampling plan,

3.1.3 Select quality level,

3.1.4 Define inspection lot,

3.1.5 Select sample,

3.1.6 Inspect sample,

3.1.7 Classify inspection lot, and

3.1.8 Dispose of inspection lot.

3.2 The need for acceptance sampling arises when a decision must be made about what to do with a quantity of articles. This quantity (called the inspection lot in this guide) may be a shipment from a supplier, may be articles that are ready for a subsequent manufacturing operation, or may be articles ready for shipment to a customer.

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[1] This 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.

Current edition approved May 15, 2005. Published June 2005. Originally approved in 1981. Last previous edition approved in 1999 as B697 – 88 (1999). DOI: 10.1520/B0697-88R05.

[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.

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

3.3 When acceptance sampling is done, several of the articles in the inspection lot are selected at random (see Section 7). These articles constitute the sample. Each article in the sample is inspected for conformance to the requirements placed on it. If an article meets a requirement, it is classified as conforming. If not, it is classified as nonconforming. If the number of nonconforming articles in the sample is no more than a predetermined number (called the acceptance number), the inspection lot is accepted. If it exceeds the acceptance number, the inspection lot is rejected.

3.4 The disposition of rejected inspection lots is beyond the scope of this guide 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 exception is rectifying inspection (3.11) in which rejected lots are screened and used.

3.5 Because the decision about the disposition of an inspection lot is based on the inspection of a sample, and because there is a chance that a sample will not be representative of an inspection lot, some inspection lots that have the desired quality level (Note 1) will be rejected and some inspection lots that do not have the desired quality level will be accepted. There are only two situations in which the results of acceptance sampling are totally predictable (Note 2). One is when there are no nonconforming articles in the inspection lot. There, of course, will be no nonconforming articles in the sample and the decision to accept the lot will always be made. The other situation is when no article in the inspection lot conforms. All of the articles in the sample will be nonconforming and the decision to reject the lot will always be made (Note 3).

NOTE 1—In this guide the term "quality level" means the percentage of nonconforming articles in an inspection lot or it means the average percentage of nonconforming articles in a series of inspection lots received from a single source. Terms such as high quality, increased quality, and better quality mean a relatively smaller percentage of nonconforming articles, while terms such as low quality, decreased quality, and poorer quality mean a relatively larger percentage of nonconforming articles.

NOTE 2—In this discussion and elsewhere in this guide, it is assumed that no errors are made.

NOTE 3—To be strictly correct, lots that contain no more nonconforming articles than the acceptance number will always be accepted, and lots that contain fewer conforming articles than the sample size minus the acceptance number will always be rejected.

3.6 The discussion in 3.5 leads to two important points: (*1*) acceptance sampling plans will permit the acceptance of inspection lots that contain nonconforming articles, and (*2*) in a series of inspection lots, each containing the same percentage of nonconforming articles, some will be accepted and some will be rejected, and the percentage of nonconforming articles in the accepted inspection lots will be the same as in the rejected lots. In other words, acceptance sampling does not, by itself, result in higher quality. Rectifying inspection (3.11) will result in higher average quality in the product leaving inspection.

3.7 Because acceptance sampling plans permit the acceptance of inspection lots that contain nonconforming articles, basic to the selection of a sampling plan is a decision about the percentage of nonconforming articles that is acceptable. If the function of the article is so important that no nonconformers can be tolerated, acceptance sampling cannot be used. In these cases, every article must be inspected, and, to guard against error, may have to be inspected twice.

3.8 The protection that an attributes sampling plan provides against accepting an undesirable number of nonconforming articles is determined by the size of the sample and by the acceptance number. The protection provided by a plan is usually expressed in the form of an operating characteristic (OC) curve. Fig. 1 is the OC curve for the plan that calls for a sample of 55 articles and an acceptance number of two. Plotted along the horizontal axis is the quality level of an inspection lot expressed as the percentage of the articles in the lot that are nonconforming (Note 1). The vertical axis is the probability, as a percentage, that an inspection lot will be accepted by the plan (Note 4). Inspection lots with zero percent nonconforming articles will be accepted 100 % of the time (Note 2). As the percentage of nonconforming articles in the inspection lot increases, the probability of acceptance decreases. For example, as shown in Fig. 1, an inspection lot containing 1.5 % nonconforming articles has a 95 % chance of being accepted, while one containing 9.6 % nonconforming articles has only a 10 % chance of being accepted.

NOTE 4—The vertical axis of the OC curve can have two meanings. One is the probability that a particular inspection lot will be accepted. The other meaning is the percentage of a series of lots of a given quality level that will be accepted. The latter meaning is the one that is strictly correct mathematically. The former meaning is also correct, as long as the inspection lot is at least ten times bigger than the sample.

3.9 The characteristics of a sampling plan are often expressed in terms of the Acceptable Quality Level (AQL) and the Limiting Quality Level (LQL). The AQL is the quality level that will result in the acceptance of a high percentage of incoming inspection lots; usually it is the quality level that will result in the acceptance of 95 % of the incoming inspection lots. In Fig. 1, the AQL is 1.5 %. The LQL is the quality level that will result in the rejection of a high percentage of incoming inspection lots; usually it is the quality level that will result in the rejection of 90 % of the incoming inspection lots. In Fig. 1

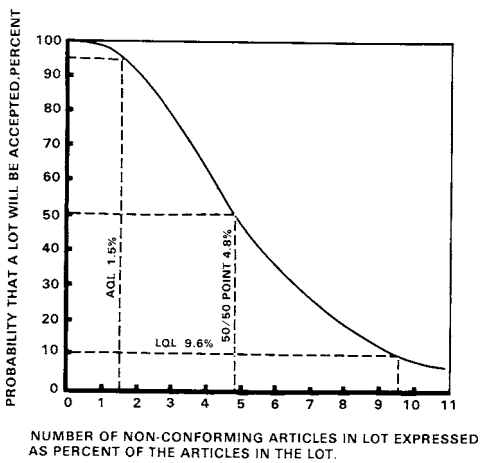


FIG. 1 Operating Characteristic Curve for Single Sample, Attributes Sampling Plan, Sample Size = 55, Acceptance Number = 2

the LQL is 9.6 %. In this standard, AQL and LQL are defined as the quality levels that will be accepted 95 and rejected 90 % of the time, respectively.

3.10 Another characteristic of sampling plans that is used in this standard is the 50/50 point. This is the quality level that will result in the acceptance of half of the incoming inspection lots. In Fig. 1 the 50/50 point is 4.8 %.

3.11 *Rectifying Inspection*:

3.11.1 As stated in 3.4, one of the options when an inspection lot is rejected is screening of the lot. In this procedure, called rectifying inspection, all of the articles in a rejected lot are inspected and the nonconforming ones are removed and replaced with conforming articles. The now 100 %-conforming inspection lot is accepted and is passed along with the inspection lots that were accepted on the basis of acceptance sampling. The addition of these 100 %-conforming inspection lots improves the average quality level of all the inspection lots taken together. The amount the quality level is improved can be calculated if the average quality level of incoming inspection lots is known. The calculations reveal that if the incoming quality level is high, few inspection lots will be rejected and screened and so the average quality of the outgoing lots will be only slightly improved over the incoming. If the quality level of the incoming inspection lots is low, many of the inspection lots will be rejected and screened. The addition of this large number of 100 %-conforming lots will result in a high outgoing quality level. At intermediate incoming quality levels, the outgoing quality will be poorer than these two extremes, and there will be a particular incoming quality level for which the outgoing level will be the poorest.

3.11.2 When rectifying inspection is used the average quality level of a series of outgoing lots is called the Average Outgoing Quality (AOQ) and the worst possible AOQ for a given plan is called the Average Outgoing Quality Limit (AOQL). Fig. 2 is a plot of the AOQ for the sampling plan of Fig. 1 (Note 5). This shows that the worst AOQ, the AOQL, is 2.5 % and occurs only if the average incoming quality level is 4.2 %. Fig. 2 also shows that when the quality level of incoming lots is high, the improvement caused by inspection is small. For example, if the incoming lots are of AQL quality, 1.5 %, the AOQ is 1.4 %. At lower incoming quality levels the relative improvement is greater; for example, at an incoming quality level of 3 %, the AOQ is 2.3 %.

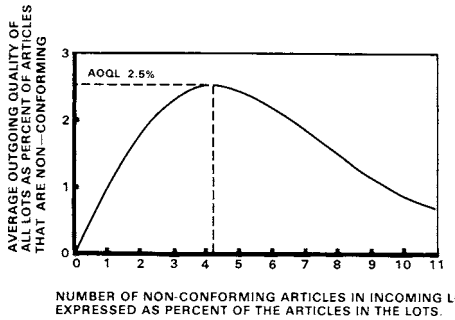


FIG. 2 Average Outgoing Quality of Rectifying Inspection with Single Sample, Attributes Plan, Sample Size = 55, Acceptance Number = 2. Rejected Lots Are 100% Inspected with Nonconforming Articles Removed and Replaced with Conforming Articles

NOTE 5—The AOQs and AOQLs in this guide are calculated on the basis that when rejected lots are screened the nonconforming articles found are replaced with conforming articles. If the discarded nonconforming articles are not replaced, a practice that is frequently done, the AOQs and AOQLs will be somewhat different from those in this guide. Chapter 16 of Ref (**4**) discusses this point.

3.11.3 Use of rectifying inspection will assure that with a continuous series of inspection lots the average quality level of all the accepted articles, considered as a whole, will not be worse than the AOQL of the sampling plan used. However, rectifying inspection can significantly increase inspection costs since every rejected inspection lot is 100 % inspected. The lower the quality of incoming lots, the more of them that will be rejected and then 100 % inspected. Fig. 3 shows how, for the sampling plan of Fig. 1 and lots of 550, the average number of articles inspected per inspection lot increases as the quality levels of incoming lots decrease. In lots containing up to about 1.5 % nonconforming articles the increase in inspection is moderate. Beyond that point the average amount of inspection increases rapidly. At an incoming quality level of 2.1 % the amount of inspection is doubled. And with incoming quality levels of 15 % virtually every inspection lot is 100 % inspected.

3.11.4 Because the cost of inspection using rectifying inspection plans is so greatly influenced by the quality level of incoming inspection lots, past information of that level is necessary before choosing an AOQL. The AOQL plans in Table 1 give the range of incoming quality level for which each plan is recommended. The cost of the inspection is also determined by the size of the inspection lot and by the size of the sample. If rectifying inspection is to be used on a large scale, it is recommended that the user refer to Ref (**3**). It contains plans that yield the lowest total inspection for each combination of AOQL, incoming quality level, and inspection lot size.

3.11.5 Whether the 100 % inspection of rejected lots is done by the purchaser or the supplier is a business decision of the purchaser. Having the supplier do the inspection provides an incentive to improve the quality of future lots. However, if the supplier does the 100 % inspection, the purchaser may want to

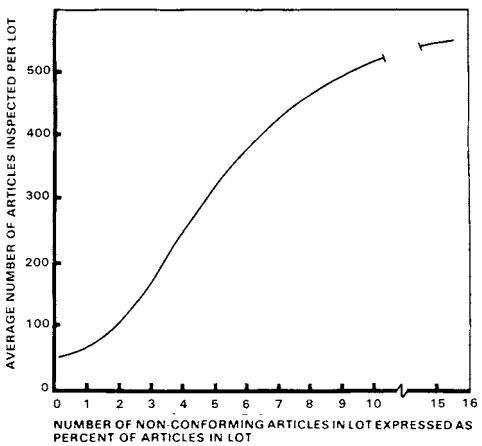


FIG. 3 Average Number of Articles Inspected Per Lot with Rectifying Inspection, Single Sampling, Attributes Plan with Sample Size = 55, Acceptance Number = 2, and Lot Size = 550

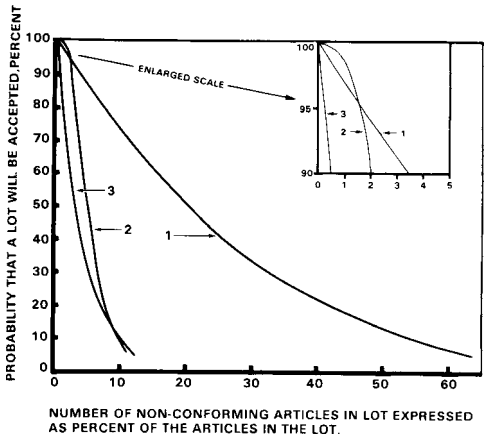
TABLE 1 Constant AQL Plans

NOTE 1—The values listed in columns headed AQL, 50/50 Point, LQL, and AOQL are the percentages of nonconforming articles in the inspection lot.

NOTE 2—The AOQL values are calculated for inspection lots that are very large compared to the sample. The values can be corrected for cases where this is not true by multiplying them by:

$$1 - \frac{\text{sample size}}{\text{lot size}}$$

AQL	Sample Size	Acceptance Number	50/50 Point	LQL	AOQL
0.25	145	1	1.2	2.7	0.6
	325	2	0.8	1.6	0.4
0.65	55	1	3.1	6.9	1.5
	126	2	2.1	4.2	1.2
	210	3	1.7	3.2	0.92
	303	4	1.5	2.6	0.84
	612	7	1.3	1.9	0.73
1.5	24	1	7.0	15	3.5
	55	2	4.9	9.4	2.5
	92	3	4.0	7.1	2.1
	132	4	3.5	6.0	1.9
	174	5	3.3	5.3	1.8
	365	7	2.9	4.4	1.7
4.0	9	1	19	37	9.3
	21	2	13	22	6.5
	35	3	10	18	5.5
	50	4	9.3	15	5.1
	66	5	8.6	14	4.8
	84	6	7.9	12	4.5



NOTE 1—Curve 2 is the plan shown in Fig. 1. Curve 1 is a plan with a sample size of three and an acceptance number of zero; it has the same AQL as Curve 2 and an LQL of 54 %. Curve 3 is a plan with a sample size of 23 and an acceptance number of zero; it has the same LQL as Curve 2 and an AQL of 0.22 %. The inset in the upper right is an enlargement of the AQL region.

FIG. 4 Operating Characteristic Curves of Three Single Sample Attributes Sampling Plans

TABLE 2 Constant LQL Plans

NOTE 1—The values listed in columns headed AQL, 50/50 Point, LQL, and AOQL are the percentages of nonconforming articles in the inspection lot.

NOTE 2—The AOQL values are calculated for inspection lots that are very large compared to the sample. The values can be corrected for cases where this is not true by multiplying them by:

$$1 - \frac{\text{sample size}}{\text{lot size}}$$

LQL	Sample Size	Acceptance Number	AQL	50/50 Point	AOQL
5.0	76	1	0.47	2.2	1.1
	105	2	0.78	2.5	1.3
	130	3	1.1	2.8	1.5
10	37	1	0.97	4.5	2.3
	52	2	1.6	5.1	2.6
	65	3	2.1	5.6	3.0
	78	4	2.6	6.0	3.4
15	24	1	1.5	7.0	3.5
	34	2	2.4	7.8	4.0
	43	3	3.2	8.5	4.5
	51	4	3.9	9.2	5.0
20	18	1	2.0	9.3	4.7
	25	2	3.4	11	5.5
	31	3	4.5	12	6.2
	38	4	5.2	12	6.7

do sampling inspection of screened lots. This adds even more to the cost of inspection.

3.11.6 Rectifying inspection, of course, cannot be used if the inspection methods destroy the inspected articles.

3.12 AQL and LQL plans with an acceptance number of zero are not included in this guide because their operating characteristics are different from plans that have acceptance numbers of one or more. They can provide LQL protection against the bad inspection lot but only at the cost of rejection of a large number of good lots. Or, if they are selected on a basis of the AQL, they will allow the acceptance of a large number of bad lots. Fig. 4 illustrates this. The OC curves of three plans are shown. Curve number 2 is the plan shown in Fig. 1, a sample of 55 and an acceptance number of two. Curve number 1 is the zero acceptance number plan that has the same AQL, 1.5 %, as curve number 2. The sample size is 3. But this plan has an LQL of 54 % as compared to 9.7 % for curve number 2. Curve number 3 is the zero acceptance number plan that has the same LQL as curve number 2. The sample size is 23. With this plan the AQL is 0.2 % as compared to 1.5 % for curve number 2.

4. Selection of the Type of Sampling Plan

4.1 The sampling plans of this guide are given in Table 1, Table 2, and Table 3. All are single sampling plans, that is, the decision is based on the results with a single sample. Each table contains several sets of plans. Within each set the plans have one characteristic in common. In Table 1 all of the plans in a set have the same AQL. In Table 2 they have the same LQL. And in Table 3 the plans in each set have the same AOQL.

4.2 Plans based on the AQL (Table 1) are usually selected when there is a continuing series of inspection lots from a single source. The AQL value selected is the quality level that the purchaser considers to be satisfactory. The supplier knows that if he operates his finishing process so that the average quality level of his output is as good as or better than the AQL,