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Guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots -- Part 1: Acceptance sampling

Lignes directrices pour la sélection d'un système, d'un programme ou d'un plan d'échantillonnage pour acceptation pour le contrôle d'unités discrètes en lots -- Partie 1: Lignes directrices générales pour l'échantillonnage pour acceptation

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TECHNICAL REPORT

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Guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots —

Part 1: Acceptance sampling

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Partie 1: Lignes directrices générales pour l'échantillonnage pour acceptation

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 8550-1 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 5, *Acceptance sampling*.

This first edition of ISO/TR 8550-1, together with ISO/TR 8550-2 and ISO/TR 8550-3, cancels and replaces ISO/TR 8550:1994.

ISO/TR 8550 consists of the following parts, under the general title *Guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots*:

— *Part 1: Acceptance sampling*

— *Part 3: Sampling by variables*

The following part is under preparation:

— *Part 2: Sampling by attributes*

Introduction

This part of ISO/TR 8550 gives guidance on the selection of an appropriate acceptance sampling scheme for the inspection of discrete items submitted in lots from the schemes described in various national and international standards.

There are many situations where products (materials, parts, components, assemblies and systems) are transferred from one organization to another, where the organizations may be different companies or parts of a single company or even different shops within a plant. In these situations both the supplier and the customer may use acceptance sampling procedures to satisfy themselves that the product is of acceptable quality. Suppliers will be seeking to maintain a reputation for good quality and to reduce the likelihood of claims under warranty, but without incurring unnecessary production and supply costs. On the other hand, customers will require adequate evidence, at minimum cost to themselves, that the product they receive conforms to specifications. Compared with, say, 100 % inspection, suitable sampling methods will often be beneficial in achieving these aims. Sometimes acceptance sampling methods are the only practical procedure, especially when the tests for conformance are destructive.

Several types of sampling systems, schemes and plans are available for these purposes. They are presented in a number of ISO Standards that explain how they are to be used. However, it is often difficult to decide on the most appropriate procedure for use in a particular situation. The purpose of this part of ISO/TR 8550 is to assist in that decision.

The choice of sampling system, scheme or plan depends on a number of conditions and on the prevailing circumstances. In any supply situation, the first essential is that the supplier and the customer understand, and have agreed upon, the requirements and the basis for release and acceptance of the product, including any acceptance sampling methods to be used.

Lots that are non-acceptable cause difficulties for both supplier and customer. The supplier incurs additional costs in rework, scrap, increased inspection, damage to reputation and possibly loss of sales. Delays in delivery and re-inspection costs are a burden to the customer. For these reasons, it is usually considered essential for the supplier to provide lots that have a very high probability of being accepted, i.e. 95 % or more. The supplier has to ensure that quality control of the production or delivery process provides lots of a quality sufficient to meet this objective. A basic principle of some acceptance sampling inspection schemes is to promote the production of lots of acceptable quality. The primary purpose of these schemes is not to discriminate between acceptable and non-acceptable lots, i.e. to sort, but to keep production under control to yield an acceptable process average quality. Although all acceptance sampling plans are discriminatory to some degree, the process average quality (expressed in terms of percent nonconforming or number of nonconformities) should not be greater than half the acceptance quality limit in order to ensure a very high probability of acceptance.

The primary purpose of the ISO/TR 8550 series is to give guidance on the selection of an acceptance sampling system, scheme or plan. It does this principally by reviewing the available systems specified by various standards and showing ways in which these can be compared in order to assess their suitability for an intended application. The guide also indicates how prior knowledge of the manufacturing or service delivery process and quality performance might influence the choice of sampling system, scheme or plan, and likewise how the particular needs of the customer affect selection. Some specific circumstances encountered in practice are described and the method of choosing a plan is explained. Some checklists or pointers and tables are provided to assist users in selecting an appropriate system, scheme or plan for their purposes. Charts are included to illustrate the procedures to be followed in the selection process.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Guidance on the selection and usage of acceptance sampling systems for inspection of discrete items in lots —

Part 1: Acceptance sampling

1 Scope

This part of ISO/TR 8550 gives general guidance on the selection of an acceptance sampling system, scheme or plan. It does this principally in the context of standards that either already exist or are presently under development. (For more detailed information about specific acceptance sampling systems, see ISO/TR 8550-2 for sampling by attributes or ISO/TR 8550-3 for sampling by variables.)

The guidance in this part of ISO/TR 8550 is confined to acceptance sampling of products that are supplied in lots and that can be classified as consisting of discrete items (i.e. discrete articles of product). It is assumed that each item in a lot can be identified and segregated from the other items in the lot and has an equal chance of being included in the sample. Each item of product is countable and has specific characteristics that are measurable or classifiable as being conforming or nonconforming (to a given product specification).

Standards on acceptance sampling are typically generic, as a result of which they can be applied to a wide variety of inspection situations. These include, but are not limited to, the following:

a) end items, such as complete products or sub-assemblies;

b) components and raw materials;

c) services;

d) materials in process;

e) supplies in storage;

f) maintenance operations;

g) data or records;

h) administrative procedures.

Although this part of ISO/TR 8550 is written principally in terms of manufacture and production, this should be interpreted liberally, as it is applicable to the selection of sampling systems, schemes and plans for all types of products and processes as defined in ISO 9000.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition listed applies. For undated references, the latest edition of the referenced document (including any amendment) applies.

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

ISO 9000, *Quality management systems — Fundamentals and vocabulary*

3 Terms and definitions

For the purposes of this part of ISO/TR 8550, the terms and definitions given in ISO 3534-1, ISO 3534-2 and ISO 9000 apply.

4 Abuses and uses of acceptance sampling

4.1 Abuses of acceptance sampling

Acceptance sampling has become unpopular since the early 1980s. Some of the reasons for this (although certainly not all) are well founded, so it is important to be able to distinguish those situations where acceptance sampling should not be used from those where it may be appropriate.

The chief arguments used against the use of acceptance sampling are as follows.

a) When quality is generally very high, the sample sizes needed to detect a slip in quality are uneconomically large.

b) Quality cannot be inspected into a product.

c) It is far better to establish a robust design and to implement comprehensive process controls than to try to find and eliminate nonconforming items after manufacture.

d) Most acceptance sampling standards are indexed in terms of acceptable quality level (AQL). Once an AQL has been established and quality has been brought sufficiently below the AQL to achieve high probabilities of lot acceptance, there is no incentive for the producer to try continuously to improve quality.

e) Quoting an AQL is tantamount to granting a licence to produce defects.

f) The only acceptable quality level is zero defects.

These arguments are examined in turn in the following subclauses.

4.2 Example 1

The following simplified example, devised by Baillie [18], demonstrates how the optimum sampling plan can vary according to the quality level against which it is desired to guard. A certain item is produced in lots of size 10 000, with a unit production cost of £10,00. The selling price per item is £a in accepted lots and at a discounted price of £0,50 in lots non-accepted by the acceptance procedure. Testing is destructive, and the cost of testing each item is £1,00. The downstream cost (e.g. warranty cost plus loss of goodwill) of a nonconforming item in an accepted lot is £10 000, but zero in non-accepted lots sold at a discount. Historical data indicate that the process fraction nonconforming is p for 99 % of lots, but that it unaccountably and randomly slips to 100p for 1 % of the lots. A single sampling plan by attributes is to be used, i.e. a random sample of size n is to be selected from each lot, and the lot is to be considered acceptable if the sample contains no more than Ac nonconforming items. What is the optimal sampling plan, i.e. the plan that maximizes the profit per item sold?

Mathematical details are provided in Annex A for information. Table 1 shows the optimal sampling plan for a range of values of the process quality level p. The results are instructive.

Table 1 — Optimal sampling plans for Example 1

Usual quality level, in fraction nonconforming	Quality level after slippage, in fraction nonconforming	Optimal plan		Selling price per item, a (£)	Average profit per item sold (£)
		Sample size n	Acceptance number, Ac		
0,001 00	0,100	104	2	20,25	0,022
0,000 50	0,050	139	1	15,40	0,091
0,000 30	0,030	197	1	13,60	0,211
0,000 20	0,020	249	1	12,75	0,280
0,000 10	0,010	141	0	12,00	0,378
0,000 09	0,009	137	0	11,95	0,436
0,000 08	0,008	129	0	11,90	0,499
0,000 07	0,007	113	0	11.85	0,570
0,000 06	0,006	86	0	11,75	0,603
0,000 05	0,005	34	0	11,70	0,710
0,000 04	0,004	Accept without sampling		11,60	0,804
0,000 03	0,003	Accept without sampling		11,50	0,903
0,000 02	0,002	Accept without sampling		11,35	0,952
0,000 01	0,001	Accept without sampling		11,20	1,001

Not surprisingly, it is found that improvements in the quality level allow the selling price to be decreased while at the same time increasing the profit per item sold. At first, improvements in quality levels necessitate larger sample sizes in order to be able to provide the necessary discrimination between the two quality levels. As quality levels improve, the optimal acceptance number Ac reduces and there comes a point when the sample size that is required also begins to reduce until, eventually, it becomes uneconomical to sample at all. This final state is called “indirect inspection” as the inspection has effectively been transferred from the producer to the consumer; nonconforming items are so rare that it is more economical not to sample and inspect but to reimburse consumers on the infrequent occasions that they invoke the warranty. Thus 4.1a) is seen to be misleading for, when quality levels reach a sufficiently high level, acceptance sampling simply becomes an unnecessary overhead rather than requiring uneconomically large sample sizes.

4.3 Inspecting quality into a product

Inspection makes little difference to the outgoing quality if the incoming quality is more or less constant unless the sample size is a large proportion of the lot size, in which case the inspection process is a large overhead. Either way, it is not a particularly sensible approach to improving quality levels.

4.4 Design and control

The advantages of establishing a robust design and a comprehensive process control system are many. The robust design places the least possible demands on the manufacturing process and the process control system tends to prevent process parameters from straying too far from their target values, so process variation and waste is kept low and output quality is kept high. Moreover, the design and the control system of the production process can be reviewed and improved in the light of experience to provide continual quality improvement.

4.5 AQLs

The initials AQL used to stand for Acceptable Quality Level, although in reality the AQL is simply an index to a sampling plan. Standards tried to make this clear by explaining that the level was acceptable for the purposes

of acceptance sampling (rather than in an absolute sense). Indeed, lot quality levels typically have to be better than half the AQL to have a very high chance of being accepted.

During the late 20th century, many companies came to realize that the only way to survive in a global marketplace was to strive endlessly for improved levels of quality. The notion that any level of quality other than zero defects (see 4.7) was acceptable began to be scorned. In order to clarify the situation, the meaning of the initials AQL was changed in international standards to Acceptance Quality Limit, which more accurately describes its function. Unfortunately, the damage was already done, for many organizations no longer entertain the use of standards indexed by AQL.

The argument that AQLs provide no incentive for the producer to continuously improve quality once it has been improved to a level that is better than the AQL is not a strong one; in many medium or long-term agreements between supplier and customer, a progressive reduction in the AQL could easily be agreed upon and written into the contract. Moreover, a producer intent on staying in business is already striving for better levels of quality in order to maintain or improve his place in the national or global market.

4.6 A licence to produce defects?

It is untrue that an AQL provides a licence for the producer to provide defects. Most AQL-indexed standards expressly caution that the designation of an AQL does not imply that the supplier has the right knowingly to supply any nonconforming items of product.

4.7 The zero defects philosophy

Crosby [19] introduced the idea that quality can be free, i.e. the extra resources used to improve quality would often be more than compensated for by the reduction in rework or scrap or loss of goodwill. Unfortunately, the corresponding idea that the producer should strive for a perfect process that produces no nonconforming items inevitably often became misconstrued to stipulate that acceptance sampling plans should always have an acceptance number of zero, i.e. that the plans should lead to lot non-acceptance if one or more nonconforming items are found in the sample. Example 1 shows this not to be an inevitable corollary. An acceptance number of zero is seen to be optimal only over a certain range of quality levels; at lower quality levels, acceptance numbers of 1 or more are optimal, while at higher quality levels, it is best not to sample at all.

4.8 The use of acceptance sampling

For many mature production processes, quality levels will have become so close to perfection that it is a needless waste of resources to implement acceptance sampling procedures. The design will have been refined such that there are no difficulties in the production process due to any of the process parameters being difficult to achieve or maintain, and safeguards will have been built into the process control system wherever necessary.

It can be seen from Table 1 that acceptance sampling became redundant at a quality level somewhere in the range 0,000 1 to 0,000 2 nonconforming. One of the variables in Example 1 was the 1 % of lots that slip to the worse quality level. If this percentage could be substantially reduced, then acceptance sampling would become redundant at quality levels in the good lots worse than 0,000 2 nonconforming. Thus a two-pronged attack on internal variation and on external, “special causes” of variation in the production process, together with repeated reviews of the product design, ultimately lead to acceptance sampling becoming unnecessary for many products.

However, what about the early stages while the process and its controls are being refined? Example 1 demonstrates that appropriate use of acceptance sampling can play a key part in maximizing profitability during this interim period.

Some processes never run long enough to become mature. This is particularly true for some defence industries. There is not much point in continuing to build an offensive weapon of a given specification once an effective defence to it has been devised and is widely available. Specifications are therefore frequently modified, which can make it difficult to achieve a robust design or efficient process controls. Sometimes the

materials used in the production of armaments are so new that they have properties and limitations that are not completely understood. Sometimes it is in the assembly of individually sound components into complex items where it might be necessary to use acceptance sampling to maintain quality; it will be too late once the items are being used in anger. Sometimes what might seem to be very high levels of nonconformity may be acceptable. For example, an over-the-shoulder anti-tank weapon system would be more than acceptable even if it had only a 50 % chance of destroying a tank costing one thousand times as much, although this translates into 50 % nonconforming. Acceptance sampling may be applied periodically to munitions held in storage over many years, to check that they have not degraded to an intolerable level. In the computer industry, a process yield as low as 50 % when etching the latest and fastest computer chips may be considered acceptable. Acceptance sampling might even be used as a tool by which to verify statistical process control results.

In summary, acceptance sampling has a legitimate part to play in the quality assurance of many products.

5 Acceptance sampling plans, schemes and systems

An acceptance sampling plan is a set of rules by which a lot is to be inspected and its acceptability determined. The plan stipulates the number of items (units) in the sample, to be drawn randomly from a lot for inspection against the product specification. The lot is then sentenced as “acceptable” or “non-acceptable” according to how the inspection results compare with the criteria of the acceptance sampling plan.

Sometimes, when a long series of lots is being inspected, a sampling procedure might call for a shift from one sampling plan to another, depending on the current and previous sample results. Sampling procedures that call for switching from one sampling plan to another, and possibly back again, are called sampling schemes. A sampling scheme might also call for discontinuation of inspection if product quality appears to remain poor. The customer may then shift to another supplier, if available, or initiate 100 % screening until the supplier can improve the production process sufficiently to produce acceptable product.

In the case of destructive testing, the customer may cease to accept product until the supplier has demonstrated to his satisfaction that the production problems that were giving rise to the previous low quality have been overcome.

A collection of sampling plans and related sampling schemes constitute a sampling system. The system is generally indexed in some way, e.g. by lot size, inspection level and acceptance quality limit (e.g. ISO 2859-1).

The standards reviewed in ISO/TR 8550-2 and ISO/TR 8550-3 present plans for single, double, multiple or sequential sampling. Procedures for skip-lot sampling for inspection by attributes are given in ISO 2859-3. A comparison of the various sampling methods and the principles on which they are based assists in assessing their suitability for a particular application and enables an appropriate selection to be made.

6 Practical and economic advantages of using standard sampling plans

To those concerned with the writing of specifications, it is of benefit that statistically sound sampling procedures be provided. Because there are economies of scale for larger lots, most sampling schemes presented in the standards reviewed in ISO/TR 8550-2 and ISO/TR 8550-3 relate sample size to lot size. Apart from providing control over the methods of selection of the sample, these standards should normally be invoked because they specify requirements that control the treatment of nonconformities found during inspection and the treatment of lots resubmitted after initial non-acceptance. Furthermore, most of these sampling systems contain built-in switching rules (e.g. from ‘normal’ to ‘tightened’ or to ‘reduced’ inspection) to adjust the sampling plan in the event of deterioration or improvement in quality. Use of these basic reference standards can save much time often wasted in subjective discussion, and reduce the large areas of discretion often contained in non-standard sampling schemes that have only limited value, particularly for international trade.

Sampling involves risk and, quite naturally, all parties concerned attempt to minimize their share. Theoretically, these risks are functions of the sampling plan and the quality level agreed upon, without relation to the industry or the product. In practice, these risks are reduced by controlling the production process and improving the level of quality.