INTERNATIONAL STANDARD

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Sampling procedures for inspection by attributes —

Part 5:
System of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection

Règles d'échantillonnage pour les contrôles par attributs —

Partie 5: Système de plans d'échantillonnage progressif pour le contrôle lot par lot, indexés d'après la limite d'acceptation de qualité (LAQ)

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Contents

Page

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.

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 2859-5 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 5, *Acceptance sampling*.

This first edition cancels and replaces Annex A of ISO 8422:1991, which has been technically revised to greatly improve its compatibility with the sampling systems in ISO 2859-1.

ISO 2859 consists of the following parts, under the general title *Sampling procedures for inspection by attributes*:

— *Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

— *Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection*

— *Part 3: Skip-lot sampling procedures*

— *Part 4: Procedures for assessment of declared quality levels*

— *Part 5: System of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

— *Part 10: Overview of the ISO 2859 attribute sampling systems*

Introduction

In contemporary production processes quality is often expected to reach such high levels that the number of nonconforming items is reported in parts per million (10^{-6}). Under such circumstances, popular acceptance sampling plans, such as those presented in ISO 2859-1, require prohibitively large sample sizes. To overcome this problem, users apply acceptance sampling plans with higher probabilities of wrong decisions or, in extreme situations, abandon the use of acceptance sampling procedures altogether. However, in many situations there is still a need to accept products of high quality using standardized statistical methods. In such cases, there is a need to apply statistical procedures that require the smallest possible sample sizes. Sequential sampling plans are the only statistical procedures that satisfy that need as, among all possible sampling plans having similar statistical properties, the sequential sampling plan has the smallest average sample number. Therefore, there is a strong need to present sequential sampling plans which are statistically equivalent to the commonly used acceptance sampling plans from ISO 2859-1, but which require significantly smaller average sample numbers.

The principal advantage of sequential sampling plans is the reduction in the average sample number. The average sample number is the weighted average of all the sample sizes that may occur under a sampling plan for a given lot or process quality level. Like double and multiple sampling plans, the use of sequential sampling plans leads to a smaller average sample number than single sampling plans having the equivalent operating characteristics. However, the average savings are even greater when using a sequential sampling plan than when a double or multiple sampling plan is used. For lots of very good quality, the maximum savings for sequential sampling plans may reach 85 %, as compared to 37 % for double sampling plans and 75 % for multiple sampling plans. On the other hand, when using a double, multiple or sequential sampling plan, the actual number of items inspected for a particular lot may exceed the sample size of the corresponding single sampling plan n_0. For double and multiple sampling plans, there is an upper limit of 1,25 n_0 to the actual number of items to be inspected. For classical sequential sampling plans there is no such limit, and the actual number of inspected items may considerably exceed the corresponding single sample size, n_0, or even the lot size, N. For the sequential sampling plans in this part of ISO 2859, a curtailment rule has been introduced involving an upper limit of 1,5 n_0 on the actual number of items to be inspected.

Other factors that should be taken into account include the following.

a) Simplicity

The rules of a sequential sampling plan are more easily misunderstood by inspectors than the simple rules for a single sampling plan.

b) Variability in the amount of inspection

As the actual number of items inspected for a particular lot is not known in advance, the use of sequential sampling plans brings about various organisational difficulties. For example, scheduling of inspection operations may be difficult.

c) Ease of drawing sample items

If drawing sample items is expensive at different times, the reduction in the average sample number by sequential sampling plans may be cancelled out by the increased sampling cost.

d) Duration of test

If the test of a single item is of long duration and a number of items can be tested simultaneously, sequential sampling plans are much more time-consuming than the corresponding single sampling plans.

e) Variability of quality within the lot

If the lot consists of two or more sublots from different sources and if there is likely to be any substantial difference between the qualities of the sublots, drawing of a representative sample under a sequential sampling plan is far more awkward than under the corresponding single sampling plan.

The advantages and disadvantages of double and multiple sampling plans always lie between those of single and sequential sampling plans. The balance between the advantage of a smaller average sample number and the above disadvantages leads to the conclusion that sequential sampling plans are suitable only when inspection of individual items is costly in comparison with inspection overheads.

The choice between the use of a single, double, multiple, or sequential sampling plan shall be made before the inspection of a lot is started. During the inspection of a lot, it is not permitted to switch from one type of plan to another, because the operating characteristics of the plan may be drastically changed if the actual inspection results influence the choice of acceptability criteria.

Although use of sequential sampling plans is on average much more economical than the use of corresponding single sampling plans, during inspection of a particular lot, acceptance or non-acceptance may occur at a very late stage due to the cumulative count of nonconforming items (or nonconformities) remaining between the acceptance number and the rejection number for a long time. When using the graphical method, this corresponds to the random progress of the step curve remaining in the indecision zone. Such a situation is most likely to occur when the lot or process quality level (in terms of percent nonconforming or in nonconformities per 100 items) is close to ($100g$), where g is the parameter giving the slope of the acceptance and rejection lines.

To improve upon this situation the sample size curtailment value is set before the inspection of a lot begins. If the cumulative sample size reaches the curtailment value n_t without determination of lot acceptability, inspection terminates and the acceptance or non-acceptance of the lot is then determined using the curtailment values of the acceptance and rejection numbers.

For sequential sampling plans in common use, curtailment usually represents a deviation from their intended usage, leading to a distortion of their operating characteristics. In this part of ISO 2859; however, the operating characteristics of the sequential sampling plans have been determined with curtailment taken into account, so curtailment is an integral component of the provided plans.

Sampling procedures for inspection by attributes —

Part 5:
System of sequential sampling plans indexed by acceptance quality limit (AQL) for lot-by-lot inspection

1 Scope

This part of ISO 2859 specifies sequential sampling schemes that supplement the ISO 2859-1 acceptance sampling system for inspection by attributes.

The ISO 2859-1 acceptance sampling system is indexed in terms of the acceptance quality limit (AQL). Its purpose is to induce a supplier, through the economic and psychological pressure of lot non-acceptance, to maintain a process average at least as good as the specified acceptance quality limit, while at the same time providing an upper limit for the risk to the consumer of accepting the occasional poor lot.

The sampling schemes defined in this part of ISO 2859 are applicable, but not limited, to the inspection of:

— end items,

— components and raw materials,

— operations,

— materials in process,

— supplies in storage,

— maintenance operations,

— data or records, and

— administrative procedures.

These schemes are designed to be applied to a continuing series of lots, that is, a series long enough to permit the switching rules in 10.3 to be applied. These switching rules provide

a) enhanced protection to the consumer (by means of tightened sampling inspection criteria or discontinuation of sampling inspection) should deterioration in quality occur,

b) an incentive, at the discretion of the responsible authority, to reduce inspection costs (by means of reduced sampling inspection criteria) should consistently good quality be demonstrated over time.

The individual sampling plans are not designed to be used outside of the schemes in which they are presented. Where lots are produced in isolation or in a series too short for this part of ISO 2859 to apply, the user is advised to consult ISO 2859-2 for appropriate sampling plans.

2 Normative references

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

ISO 2859-1:1999, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 3534-2:—[1)], *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
inspection
conformity evaluation by observation and judgement accompanied as appropriate by measurement, testing or gauging

[ISO 3534-2]

3.2
original inspection
inspection of a lot, or other amount, not previously inspected

NOTE This is in contrast, for example, to inspection of a lot which has previously been designated as not acceptable and which is submitted again for inspection after having been further sorted, reprocessed, etc.

[ISO 3534-2]

3.3
inspection by attributes
inspection by noting the presence, or absence, of the characteristic(s) in each of the items in the group of consideration, and counting how many items do, or do not, possess the characteristic(s), or how many such events occur in the item, group or opportunity space

NOTE When inspection is performed by simply noting whether the item is nonconforming or not, the inspection is termed inspection for nonconforming items. When inspection is performed by noting whether the number of nonconformities on each unit, the inspection is termed inspection for number of nonconformities

[ISO 3534-2]

3.4
item
anything that can be described and considered separately

EXAMPLES A discrete physical item; a defined amount of bulk material, a service, activity, person and or some combination thereof.

[ISO 3534-2]

3.5
nonconformity
non-fulfilment of a requirement

[ISO 3534-2]

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1) To be published. (Revision of ISO 3534-2:1993)

NOTE 1 In some situations, specified requirements coincide with customer usage requirements (see **defect**, 3.6). In other situations they may not coincide, being either more or less stringent, or the exact relationship between the two is not fully known or understood.

NOTE 2 Nonconformity is generally classified according to its degree of seriousness such as:

— Class A: those nonconformities of a type considered to be of the highest concern; in acceptance sampling such types of nonconformities will be assigned a very small acceptance quality limit value;

— Class B: those nonconformities of a type considered to have the next lower degree of concern; therefore, these can be assigned a larger acceptance quality limit value than those in Class A and smaller than in Class C, if a third class exists, etc.

NOTE 3 Adding characteristics and classes of nonconformities generally affects the overall probability of acceptance of the product.

NOTE 4 The number of classes, the assignment into a class, and the choice of acceptance quality limit for each class should be appropriate to the quality requirements of the specific situation.

3.6
defect
non-fulfilment of a requirement related to an intended or specified use

NOTE 1 The distinction between the concepts "defect" and "nonconformity" is important as it has legal connotations, particularly those associated with product liability issues. Consequently the term "defect" should be used with extreme caution.

NOTE 2 The intended use by the customer can be affected by the nature of information, such as operating or maintenance instructions, provided by the customer.

[ISO 3534-2]

3.7
nonconforming item
item (3.4) with one or more **nonconformities** (3.5)

[ISO 3534-2]

NOTE Nonconforming items are generally classified by their degree of seriousness such as:

— Class A: an item which contains one or more nonconformities of Class A and may also contain nonconformities of Class B and/or Class C, etc.;

— Class B: an item which contains one or more nonconformities of Class B and may also contain nonconformities of Class C, etc. but contains no nonconformity of Class A.

3.8
percent nonconforming
⟨in a sample⟩ 100 times the number of **nonconforming items** (3.7) in the **sample** (3.15) divided by the **sample size** (3.16), viz:

$$100 \times \frac{d}{n}$$

where

d is the number of nonconforming items in the sample;

n is the sample size.

[ISO 2859-1:1999, 3.1.8]

3.9
percent nonconforming
⟨in a population or lot⟩ 100 times the number of **nonconforming items** (3.7) in the population or **lot** (3.13) divided by the population or **lot size** (3.14), viz:

$$100 \times p_{\text{ni}} = 100 \times \frac{D_{\text{ni}}}{N}$$

where

p_{ni} is the proportion of nonconforming items;

D_{ni} is the number of nonconforming items in the population or lot;

N is the population or lot size.

NOTE 1 Adapted from ISO 2859-1:1999, 3.1.9.

NOTE 2 In this part of ISO 2859 the terms **percent nonconforming** (3.8 and 3.9) or **nonconformities per 100 items** (3.10 and 3.11) are mainly used in place of the theoretical terms “proportion of nonconforming items” and “nonconformities per item” because the former terms are the most widely used.

3.10
nonconformities per 100 items
⟨in a sample⟩ 100 times the number of **nonconformities** (3.5) in the **sample** (3.15) divided by the **sample size** (3.16), viz:

$$100 \times \frac{d}{n}$$

where

d is the number of nonconformities in the sample;

n is the sample size.

[ISO 2859-1:1999, 3.1.10]

3.11
nonconformities per 100 items
⟨in a population or lot⟩ 100 times the number of **nonconformities** (3.5) in the population or **lot** (3.13) divided by the population or **lot size** (3.14), viz:

$$100 \times p_{\text{nt}} = 100 \times \frac{D_{\text{nt}}}{N}$$

where

p_{nt} is the number of nonconformities per **item** (3.4);

D_{nt} is the number of nonconformities in the population or lot;

N is the population or lot size.

NOTE 1 Adapted from ISO 2859-1:1999, 3.1.11.

NOTE 2 An **item** (3.4) can contain one or more nonconformities.

3.12
responsible authority
concept used to maintain the neutrality of this part of ISO 2859 (primarily for specification purposes), irrespective of whether it is being invoked or applied by the first, second or third party

[ISO 2859-1:1999, 3.1.12]

NOTE 1 The responsible authority may be:

a) the quality department within a supplier's organisation (first party);

b) the purchaser or procurement organization (second party);

c) an independent verification or certification authority (third party);

d) any of a), b) or c), differing according to function (see Note 2) as described in a written agreement between two of the parties, for example a document between supplier and purchaser.

NOTE 2 The duties and functions of a responsible authority are outlined in ISO 2859-1:1999, 5.2, 6.2, 7.2, 7.3, 7.5, 7.6, 9.1, 9.3.3, 9.4, 10.1, 10.3, 13.1.

3.13
lot
definite part of a population constituted under essentially the same conditions as the population with respect to the sampling purpose

NOTE The sampling purpose may, for example, be to determine lot acceptability, or to estimate the mean value of a particular characteristic.

[ISO 3534-2]

3.14
lot size
number of **items** (3.4) in a **lot** (3.13)

[ISO 2859-1:1999, 3.1.14]

3.15
sample
subset of a population made up of one or more sampling units

[ISO 3534-2]

3.16
sample size
number of sampling units in a **sample** (3.15)

[ISO 3534-2]

3.17
acceptance sampling plan
plan which states the **sample size**(s) (3.16) to be used and the associated criteria for lot acceptance

[ISO 3534-2]

NOTE 1 A single sampling plan is a combination of sample size and acceptance and rejection numbers. A double sampling plan is a combination of two sample sizes and acceptance and rejection numbers for the first sample and for the combined sample.

NOTE 2 A sampling plan does not contain the rules on how to draw the sample.

NOTE 3 For the purposes of this part of ISO 2859, a distinction should be made between the terms **acceptance sampling plan** (3.17), **acceptance sampling scheme** (3.18) and **acceptance sampling inspection system** (3.19).

3.18
acceptance sampling scheme
combination of **acceptance sampling plans** (3.17) with switching rules for changing from one plan to another

[ISO 3534-2]

NOTE See 10.3.

3.19
acceptance sampling inspection system
collection of **acceptance sampling plans** (3.17), or **acceptance sampling schemes** (3.18) together with criteria by which appropriate sampling plans or schemes may be chosen

[ISO 3534-2]

NOTE This part of ISO 2859 is a sampling system indexed by lot-size ranges, inspection levels and AQLs. A sampling system for **LQ** (3.30) plans is given in ISO 2859-2.

3.20
normal inspection
inspection (3.1) which is used when there is no reason to think that the quality level achieved by the process differs from a specified level

[ISO 3534-2]

3.21
tightened inspection
inspection (3.1) more severe than **normal inspection** (3.20), to which the latter is switched when inspection results of a predetermined number of **lots** (3.13) indicate that the quality level achieved by a process is poorer than that specified

[ISO 3534-2]

3.22
reduced inspection
inspection (3.1) less severe than **normal inspection** (3.20), to which the latter is switched when inspection results of a predetermined number of **lots** (3.13) indicate that the quality level achieved by a process is better than that specified

[ISO 3534-2]

NOTE The discriminatory ability under reduced inspection is less than under normal inspection.

3.23
switching score
indicator that is used under **normal inspection** (3.20) to determine whether the current inspection results are sufficient to allow for a switch to **reduced inspection** (3.22)

[ISO 2859-1:1999, 3.1.23]

NOTE See 10.3.3.

3.24
process average
process level averaged over a defined time period or quantity of production

[ISO 2859-1:1999, 3.1.25]

NOTE In this part of ISO 2859 the process average is the quality level (percent nonconforming or number of nonconformities per 100 items) during a period when the process is in a state of statistical control.

3.25
acceptance quality limit
AQL
worst tolerable product quality level

[ISO 3534-2]

NOTE 1 This concept only applies when a sampling scheme with rules for switching and for discontinuation, such as in this part of ISO 2859, ISO 2859-1 or ISO 3951, is used.

NOTE 2 Although individual lots with quality as bad as the acceptance quality limit may be accepted with fairly high probability, the designation of an acceptance quality limit does not suggest that this is a desirable quality level. Sampling schemes found in International Standards such as in this part of ISO 2859 or ISO 2859-1, with their rules for switching and for discontinuation of sampling inspection, are designed to encourage suppliers to have process averages consistently better than the AQL. Otherwise, there is a high risk that the inspection severity will be switched to tightened inspection under which the criteria for lot acceptance become more demanding. Once on tightened inspection, unless action is taken to improve the process, it is very likely that the rule requiring discontinuation of sampling inspection pending such improvement will be invoked.

3.26
consumer's risk
CR
probability of acceptance when the quality level has a value stated by the **acceptance sampling plan (3.17)** as unsatisfactory

[ISO 3534-2]

3.27
producer's risk
PR
probability of non-acceptance when the quality level has a value stated by the plan as acceptable

[ISO 3534-2]

3.28
consumer's risk quality

Q_{CR}
quality level of a **lot** (3.13) or process which, in the **acceptance sampling plan** (3.17), corresponds to a specified **consumer's risk** (3.26)

[ISO 3534-2]

NOTE The specified consumer's risk is usually 10 %.

3.29
producer's risk quality
Q_{PR}
quality level of a **lot** (3.13) or process which, in the **acceptance sampling plan** (3.17), corresponds to a specified **producer's risk** (3.27)

[ISO 3534-2]

NOTE The specified producer's risk is usually 5 %.

3.30
limiting quality
LQ
quality level, when a lot is considered in isolation, which, for the purposes of acceptance sampling inspection, is limited to a low probability of acceptance

[ISO 3534-2]

3.31
count
when inspection by attributes is performed, the result of the inspection of each sample item

NOTE In the case of inspection for nonconforming items, the count is set to 1 if the sample item is nonconforming or to 0 otherwise. In the case of inspection for nonconformities, the count is set to the number of nonconformities found in the sample item

3.32
cumulative count
when a sequential sampling plan is used, the total number of counts during inspection, counting from the start of the inspection of the lot up to, and including, the sample item last inspected

3.33
cumulative sample size
when a sequential sampling plan is used, the total number of sample items during inspection, counting from the start of the inspection of the lot up to, and including, the sample item last inspected

3.34
acceptance value
⟨for sequential sampling⟩ value used in the graphical method for determination of acceptance of the lot, that is derived from the specified parameters of the sampling plan and the cumulative sample size

3.35
acceptance number
⟨for sequential sampling⟩ number used in the numerical method for determination of acceptance of the lot, that is obtained by rounding the acceptance value down to the nearest integer

3.36
rejection value
⟨for sequential sampling⟩ value used in the graphical method for determination of non-acceptance of the lot, that is derived from the specified parameters of the sampling plan and the cumulative sample size

3.37
rejection number
⟨for sequential sampling⟩ number used in the numerical method for determination of non-acceptance of the lot, that is obtained by rounding the rejection value up to the nearest integer

3.38
acceptability table
table used for the lot acceptability determination in the numerical method

3.39
acceptability chart
chart used for the lot acceptability determination in the graphical method, consisting of the following three zones:

— acceptance zone;

— rejection zone;

— indecision zone;

the borders being acceptance, rejection and curtailment lines

