



BSI Standards Publication

Sampling procedures for inspection by variables

Part 6: Specification for single sampling plans for isolated lot inspection indexed by limiting quality (LQ)

National foreword

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Sampling procedures for inspection by variables —

Part 6: Specification for single sampling plans for isolated lot inspection indexed by limiting quality (LQ)

Règles d'échantillonnage pour les contrôles par mesures —

*Partie 6: Spécification pour les plans d'échantillonnage simples pour
les contrôles de lots isolés, indexés d'après la qualité limite (QL)*





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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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

A list of all parts in the ISO 3951 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document specifies an acceptance sampling system of single sampling plans for inspection by variables. It is indexed in terms of the limiting quality (LQ) for the inspection of lots where switching rules as used in ISO 3951-1 are not applicable. These switching rules provide protection to the consumer (by the prospect of switching to tightened inspection and discontinuation) and also provide an incentive to the supplier to improve the quality level. However, there are various cases where the switching rules of ISO 3951-1 are not applicable, such as isolated lots or a short series of lots.

This document is designed for the inspection of a single quality characteristic that is measurable on a continuous scale and is normally distributed, under conditions where ISO 3951-1 is not applicable, and is complementary to the attributes standard ISO 2859-2. The operating characteristic curves (OC curves) of the variables plans in this document are similar but not identical to those of the corresponding attributes plans in ISO 2859-2. The OC curves have been matched by minimizing the difference of the OC curves on condition of getting a comprehensible sample size structure (see [Clause 9](#)).

In this document, the acceptance of a lot is implicitly determined from an estimate of the fraction of nonconforming items in the process, based on a random sample of items from the lot. The objectives of the methods laid down in this document are to ensure that lots of limiting quality have a probability of acceptance about 10 % and that the probability of accepting lots with good quality is as high as practicable.

It is assumed in the main body of this document that measurement error is negligible. For information on accommodating measurement error, see [Annex B](#), which was derived from References [24], [29] and [30].

CAUTION — The procedures in this document are not suitable for application to lots that have been screened for nonconforming items.

Inspection by variables for nonconforming items, as described in this document, includes several possible modes, the combination of which leads to a presentation that can appear quite complex to the user:

- unknown standard deviation, or known since the start of inspection;
- a single specification limit, or combined control of double specification limits.

The choice of the most suitable variables plan, if one exists, requires experience, judgement, and some knowledge of both statistics and the product to be inspected. [Clause 5](#) is intended to help those responsible for specifying sampling plans in making this choice. It suggests the considerations that should be borne in mind when deciding whether a variables plan would be suitable and the choices to be made when selecting an appropriate standard plan.

The basic definitions and notations are provided by [Clauses 3](#) and [4](#). The basic operational rules are contained in [Clauses 5](#) through [8](#). [Clause 9](#) informs about the relations between this document and the attributes sampling standard ISO 2859-2. [Clauses 10](#) and [11](#) provide background on accounting for measurement uncertainty and the underlying normality assumption. All tables needed for the sampling procedure can be found in [Clause 12](#), and examples for the s -method and the σ -method for both single and double specification limits can be found in [Clause 13](#).

Nine annexes are provided. [Annex A](#) indicates how the sample standard deviation, s , and the presumed known value of the process standard deviation, σ , should be determined. [Annex B](#) provides procedures for accommodating measurement uncertainty. [Annex C](#) shows five different sampling strategies. [Annex D](#) gives the general formula for the operating characteristics of the s -method. [Annex E](#) gives the general formula for the operating characteristics of the σ -method. [Annex F](#) gives the theory underlying the calculation of consumer's risks. [Annex G](#) gives the theory underlying the calculation of producer's risk quality. [Annex H](#) gives details of how acceptance diagrams for double specification limits are constructed. [Annex I](#) gives a description of the use of the underlying software, R package ISO 3951, to support implementation of this document.

Sampling procedures for inspection by variables —

Part 6:

Specification for single sampling plans for isolated lot inspection indexed by limiting quality (LQ)

1 Scope

This document specifies an acceptance sampling system of single sampling plans for inspection by variables, primarily designed for use under the following conditions:

- a) where the inspection procedure is applied to an isolated lot of discrete products all supplied by one producer using one production process;
- b) where only a single quality characteristic, x , of this process is taken into consideration, which is measurable on a continuous scale;
- c) where the quality characteristic, x , is distributed according to a normal distribution or a close approximation to a normal distribution;
- d) where the quality characteristic can be measured without error or with moderate measurement error;
- e) where a contract or standard defines a lower specification limit, L , an upper specification limit, U , or both; an item is qualified as conforming if and only if its measured quality characteristic, x , satisfies the appropriate one of the following inequalities:
 - 1) $x \geq L$ (i.e. the lower specification limit is not violated);
 - 2) $x \leq U$ (i.e. the upper specification limit is not violated);
 - 3) $x \geq L$ and $x \leq U$ (i.e. neither the lower nor the upper specification limit is violated).

Inequalities 1) and 2) are cases with a single specification limit, whereas inequality 3) is a case with double specification limits.

Where double specification limits apply, it is assumed in this document that conformance to both specification limits is equally important to the integrity of the product. In such cases, it is appropriate to apply a single LQ to the combined fraction of a product outside the two specification limits. This is referred to as combined control.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

ISO 2859-2, *Sampling procedures for inspection by attributes — Part 2: Sampling plans indexed by limiting quality (LQ) for isolated lot inspection*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2859-1, ISO 2859-2, ISO 3534-1, and ISO 3534-2 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 inspection by variables

inspection by measuring the magnitude of a characteristic of an item

[SOURCE: ISO 3534-2:2006, 4.1.4, modified — "the magnitude(s) of the characteristic(s)" replaced with "the magnitude of a characteristic".]

3.2 sampling inspection

inspection of selected items in the group under consideration

[SOURCE: ISO 3534-2:2006, 4.1.6]

3.3 acceptance sampling inspection acceptance sampling

sampling inspection (3.2) to determine whether or not to accept a lot or other amount of product, material, or service

[SOURCE: ISO 3534-2:2006, 4.1.8, modified — "acceptance sampling" added as second preferred term; original definition, "acceptance inspection where the acceptability is determined by means of sampling inspection" replaced with the current one.]

3.4 acceptance sampling inspection by variables

acceptance sampling inspection (3.3) in which the acceptance of a lot is determined statistically from measurements on specified quality characteristics of each item in a sample from a lot

[SOURCE: ISO 3534-2:2006, 4.2.11, modified — "the process" replaced by "a lot", and "on specified quality characteristics of each item in a sample from a lot" has been replaced by "from inspection by variables"]

3.5 process fraction nonconforming

rate at which nonconforming items are generated by a process

Note 1 to entry: It is expressed as a proportion.

3.6 quality level

quality expressed as the fraction nonconforming

3.7**consumer's risk****CR**

probability of acceptance when the *quality level* (3.6) has a value stated by the acceptance sampling plan as unsatisfactory

Note 1 to entry: For the purposes of this document, the consumer's risk is approximately 10 %.

[SOURCE: ISO 3534-2:2006, 4.6.2, modified — Deleted symbol β ; original Note 1 to entry replaced with the current one.]

3.8**consumer's risk quality****CRQ**

quality level (3.6) of a lot or process which, in the acceptance sampling plan, corresponds to a specified *consumer's risk* (3.7)

Note 1 to entry: For the purposes of this document, the consumer's risk quality is the *limiting quality* (3.9).

[SOURCE: ISO 3534-2:2006, 4.6.9, modified — Deleted symbol Q_{CR} ; original Note 1 to entry replaced with the current one.]

3.9**limiting quality****LQ**

quality level (3.6), when a lot is considered in isolation, which, for the purposes of *acceptance sampling inspection* (3.3), is limited to a low probability of acceptance

[SOURCE: ISO 3534-2:2006, 4.6.13]

3.10**producer's risk****PR**

probability of non-acceptance when the *quality level* (3.6) has a value stated by the plan as acceptable

Note 1 to entry: For the purposes of this document, the producer's risk is 5 %.

[SOURCE: ISO 3534-2:2006, 4.6.4, modified — Deleted symbol α ; original Notes 1 and 2 to entry replaced with the current one.]

3.11**producer's risk quality****PRQ**

quality level (3.6) of a lot or process which, in the acceptance sampling plan, corresponds to a specified *producer's risk* (3.10)

[SOURCE: ISO 3534-2:2006, 4.6.10, modified — Deleted symbol Q_{PR} ; deleted Notes 1 and 2 to entry.]

3.12**nonconformity**

non-fulfilment of a requirement

[SOURCE: ISO 3534-2:2006, 3.1.11]

3.13**s-method acceptance sampling plan****s-method**

acceptance sampling (3.3) plan by variables using the sample standard deviation.

Note 1 to entry: See [Clause 6](#).

[SOURCE: ISO 3534-2:2006, 4.3.10, modified – “s method” has been replaced by “s-method”, “acceptance sampling plan” has been added; “s-method” left as a second preferred term; in the definition, “acceptance sampling inspection by variables” replaced with “acceptance sampling plan by variables”; added Note 1 to entry.]

3.14

σ -method acceptance sampling plan

σ -method

acceptance sampling (3.3) plan by variables using the presumed value of the process standard deviation

Note 1 to entry: See [Clause 7](#).

[SOURCE: ISO 3534-2:2006, 4.3.9, modified — “sigma method” has been replaced with “ σ -method”; “acceptance sampling plan” has been added with “ σ -method” left as a second preferred term; in the definition, “acceptance sampling inspection by variables” replaced with “acceptance sampling plan by variables”; added Note 1 to entry.]

3.15

specification limit

conformance boundary specified for a characteristic

[SOURCE: ISO 3534-2:2006, 3.1.3, modified — “limiting value stated” replaced with “conformance boundary specified”.]

3.16

lower specification limit

L

specification limit (3.15) that defines the lower conformance boundary

[SOURCE: ISO 3534-2:2006, 3.1.5, modified — “limiting value” replaced with “conformance boundary”.]

3.17

upper specification limit

U

specification limit (3.15) that defines the upper conformance boundary

[SOURCE: ISO 3534-2:2006, 3.1.4, modified — “limiting value” replaced with “conformance boundary”.]

3.18

combined control

requirement when both upper and lower limits are specified for the quality characteristic and an *LQ* (3.9) that applies to the combined fraction nonconforming beyond the two limits is given

Note 1 to entry: The use of combined control implies that *nonconformity* (3.12) beyond either *specification limit* (3.15) is believed to be of equal, or at least roughly equal, importance to the lack of integrity of the product.

3.19

form k acceptance constant

k

constant depending on the specified value of the *limiting quality* (3.9) and the sample size, used in the criteria for accepting the lot in an *acceptance sampling* (3.3) plan by variables

Note 1 to entry: See [Clauses 6](#) and [7](#).

[SOURCE: ISO 3534-2:2006, 4.4.4, modified – “acceptability constant” has been replaced with “form k acceptance constant”; “value of the acceptance quality limit” replaced with “value of the limiting quality”; added Note 1 to entry.]

3.20**form p^* acceptance constant** **p^***

constant depending on the specified value of the *limiting quality* (3.9) and the sample size, used in the criteria for accepting the lot in an *acceptance* (3.3) plan by variables

Note 1 to entry: See [Clause 8](#).

[SOURCE: ISO 3534-2:2006, 4.4.4, modified — “acceptability constant” has been replaced with “form p^* acceptance constant”; “value of the acceptance quality limit” replaced with “value of the limiting quality”; added Note 1 to entry.]

3.21**lower quality statistic** **Q_L**

function of the *lower specification limit* (3.15), the sample mean, and the sample or process standard deviation

Note 1 to entry: For a single lower specification limit, the lot is sentenced on the result of comparing Q_L with the *form k acceptance constant* (3.19) k .

Note 2 to entry: See [Clauses 6](#) and [7](#).

[SOURCE: ISO 3534-2:2006, 4.4.11, modified — In the Note 1 to entry, “acceptability constant” has been replaced with “form k acceptance constant”; Note 2 to entry added.]

3.22**upper quality statistic** **Q_U**

function of the *upper specification limit* (3.17), the sample mean, and the sample or process standard deviation

Note 1 to entry: For a single upper specification limit, the lot is sentenced on the result of comparing Q_U with the *form k acceptance constant* (3.19) k .

Note 2 to entry: See [Clauses 6](#) and [7](#).

[SOURCE: ISO 3534-2:2006, 4.4.10, modified — In the Note 1 to entry, “acceptability constant” has been replaced with “form k acceptance constant”; Note 2 to entry added.]

3.23**maximum process standard deviation****MPSD** **$\sigma_{\max}$**

largest process standard deviation for a given sample size and *LQ* (3.9) for which it is possible to satisfy the acceptance criterion for double *specification limits* (3.15) with a combined *LQ* (3.9) when the process variability is known

[SOURCE: ISO 3534-2:2006, 4.4.8, modified — Added symbol $\sigma_{\max}$; “or a given sample size code letter and AQL” replaced with “for a given sample size and LQ”; “for a double specification limit under all inspection severities (i.e. normal, tightened and reduced) when the process variability is known” replaced with “for double specification limits with a combined *LQ* when the process variability is known”; Note 1 to entry deleted.]

3.24**measurement**

set of operations to determine the value of some quantity

[SOURCE: ISO 3534-2:2006, 3.2.1, modified – “having the object of determining a value of a quantity” replaced with “to determine the value of some quantity”.]

4 Symbols

f_σ	factor that relates the maximum process standard deviation to the difference between U and L (see Table 3)
$F_{BETA(\alpha,\beta)}(x)$	the distribution of the standard beta distribution with parameters α and β . In this document $\alpha = \beta = n/2 - 1$ throughout.
$F_{t(v,\delta)}(x)$	the distribution function of the non-central t -distribution with v degrees of freedom and non-centrality parameter δ
K_p	the upper p -quantile of the standardized normal distribution, i.e. x such that $1 - \Phi(x) = p$, which corresponds to the process fraction nonconforming p
k	form k acceptance constant for use with a single quality characteristic and a single specification limit (see Table 2 for the s -method or Table 4 for the σ -method)
L	lower specification limit (as a subscript to a variable, it denotes its value at L)
n	sample size (number of items in a sample)
P_a	probability of acceptance
p	lot quality in fraction nonconforming
$\hat{p}$	estimate of the process fraction nonconforming
$\hat{p}_L$	estimate of the process fraction nonconforming below the lower specification limit
$\hat{p}_U$	estimate of the process fraction nonconforming above the upper specification limit
p^*	form p^* acceptance constant, i.e. the maximum acceptable value for the estimate of the process fraction nonconforming (see Table 5)
$\Phi(x)$	the distribution function of the standardized normal distribution.
Q_L	lower quality statistic NOTE Q_L is defined as $(\bar{x} - L)/s$ when the process standard deviation is unknown, and as $(\bar{x} - L)/\sigma$ when it is presumed to be known.
Q_U	upper quality statistic NOTE Q_U is defined as $(U - \bar{x})/s$ when the process standard deviation is unknown, and as $(U - \bar{x})/\sigma$ when it is presumed to be known.
s	sample standard deviation of the measured values of the quality characteristic (also an estimate of the standard deviation of the process), i.e. $s = \sqrt{\frac{\sum_{j=1}^n (x_j - \bar{x})^2}{n-1}}$ (see Annex A)
σ	standard deviation of a process that is under statistical control NOTE 1 σ^2 , the square of the process standard deviation, is known as the process variance.
$\sigma_{\max}$	maximum process standard deviation (MPSD) (see Table 3)

U	upper specification limit (as a subscript to a variable, it denotes its value at U)
x_j	measured value of the quality characteristic for the j^{th} item of the sample
$\bar{x}$	Sample arithmetic mean of the measured values of the quality characteristic in the sample, i.e.

$$\bar{x} = \frac{\sum_{j=1}^n x_j}{n}$$

(see [Annex A](#))

5 Choice of a sampling plan

5.1 Choice between variables and attributes

The first question to consider is whether it is desirable to inspect by variables rather than by attributes. The following points should be taken into account.

- In terms of economics, it is necessary to compare the total cost of the relatively simple inspection of a larger number of items by means of an attributes scheme with the generally more elaborate procedure required by a variables scheme, which is usually more time consuming and costly per item.
- In terms of the knowledge gained, the advantage lies with inspection by variables as the information obtained indicates more precisely how good the product is.
- An attributes scheme can be more readily understood and accepted; for example, it may at first be difficult to accept that, when inspecting by variables, a lot can be rejected on measurements taken of a sample that does not contain any nonconforming items and vice versa (see [13.2](#) Example 2 a and Example 2 b).
- From a comparison of the size of the samples required for the same LQ from standard plans for inspection by attributes, such as from ISO 2959, and the standard plans in this document, the smallest samples are generally required by the σ -method (used when the process standard deviation is presumed to be known). The sample sizes for the s -method (used when the process standard deviation is presumed to be unknown) are larger than for the σ -method but are, in general, substantially smaller than for sampling by attributes.
- Variables sampling has a substantial advantage when the inspection process is expensive, for example, in the case of destructive testing.
- For two or more quality characteristics, ISO 3951 series does not contain specifications for sampling plans indexed by LQ.

5.2 General

The following procedures shall be followed in advance of the inspection by variables.

- Specify the limiting quality (LQ) in accordance with [5.4](#).
- Determine the lot size (N).
- Determine the quality characteristic x and an upper limit U and/or a lower limit L for x .
- For a quality characteristic with double specification limits, check that nonconformities beyond each limit are of equal importance.

- e) Check whether the s -method ([Clause 6](#)) should be used or whether the standard deviation is stable and known, in which case the σ -method ([Clause 7](#)) should be used (see [5.3](#));
- f) for the σ -method and a quality characteristic with double specification limits, a process capability study in the following sense should be done:
- 1) enter [Table 3](#) with the LQ to determine the value of the factor f_{σ} ;
 - 2) calculate the maximum allowable value of the process standard deviation using the formula $\sigma_{\max} = (U - L)f_{\sigma}$;
 - 3) If σ exceeds $\sigma_{\max}$, the process is not capable and sampling inspection is pointless until it is demonstrated that the process variability has been adequately reduced.

With the specified lot size and the limiting quality as indexing values, the sample size n and the acceptance constant k are given in [Table 2](#) (s -method) or [Table 4](#) (σ -method).

Although the primary index is the limiting quality, the producer/supplier needs guidance on the quality level required if lots are to have a high probability of acceptance.

5.3 Choice between the s -method and the σ -method

If it is desired to apply inspection by variables as proposed in this document, the decision shall be made whether to use the s -method or the σ -method. The σ -method is the more economical in terms of sample size, but before this method can be applied, it is necessary to have a reliable value of σ , usually obtained from previous process analyses.

In case no reliable assumptions on the value of σ can be made, it is necessary to use the s -method.

5.4 Choice of the limiting quality (LQ)

The purpose of this document is to guard against unsatisfactory quality. The determination of unsatisfactory quality is generally a decision that should be made by quality management. The choice of the LQ is governed by a number of factors, but is mainly a balance between the total cost of inspection and the consequences of nonconforming items passing into service. In this document, the LQ is the parameter used to protect against unsatisfactory quality. The sampling plans in this document have a probability of accepting the lot at the LQ of about 10 %. In this document, the sampling tables are indexed by a set of specified LQ values.

If the user's chosen LQ value is not among those specified in [Table 1](#), then an applicable LQ value shall be the specified LQ corresponding to the range containing the user's chosen LQ, which is the closest specified LQ below the user's chosen LQ (see Example).

Table 1 — Specified LQ values

Limiting quality (LQ) in percent nonconforming					
range	$0,05 \leq LQ < 0,08$	$0,08 \leq LQ < 0,125$	$0,125 \leq LQ < 0,2$	$0,2 \leq LQ < 0,315$	$0,315 \leq LQ < 0,5$
specified	0,05	0,08	0,125	0,2	0,315
range	$0,5 \leq LQ < 0,8$	$0,8 \leq LQ < 1,25$	$1,25 \leq LQ < 2$	$2 \leq LQ < 3,15$	$3,15 \leq LQ < 5$
specified	0,5	0,8	1,25	2	3,15
range	$5 \leq LQ < 8$	$8 \leq LQ < 12,5$	$12,5 \leq LQ < 20$	$20 \leq LQ < 31,5$	$31,5 \leq LQ$
specified	5	8	12,5	20	31,5

Where both upper and lower specification limits are given, this document addresses only the case of an overall LQ applying to the combined fraction nonconforming beyond both specification limits; this is known as combined control.

EXAMPLE

For a product, the limiting quality has been set at 3,5 % nonconforming. This is not one of the specified values and the applicable LQ shall be that for range $3,15 \% \leq LQ < 5 \%$, which is the specified value of 3,15 %, since this is the closest specified LQ below 3,5 %.

6 Standard procedures for the s-method

6.1 General

The s-method shall be used if information about the standard deviation is missing or unreliable. Under the s-method, the standard deviation is estimated directly from each sample. As soon as the conditions for the use of the σ -method are warranted, one may switch from the s-method to the σ -method (see 5.3).

6.2 Single specification limits

Before starting the inspection by variables, see [Clause 5](#).

The procedure for a single specification limit is as follows:

- a) Enter [Table 2](#) with the lot size, N , and the LQ to obtain the sample size, n , and the acceptance constant, k .
- b) Take a random sample of size n , measure the characteristic x in each item, and then calculate $\bar{x}$, the sample mean, and s , the sample standard deviation (see [Annex A](#)).

NOTE Some sampling strategies are provided in [Annex C](#).

- c) Determination of acceptance.
 - 1) If $\bar{x} < L$ or $\bar{x} > U$, reject the lot; or continue with the next step.
 - 2) If $s = 0$ accept the lot; or continue with the next step.

NOTE It is possible to get $s = 0$ when measurement uncertainty is present (see [Clause 10](#) and [Annex B](#)).

- 3) Calculate the quality statistic $Q_U = (U - \bar{x})/s$ or $Q_L = (\bar{x} - L)/s$ and compare it with the acceptance constant k . The lot is accepted if $Q_U \geq k$ or $Q_L \geq k$; or rejected if $Q_U < k$ or $Q_L < k$.

For examples of single lower and upper specification limits, see Example 1, Example 2 and Example 3) in [13.2](#).

6.3 Double specification limits

Before starting the inspection by variables, see [Clause 5](#).

The procedure for double specification limits for the s-method is as follows:

- a) Enter [Table 2](#) with the lot size, N , and the LQ to obtain the sample size, n , and the acceptance constant, k .
- b) Take a random sample of size n , measure the characteristic x in each item and then calculate $\bar{x}$, the sample mean, and s , the sample standard deviation (see [Annex A](#)).

NOTE Some sampling strategies are provided in [Annex C](#).

c) Determination of acceptance.

- 1) If $\bar{x} < L$ or $\bar{x} > U$, reject the lot; or continue with the next step.
- 2) Plot $(s, \bar{x})$ on the acceptance diagram, which can be obtained using the acceptance_region function in the underlying software (see [I.5](#)).

NOTE The standardized values $(s_S, \bar{x}_S)$ where $s_S = \frac{s}{U-L}$ and $\bar{x}_S = \frac{\bar{x}-L}{U-L}$ may be used in which case $(s_S, \bar{x}_S)$ is plotted on the standardized acceptance diagram, which can be obtained using the acceptance_region function in the underlying software without providing the standardized lower and upper specification limits $L = 0, U = 1$ (see [I.5](#)).

- 3) If the plotted point is outside the acceptance region the lot is rejected; otherwise, the lot is accepted.

For examples of combined control of double specification limits see Example 4 and Example 5 in [13.2](#).

7 Standard procedures for the σ -method

7.1 General

The σ -method shall only be used when there is valid evidence that the standard deviation σ of the process can be considered constant with a known value.

7.2 Single specification limits

Before starting the inspection by variables, see [Clause 5](#).

The procedure for the σ -method for a single limit is as follows.

- a) Enter [Table 4](#) with the lot size, N , and the LQ to obtain the sample size, n , and the acceptance constant, k .
- b) Take a random sample of size n , measure the characteristic x in each item and then calculate $\bar{x}$.

NOTE Some sampling strategies are provided in [Annex C](#).

- c) Calculate the quality statistic $Q_U = (U - \bar{x})/\sigma$ or $Q_L = (\bar{x} - L)/\sigma$ and compare it with the acceptance constant k . The lot is accepted if $Q_U \geq k$ or $Q_L \geq k$; or rejected if $Q_U < k$ or $Q_L < k$.

For examples of single lower and upper specification limits using the σ -method, see Example 1 and Example 2 in [13.3](#).

7.3 Double specification limits

Before starting the inspection by variables, see [Clause 5](#).

- a) For double specification limits, a process capability study in the following sense should be done:
 - 1) Enter [Table 3](#) with the Lot size, N , and the LQ to get f_σ .
 - 2) Calculate $U - L$ and multiply this value by f_σ to give $\sigma_{\max}$ the maximum process standard deviation (MPSD).
 - 3) If the known value of σ is less than or equal to $\sigma_{\max}$ then acceptance sampling using the σ -method can begin.

- 4) Enter [Table 4](#) with the lot size, N , and the LQ to obtain the sample size, n , and the acceptance constant, k .
- b) Determination of acceptance:
- 1) If $\bar{x} < L$ or $\bar{x} > U$, reject the lot; or continue with the next step.
 - 2) Calculate the quality statistics $Q_L = (\bar{x} - L) / \sigma$ and $Q_U = (U - \bar{x}) / \sigma$. If $Q_L < k$ or $Q_U < k$, reject the lot; or continue with the next step.
 - 3) If $\sigma \leq 0,75 \sigma_{\max}$ accept the lot; otherwise continue with the next step.
 - 4) If neither Q_L or Q_U are close to k accept the lot; otherwise use the p^* -method in [Clause 8](#).

For examples of combined control of double specification limits using the σ -method, see Example 3 in [13.3](#).

8 The p^* -method

The p^* -method is an alternative to the standard procedures in [Clause 6](#) and [Clause 7](#). For the application of this method, distribution functions are calculated.

Before starting the inspection by variables, see [Clause 5](#).

The procedure for the p^* -method for a single specification limit and double specification limits is as follows.

- a) Enter [Table 2](#) for unknown standard deviation or [Table 4](#) for known standard deviation with the lot size, N , and the LQ to obtain the sample size, n .
- b) Enter [Table 5](#) with the lot size, N , and the LQ to obtain the acceptance constant, i.e. the maximum fraction nonconforming, p^* .
- c) Take a random sample of size n , measure the characteristic x in each item and then calculate $\bar{x}$, the sample mean. For unknown standard deviations, also calculate s , the sample standard deviation (see [Annex A](#)).

NOTE 1 Some sampling strategies are provided in [Annex C](#).

- d) Estimated fraction nonconforming.
- 1) **Unknown standard deviation:** For a lower specification limit, calculate $\hat{p}_L$, for an upper limit, calculate $\hat{p}_U$, and for double specification limits, calculate both.

$$\hat{p}_L = F_{BETA\left(\frac{n}{2}-1, \frac{n}{2}-1\right)}\left(\max\left\{0, \frac{1}{2} - \frac{1}{2} \frac{\bar{x} - L}{s} \frac{\sqrt{n}}{n-1}\right\}\right) = F_{BETA\left(\frac{n}{2}-1, \frac{n}{2}-1\right)}\left(\max\left\{0, \frac{1}{2} \left[1 - Q_L \frac{\sqrt{n}}{n-1}\right]\right\}\right)$$

$$\hat{p}_U = F_{BETA\left(\frac{n}{2}-1, \frac{n}{2}-1\right)}\left(\max\left\{0, \frac{1}{2} - \frac{1}{2} \frac{U - \bar{x}}{s} \frac{\sqrt{n}}{n-1}\right\}\right) = F_{BETA\left(\frac{n}{2}-1, \frac{n}{2}-1\right)}\left(\max\left\{0, \frac{1}{2} \left[1 - Q_U \frac{\sqrt{n}}{n-1}\right]\right\}\right)$$
 - 2) **Known standard deviation:** For a lower specification limit, calculate $\hat{p}_L$, for an upper limit, calculate $\hat{p}_U$, and for double specification limits, calculate both.

$$\hat{p}_L = \Phi\left(\frac{L - \bar{x}}{\sigma} \sqrt{\frac{n}{n-1}}\right) = \Phi\left(-Q_L \sqrt{\frac{n}{n-1}}\right)$$

$$\hat{p}_U = \Phi \left(\frac{\bar{x} - U}{\sigma} \sqrt{\frac{n}{n-1}} \right) = \Phi \left(-Q_U \sqrt{\frac{n}{n-1}} \right)$$

e) Determination of acceptance:

- 1) **single limit:** A lot shall be accepted if $\hat{p}_L \leq p^*$ for a lower limit, and if $\hat{p}_U \leq p^*$ for an upper limit; if $\hat{p}_L > p^*$ or $\hat{p}_U > p^*$ respectively, the lot is rejected.
- 2) **double limits:** A lot shall be accepted if $\hat{p}_L + \hat{p}_U \leq p^*$; if $\hat{p}_L + \hat{p}_U > p^*$, the lot is rejected.

For an example of single specification limits see Example 7 in [13.4](#). For examples of combined control of double specification limits see Example 8 and Example 9 in [13.4](#).

9 Relation to ISO 2859-2

9.1 Similarities

- a) This document is complementary to ISO 2859-2; the two documents share a common philosophy and, as far as possible, their procedures and vocabulary are the same.
- b) Both use the LQ to index the sampling plans, and the specified values used in this document are identical to those given for percent nonconforming in ISO 2859-2 (i.e. from 0,05 % to 31,5 %).
- c) In both this document and ISO 2859-2, tables give the sample size to be taken and the acceptance constants, indexed by the lot size and the LQ. Separate tables are given for the *s*-method and the σ -method.

9.2 Differences

- a) **Determination of acceptance.** In ISO 2859-2, acceptance for an attributes sampling plan for nonconforming items is determined by the number of nonconforming items found in the sample. In this document, acceptance for a plan for inspection by variables is based on the distance of the estimated value of the process mean from the specification limit(s) in terms of the process standard deviation. In this document, two methods are considered: the *s*-method, for use when the process standard deviation, σ , is unknown, and the σ -method, for use when σ is presumed to be known.
- b) **Normality.** In ISO 2859-2, there is no requirement relating to the distribution of the characteristics. However, in this document, it is necessary for the efficient operation of the plans that the measurements be distributed according to a normal distribution (see [11.1](#)) or a close approximation to a normal distribution or the data is appropriately transformed to a normal distribution (see [11.2](#)).
- c) **Sample sizes.** The variables sample sizes for given lot size and LQ are smaller than the corresponding attributes sample sizes. This is particularly true for the σ -method.
- d) **Operating characteristic curves (OC curves).** The OC curves of the variables plans in this document are not identical to those of the corresponding attributes plans in ISO 2859-2. However, the curves have been matched in the sense that the OC curves are as similar as possible. The curves for unknown process standard deviation have been matched by minimizing the difference of the curves on condition of getting a comprehensible sample size structure.

In most cases, the resulting match between the OC curves is so close that, for most practical purposes, the attributes and variables OC curves have the same characteristic. The plans for known process standard deviation were derived by keeping the same form p^* acceptance constant as for the corresponding case for unknown process standard deviation and the same approach for a comprehensible sample size structure, i.e. no parameter was open to choose, so the match was, in general, less perfect. For more details see Reference [\[21\]](#).

- e) **Consumer's risk.** For process quality precisely at the LQ, the producer's risk that a lot will not be accepted in this document is strictly below 10 % for the s -method and about 10 % for the σ -method, whereas in ISO 2859-2 the producer's risk is only about 10 %.

NOTE The consumer's risks of the plans are given in [Table 6](#) and [Table 7](#).

- f) **Producer's risk quality.** The process qualities precisely at the producer's risk of 5 % deviate in some cases from those in ISO 2859-2 to the benefit of a comprehensible sample size structure.

NOTE The producer's risk qualities of the plans are given in [Table 6](#) and [Table 7](#).

10 Allowing for measurement uncertainty

The master, i.e. the tables in [Clause 12](#), are based on the assumption that the quality characteristic, x , of the items in the lots is normally distributed with unknown process mean, μ , and either known or unknown process standard deviation, σ . The assumption is also made that x can be measured without measurement error, i.e. that measurement of an item with the true value, x_i , results in the value x_i . However, the tables in [Clause 12](#) can also be used, with appropriate adjustments, in the presence of measurement error.

Ideally, as a prerequisite for the application of the proposed sampling schemes, the measurement uncertainty, i.e. the measurement standard deviation, is determined by a structured measurement analysis, followed by a measurement system capability assessment (see Reference [14]). If the measurement standard deviation is not higher than 10 % of the process standard deviation and if there is no measurement bias, the measurement system can be considered as capable and no further adjustments on sample sizes are required (see Reference [24]).

For measurement standard deviations higher than 10 % of the process standard deviation, or in case of measurement bias that cannot be simply adjusted, the sample size needs to be increased, although the acceptance constant remains the same. Moreover, if neither the measurement standard deviation nor the process standard deviation is known, more than one measurement needs to be made on each sampled item, and the total variability of the measurements needs to be separated into the components due to the measurements and to the process.

In cases where measurement error is not negligible, the sampling plans of this document shall be used using the adjustments provided in [Annex B](#).

11 Normality, data transformations and outliers

11.1 Normality

The assumption of a normal distribution for the inspected quality characteristic x is the fundamental requirement for the application of the proposed variable sampling plans. Therefore, it is essential to assess the data normality before applying the sampling plans, which could be done by several approaches:

- assessment based on practical, engineering experience and expertise;
- assessment based on graphical, descriptive methods such as histograms, quantile/quantile or normal probability plots (see ISO 5479 and Reference [18]);
- statistical tests for departure from normality, such as those given in ISO 5479.

11.2 Data transformations

For non-normal distributed data, the first approach is usually to try to find a suitable transformation f of the observed data x , so that $Z = f(x)$ follows an (approximate) normal distribution. The most commonly used data transformations are (see ISO 16269-4):

- a) power transformations;
- b) Box-Cox transformations ;
- c) Johnson transformations ;
- d) transformation using Pearson functions.

For the transformed data, the goodness of fit to a normal distribution can be assessed using normal probability plots and/or statistical tests for normality. For subsequent capability analyses and assessments, the targets and specification limits of the quality characteristic x have to be transformed in the same way as the observed process data.

11.3 Outliers

An outlier (or an outlying observation) is one that appears to deviate markedly from other observations in the sample in which it occurs. A single outlier, even when it lies within specification limits, increases variability, changes the mean, and can consequently lead to non-acceptance of the lot (see ISO 16269-4).

Generally, outliers can be a result of

- a) (unexpected high) natural process variability,
- b) presence of special causes not representing the controlled and capable process status.

For case b), one can exclude the outlying observations for the quality assessment, whereas for case a), these values have to be considered in the analysis. Nevertheless, a sensitivity analysis including and excluding the outliers can help to assess the impact of these values on the decision on lot acceptance.

When outliers are detected, the disposition of the lot should be a matter for negotiation between the producer and the responsible authority.

12 Tables

12.1 Information about the tables

[Table 2](#)

With the specified lot size and the limiting quality as indexing values, the single sampling plans of Form k (sample size n and the acceptance constant k) are given for the s -method.

NOTE The cell entry '100 %' denotes that in this case a 100 % inspection has to be done.

[Table 3](#)

The values of f_σ for maximum process standard deviation for combined control of double specification limits are given for the σ -method.

The MPSD indicates the greatest allowable magnitude of the process standard deviation when using plans for combined control of double specification limits when the process variability is known. If the process standard deviation is less than the MPSD, then there is a possibility, but not a certainty, that the lot shall be accepted.

The method used to calculate these values is not the same as that used to calculate those in ISO 3951-1:2022, Table 11. More detail is given in [Annex H](#). The two tables should not be used interchangeably.

Table 4

With the specified lot size and the limiting quality as indexing values, the single sampling plans of Form k (sample size n and the acceptance constant k) are given for the σ -method.

NOTE The cell entry '100 %' denotes that in this case a 100 % inspection has to be done.

Table 5

With the specified lot size and the limiting quality as indexing values, the single sampling plans of form p^* (sample size n and acceptance constant, i.e. the maximum fractions nonconforming p^*) are given.

The values of p^* are given to 6 significant figures. This allows the form k acceptance constants, in [Table 2](#) and [Table 4](#), to be calculated from the values of p^* . This is consistent with the fitting process described in [Clause 9 d](#)).

NOTE The formulae for calculating k can be found in [Annex H](#). [Formula \(H.3\)](#) is for the s -method and [Formula \(H.7\)](#) is for the σ -method.

Tables 6 to 11

For a given sampling plan, the consumer's risk (CR) is the probability of accepting a given lot when the fraction nonconforming is equal to the LQ. The producer's risk quality (PRQ) is the quality for which the probability of not accepting a given lot is 5 %.

Both tables are named 'Consumer's risk and producer's risk quality'. The difference is between the s -method and σ -method.

The cell entries display:

- a) upper left: sample size n ;
- b) upper right: acceptance constant k ;
- c) lower left: PRQ in percent nonconforming with <0,001 indicating non-zero values less than 0,001;
- d) lower right: CR in percent;

NOTE The formulae for calculating CR and PRQ can be found in [Annex F](#) and [Annex G](#).

Table 2 — Single sampling plans of Form k: s-method

Lot size	Limiting quality (in percent nonconforming)														
	0,05	0,08	0,125	0,2	0,315	0,5	0,8	1,25	2	3,15	5	8	12,5	20	31,5
16 to 25 <i>n</i> <i>k</i>	100 %	100 %	100 %	3,665 1	22 3,507 4	20 3,363 3	18 3,210 1	17 3,028 4	15 2,856 9	13 2,685 8	12 2,448 3	10 2,235 5	9 1,949 2	7 1,675 6	5 1,388 5
26 to 50 <i>n</i> <i>k</i>	32 4,004 3	30 3,872 9	28 3,745 4	26 3,604 4	24 3,464 1	23 3,293 2	21 3,130 6	19 2,970 5	17 2,789 4	15 2,604 9	13 2,402 5	11 2,177 3	10 1,887 0	8 1,683 3	6 1,313 6
51 to 90 <i>n</i> <i>k</i>	36 3,953 6	34 3,818 6	32 3,686 7	30 3,540 9	28 3,394 6	26 3,238 1	24 3,069 8	21 2,923 1	19 2,735 6	17 2,542 7	15 2,329 0	13 2,088 4	11 1,863 5	9 1,551 5	7 1,499 5
91 to 150 <i>n</i> <i>k</i>	41 3,902 7	39 3,764 7	36 3,639 8	34 3,490 8	31 3,353 1	29 3,193 5	26 3,036 4	24 2,865 9	22 2,672 2	19 2,493 0	17 2,272 5	14 2,086 5	12 1,886 7	10 1,716 3	8 1,511 7
151 to 280 <i>n</i> <i>k</i>	47 3,854 1	44 3,721 6	42 3,584 2	39 3,441 1	36 3,297 9	33 3,145 3	30 2,981 8	28 2,807 1	25 2,623 0	22 2,469 4	19 2,247 3	16 2,042 4	14 1,864 7	11 1,432 7	9 1,199 9
281 to 500 <i>n</i> <i>k</i>	55 3,803 8	51 3,673 7	48 3,540 9	45 3,394 3	41 3,254 6	38 3,097 9	35 2,929 4	32 2,777 6	28 2,614 4	25 2,520 9	22 2,275 9	19 2,047 3	16 1,678 8	13 1,461 4	10 1,012 1
501 to 1 200 <i>n</i> <i>k</i>	66 3,751 8	62 3,617 4	58 3,486 0	54 3,341 2	50 3,195 9	46 3,065 9	42 2,893 7	38 2,715 5	34 2,606 1	30 2,331 5	27 2,109 3	23 1,886 2	19 1,673 6	15 1,320 7	12 0,952 0
1 201 to 3 200 <i>n</i> <i>k</i>	85 3,689 4	80 3,554 3	75 3,422 0	69 3,305 5	64 3,142 4	59 2,988 4	54 2,823 1	49 2,691 4	44 2,455 4	39 2,272 6	34 2,047 8	29 1,808 5	24 1,557 8	19 1,253 6	15 0,890 3
3 201 to 10 000 <i>n</i> <i>k</i>	113 3,630 3	106 3,506 7	99 3,368 8	92 3,219 8	85 3,073 1	78 2,917 7	71 2,787 2	65 2,587 3	58 2,407 2	51 2,202 4	44 1,990 3	38 1,747 9	31 1,499 0	25 1,190 0	20 0,825 3
10 001 to 35 000 <i>n</i> <i>k</i>	155 3,578 1	145 3,442 9	135 3,309 8	126 3,163 9	116 3,018 4	106 2,890 4	97 2,708 8	88 2,535 3	78 2,341 9	69 2,147 5	60 1,933 3	51 1,693 7	42 1,441 9	34 1,132 3	27 0,770 5
35 001 to 150 000 <i>n</i> <i>k</i>	213 3,531 4	199 3,397 1	186 3,264 7	173 3,119 3	160 2,995 9	146 2,827 8	133 2,660 7	120 2,482 8	107 2,295 1	94 2,101 5	82 1,886 6	69 1,648 1	58 1,392 8	47 1,083 2	37 0,723 7
150 001 to 500 000 <i>n</i> <i>k</i>	269 3,502 9	252 3,368 2	235 3,236 0	218 3,110 8	201 2,949 7	184 2,798 2	167 2,621 5	151 2,454 2	135 2,266 1	119 2,071 8	103 1,857 8	87 1,618 6	73 1,363 5	59 1,054 4	47 0,722 9
> 500 000 <i>n</i> <i>k</i>	288 3,495 3	269 3,360 9	251 3,247 6	233 3,092 3	215 2,941 1	197 2,780 5	179 2,613 6	162 2,446 2	144 2,258 8	127 2,064 4	110 1,850 2	93 1,610 8	78 1,355 8	63 1,046 9	50 0,729 9

Table 3 — Values of f_σ for maximum process standard deviation for combined control of double specification limits: σ -method

Lot size	Limiting quality (in percent nonconforming)														
	0,05	0,08	0,125	0,2	0,315	0,5	0,8	1,25	2	3,15	5	8	12,5	20	31,5
16 to 25	f_σ	0,117 595	0,120 519	0,126 170	0,129 888	0,137 225	0,141 951	0,158 291	0,166 082	0,173 845	0,194 739	0,209 992	0,245 538	0,280 291	0,327 321
26 to 50	f_σ	0,118 145	0,121 939	0,125 719	0,130 333	0,135 143	0,143 506	0,158 035	0,167 667	0,178 510	0,192 224	0,210 299	0,244 745	0,268 789	0,334 105
51 to 90	f_σ	0,123 234	0,127 586	0,132 058	0,137 477	0,143 305	0,150 142	0,158 283	0,175 444	0,188 151	0,204 541	0,226 612	0,250 834	0,294 755	0,298 264
91 to 150	f_σ	0,123 812	0,128 435	0,132 310	0,138 023	0,143 016	0,150 152	0,157 033	0,177 957	0,189 009	0,206 386	0,221 411	0,241 859	0,261 409	0,362 089
151 to 280	f_σ	0,125 177	0,129 390	0,134 394	0,139 660	0,145 300	0,151 845	0,159 552	0,180 086	0,189 758	0,206 529	0,224 222	0,242 529	0,302 107	0,344 763
281 to 500	f_σ	0,127 103	0,131 229	0,135 930	0,141 559	0,147 019	0,154 043	0,162 372	0,179 715	0,185 014	0,203 165	0,222 986	0,264 318	0,294 477	0,381 251
501 to 1 200	f_σ	0,129 318	0,133 857	0,138 571	0,144 190	0,150 262	0,156 023	0,164 563	0,180 527	0,199 709	0,218 120	0,239 518	0,263 606	0,315 537	0,391 257
1 201 to 3 200	f_σ	0,130 747	0,135 411	0,140 279	0,144 709	0,151 668	0,158 801	0,167 216	0,174 405	0,202 454	0,221 179	0,244 880	0,275 073	0,321 819	0,398 426
3 201 to 10 000	f_σ	0,132 435	0,136 742	0,141 900	0,147 922	0,154 329	0,161 725	0,168 398	0,179 969	0,206 696	0,224 800	0,249 496	0,280 302	0,329 334	0,409 174
10 001 to 35 000	f_σ	0,133 952	0,138 787	0,143 876	0,149 914	0,156 406	0,162 535	0,172 190	0,182 448	0,210 046	0,228 867	0,253 911	0,286 070	0,336 879	0,419 155
35 001 to 150 000	f_σ	0,135 315	0,140 203	0,145 368	0,151 484	0,157 046	0,165 316	0,174 399	0,185 161	0,212 957	0,232 301	0,257 846	0,291 409	0,343 868	0,428 643
150 001 to 500 000	f_σ	0,136 222	0,141 189	0,146 407	0,151 691	0,159 079	0,166 664	0,176 437	0,199 734	0,215 048	0,234 618	0,260 696	0,294 868	0,348 330	0,427 140
>500 000	f_σ	0,136 454	0,141 420	0,145 872	0,152 460	0,159 434	0,167 538	0,176 825	0,200 165	0,215 547	0,235 219	0,261 442	0,295 772	0,349 492	0,424 719

NOTE The MPD is obtained by multiplying the standardized MPD, f_{σ} , by the difference between the upper specification limit, U , and the lower specification limit, L , i.e. $MPD = (U - L) f_{\sigma}$.

Table 4 — Single sampling plans of Form k: σ -method

Lot size	n	Limiting quality (in percent nonconforming)														
		0,05	0,08	0,125	0,2	0,315	0,5	0,8	1,25	2	3,15	5	8	12,5	20	31,5
16 to 25	k	4,145 6	4,039 9	3,849 2	3,732 6	3,520 5	3,395 2	3,262 5	3,017 9	2,863 3	2,722 5	2,597 1	2,498 6	2,397 1	2,300 0	2,202 0
26 to 50	k	4,112 3	3,977 0	3,850 0	3,704 8	3,563 7	3,440 2	3,316 6	3,006 3	2,815 7	2,624 8	2,412 7	2,273 3	2,180 7	2,083 5	1,986 3
51 to 90	k	3,932 6	3,790 0	3,653 0	3,498 7	3,345 2	3,180 0	3,001 1	2,876 4	2,676 5	2,472 6	2,245 3	2,088 3	1,988 3	1,888 3	1,788 3
91 to 150	k	3,905 0	3,754 9	3,637 0	3,474 8	3,343 3	3,170 1	3,017 4	2,833 4	2,622 8	2,448 0	2,209 2	2,031 2	1,822 1	1,650 7	1,493 3
151 to 280	k	3,854 1	3,719 6	3,570 4	3,424 7	3,279 8	3,124 8	2,957 9	2,768 8	2,580 0	2,429 1	2,199 0	1,991 4	1,806 3	1,648 4	1,493 4
281 to 500	k	3,787 6	3,659 4	3,522 6	3,370 3	3,233 4	3,070 9	2,895 7	2,740 8	2,580 8	2,495 8	2,236 4	1,998 6	1,609 9	1,389 8	1,233 7
501 to 1 200	k	3,714 8	3,578 7	3,446 5	3,299 8	3,153 1	3,024 1	2,848 8	2,667 6	2,563 5	2,278 0	2,048 6	1,823 3	1,610 2	1,252 6	1,085 6
1 201 to 3 200	k	3,665 2	3,528 2	3,394 5	3,280 5	3,114 2	2,958 2	2,790 6	2,659 6	2,417 4	2,233 0	2,004 9	1,762 9	1,510 3	1,204 7	1,043 7
3 201 to 10 000	k	3,610 4	3,486 4	3,347 6	3,197 3	3,049 7	2,893 2	2,763 3	2,559 7	2,378 4	2,171 9	1,958 5	1,713 7	1,464 0	1,154 4	1,092 8
10 001 to 35 000	k	3,562 6	3,426 8	3,293 4	3,146 4	3,000 5	2,873 0	2,689 6	2,515 0	2,320 6	2,125 1	1,909 7	1,669 0	1,416 7	1,107 2	1,048 4
35 001 to 150 000	k	3,520 9	3,386 2	3,253 4	3,107 3	2,984 0	2,815 1	2,647 3	2,468 6	2,280 1	2,085 9	1,870 1	1,630 9	1,375 1	1,065 9	1,008 9
150 001 to 500 000	k	3,493 9	3,358 9	3,226 4	3,101 2	2,939 5	2,787 7	2,610 3	2,442 6	2,253 8	2,059 0	1,844 5	1,604 9	1,349 5	1,040 8	1,011 3
>500 000	k	3,487 1	3,352 4	3,239 3	3,083 3	2,931 7	2,770 6	2,603 3	2,435 4	2,247 5	2,052 6	1,837 9	1,598 1	1,342 8	1,034 4	1,019 1