INTERNATIONAL STANDARD

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Structural timber — Machine strength grading — Basic principles

Bois de structure — Classification mécanique selon la résistance — Principes de base

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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.

ISO 13912 was prepared by Technical Committee ISO/TC 165, *Timber structures*.

Introduction

The general principle of this International Standard is that any type of machine strength-grading procedure is acceptable, provided it is defined, controlled, and documented to the extent required to reflect the degree of reliability intended for the structural application of the product.

The body of this International Standard specifies the essential features common to all machine strength-grading operations. The requirements are minimal so as to ensure maximum scope and flexibility in the application of this International Standard to the machine strength-grading process as applied to timber.

Annex A provides a conformance standard reflecting the requirements of this International Standard.

Structural timber — Machine strength grading — Basic principles

1 Scope

This International Standard establishes the basic principles for rules and procedures governing the machine sorting of timber for use in structural applications.

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 13910, *Structural timber — Characteristic values of strength-graded timber — Sampling, full-size testing and evaluation*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13910 and in Annex A apply. The terms and definitions given in Annex A are representative of those in rules and procedures governing the machine sorting of timber for use in structural applications.

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviated terms given in ISO 13910 and in Annex A apply. The symbols and abbreviated terms given in Annex A are representative of those in rules and procedures governing the machine sorting of timber for use in structural applications.

5 General

5.1 Machine strength-graded timber

Machine strength graded timber is sawn wood that has been machine sorted according to selected criteria allowing for classification into structural grades. The machine criteria identify mechanical and/or physical properties that reflect the timber strength and may affect the utility of the product.

5.2 Machine strength-grading operations

A typical machine strength-grading operation shall be comprised of a grading machine that sorts an input resource into one or more grades (see Figure 1). Some of the lumber may not meet the requirements of the minimum specified grade.

The grading machine comprises one or more devices that may measure properties along the length of a piece of timber as it passes through the machine. For some machines, properties along the length of a piece of timber are not measured, but rather properties are measured that relate to the piece of timber considered in total as a single unit. End portions of the timber may not be scanned [see Figure 2 a)].

The data recorded by the machine shall be processed so as to produce a sorting criterion, and this sorting criterion is used as a basis for assigning a grade of machine strength timber.

Visual requirements for the total piece of timber, the unscanned end portions, or both should be specified to supplement the information obtained by the machine.

NOTE 1 Within the context of this International Standard, the term “scanner” is used to denote the device used to measure a property of the timber, and the term “scanned length” is used to denote that portion of the timber for which measurements are made by the scanning device if it measures properties along the length of a piece of timber.

NOTE 2 In the use of the conventional bending type of strength-grading machine, the only parameter that is measured (mechanically) along the length of each piece of timber (except for the unscanned end lengths) is the local modulus of elasticity on flat.

NOTE 3 For a machine using single or multiple scanners, it may be common to use the data obtained to produce a prediction of strength along the length of a piece of timber [see Figure 2 b)]. For this case, the minimum predicted strength value within the piece is usually taken to be the grade control criterion.

5.3 Machine strength-grading principles of quality control

Machine grading is one element of quality control operations. This International Standard requires that the quality control related to the machine grading operation is undertaken by placing checks on the four components of the strength grading operation: 1) the resource and sawn timber inputs; 2) the machine operation; 3) the visual requirements (when specified); and 4) the graded timber output (see Figure 1).

In theory, it should be possible to control quality, either

a) by control on the resource input and the machine operation, or

b) by checks of the quality of the output grades.

However, in practice, additional monitoring is generally required.

For example,

— when using a), care must be taken to define and ensure that the resource is similar to that initially used to establish the machine settings;

— when using b), the initial evaluation (see 8.2) should involve sample sizes larger than those normally used for daily evaluation (see 8.3) to ensure that the 5-percentile strength requirements are met.

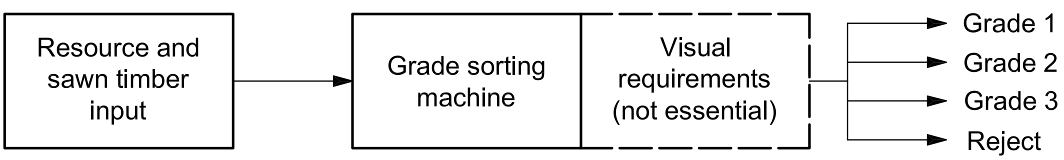
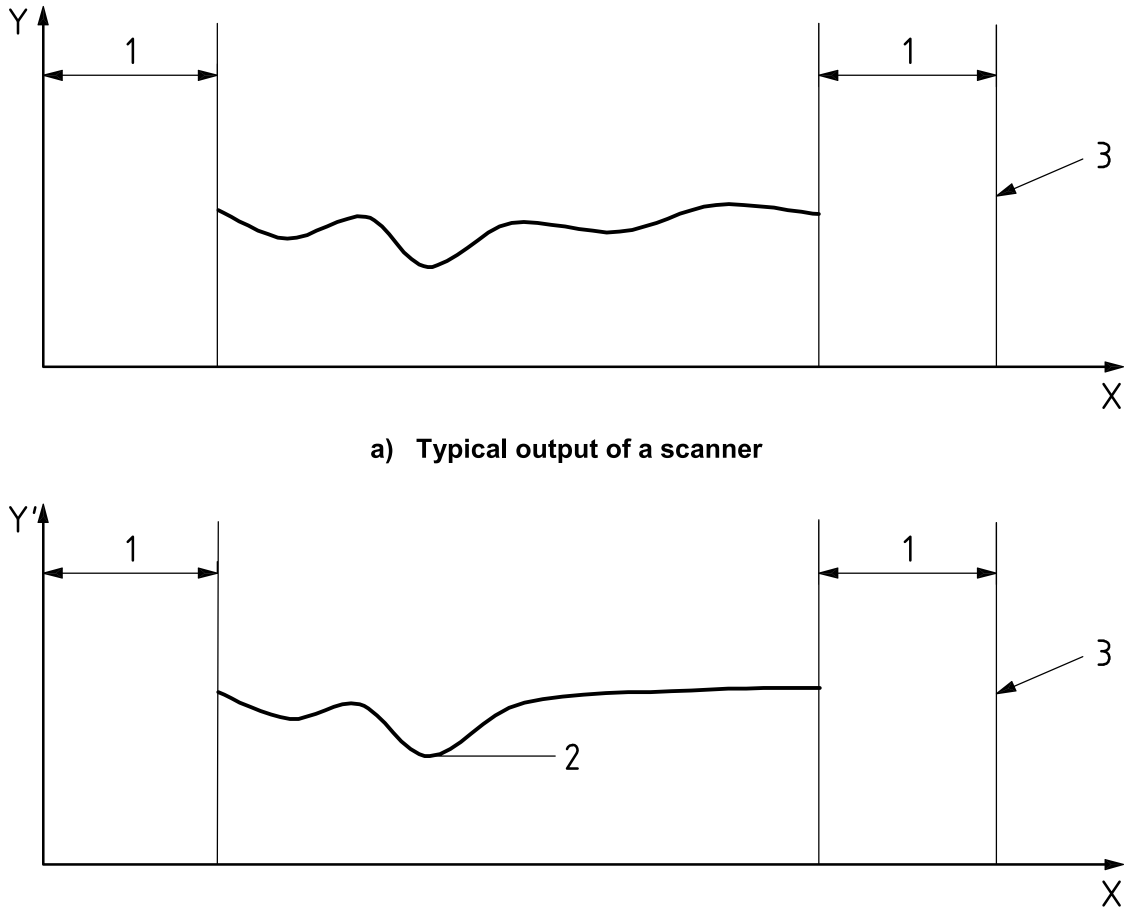


Figure 1 — Schematic of machine strength-grading operation



a) **Typical output of a scanner**

b) **Typical form of processed output**

Key

X distance from start of piece

Y scanner output

Y′ predicted strength

1 unscanned length

2 minimum predicted strength

3 end of piece

Figure 2 — Measurements made by a typical strength-grading machine

6 Resource and sawn timber input requirements

6.1 General

The input resources shall be identified in terms of all parameters that may affect the output of the machine grade sorting operation.

6.2 Input requirements

6.2.1 Resource

The parameter that shall be identified is the timber species or mixture of species.

Other parameters that may be identified are

a) silvicultural practices used,

b) log source,

c) log size,

d) cutting pattern used to manufacture sawn timber from logs, and

e) any other parameters deemed to be important.

6.2.2 Sawn timber

Parameters that shall be specified are

a) condition (such as seasoned, unseasoned, etc.),

b) moisture content, and

c) any other parameters deemed to be important.

6.3 Control of inputs

A periodic check on the resource and sawn timber inputs should be defined and specified.

6.4 Reprocessing of previously graded material

If major reprocessing of previously graded material is permitted, then any requirements for re-grading of the material should be specified.

7 Machine strength-grading requirements

7.1 Machine requirements

In addition to verification of the calibration of the scanner, all machine checks specified by the machine manufacturer shall be undertaken.

7.2 Machine grading requirements

The machine grading process shall specify, at regular intervals, checks to ensure:

a) **repeatability** – within prescribed limits, the scanners shall provide the same readings for repeated passes of the same piece of timber;

b) **calibration** – within prescribed limits, scanners shall reproduce the original readings made on special pieces of timber set aside for calibration purposes or on non-timber calibration bars;

c) **consistency** – within prescribed limits and where scanners provide readings along the length of timber, the data from scanners shall indicate a consistent calibration all along the length of a piece of timber.

Grading machines that use the same types of scanners should be calibrated against the same check procedure.

NOTE Grading machines that are not identical but use the same types of scanners include a number of conventional strength-grading machines. In such cases and for calibration purposes, all machines should be calibrated against a common standard test (e.g. ISO 13910) on timbers selected for calibration purposes.

7.3 Visual grading requirements

Where visual grading requirements are deemed to be important then rules to satisfy the strength requirements shall be specified and rules to satisfy the utility requirements may be specified.

For the visual grading requirements that are specified, then a periodic check shall be made to assess the accuracy of the grading process. If a check indicates that the process is inadequate, then appropriate measures may be specified to modify the process so that the process is adequate.

An example of visual strength-grading requirements, as applied to rectangular timber for structural applications, is given in Annex A.

8 Machine graded timber structural properties

8.1 General

The critical properties of strength-graded timber are structural properties. These properties shall be as defined and measured as specified in the test methods defined in ISO 13910.

The structural design properties shall be determined from tests on timber having a defined moisture content, if the tests are conducted on timber having a moisture content that differs from that specified by the procedure conforming to this International Standard, the properties resulting from the tests shall be adjusted (using sound engineering principles) so that the structural design properties reflect the intent of these basic requirements and/or the applicable associated design codes.

8.2 Initial evaluation

Once the grading operation has been selected, evidence shall be provided that the resultant output grades have the structural properties stated for the material. This evidence may be linked to other mills carrying out equivalent or similar sorting procedures.

For cases where such evidence is not available or it is not appropriate to link the evidence to other mills, an initial test program should be specified. The requirements for this test program should be based on sound sampling principles and the tests for the structural properties shall be based on the test procedures specified in 8.1.

8.3 Daily evaluation

When specified in the documentation one or more structural properties shall be measured for each production shift on a limited sample of timber. The data obtained shall be applied to a statistical process control procedure and the results used to monitor the control of the strength grading operation.

8.4 Periodic evaluation

Direct measurement of the structural properties of full-size timber shall be undertaken if there is a reason to expect that the structural properties of machine graded lumber have changed and may also be specified to be undertaken at periodic specified intervals.

NOTE The number and scope of periodic evaluations required depends, to some extent, on the system being used to undertake the evaluations. One type of statistical process control procedure and its use in quality control is included in the example standard of Annex A.

9 Product identification

A product identification mark on the timber shall be specified to indicate the standard on which the sorting is based, the grade and/or strength class, and the producer responsible. The product identification mark may also include other information deemed important.

Each piece of timber shall be marked except for high quality strength-graded timber intended for structural and appearance purposes. For this high quality appearance timber, each shipment shall be accompanied by documentation containing the product identification requirements specified in the standard.

10 Documentation

Documentation requirements shall include:

a) standard on which the machine strength-grading process is based;

b) specifications for the timber grade criteria;

c) specifications and control checks of the resource input where applicable to machine control operations;

d) specifications and control checks for the machine grade sorting process;

e) where applicable, specifications and control checks for the visual requirements;

f) specifications and control checks of the structural properties;

g) specifications for the identification of the product;

h) methods for assigning and confirming a grade; and

i) any other specifications or materials deemed to be important.

Annex A
(informative)

Example of a machine grading timber standard

This is a practical implementation of the machine strength-grading principles defined in the main body of ISO 13912, as applied to the following case:

— rectangular timber

— for structural applications

— requiring strength characteristic values within 5 % of the expected values.

The layout corresponds to that of an International Standard (not a normal Annex) to clearly show how an International Standard in this domain should look. It includes both

— normative elements (Scope, Normative references, Terms and definitions, Symbols and abbreviated terms, Requirements, Sampling, Test methods), and

— supplementary informative elements (Bibliography).

Informative annexes (like this Annex A) and normative annexes may also form part of an International Standard.

NOTE The Scope does not usually form part of an annex, but is included in this example for completeness purposes.

A.1 Scope

This standard specifies the grading procedures for producing machine-sorted strength and stiffness graded rectangular timber for structural applications requiring strength characteristic values within 5 % of the expected values.

It is applicable for timber that is graded in the seasoned state.

It may be applicable for timber that is graded in the unseasoned state providing the structural design properties for the timber are modified to reflect the intent of this standard and/or the associated design codes.

A.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

ISO 13910, *Structural timber — Characteristic values of strength-graded timber — Sampling, full-size testing and evaluation*

ISO 13912, *Structural timber — Machine strength grading — Basic principles*

A.3 Terms and definitions

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

A.3.1
grade
population of timber derived from a specified resource and by applying a specified sorting procedure

A.3.2
CUSUM
cumulative summation procedure for assessing structural quality trends from data sampled at intervals of time

A.3.3
knot
portion of a branch or limb that has become incorporated into a piece of sawn timber

A.3.4
machine strength grading
strength grading through mechanically measuring the modulus of elasticity on flat along a piece of timber

A.3.5
seasoned timber
timber with moisture content of 19 % or less

A.3.6
split
separation of the wood at the end of the piece that runs from one surface to an opposite or adjacent face

A.3.7
structural requirements
grade requirements that affect the structural properties of the timber

A.3.8
shake
lengthwise separation of the wood which occurs between or through the annual growth rings

A.3.9
thickness
lesser dimension perpendicular to the longitudinal axis of a piece of timber

A.3.10
unseasoned timber
timber with moisture content greater than 19 %

A.3.11
utility requirements
grade requirements that do not affect the structural properties of the timber and/or to an amount which threatens the serviceability of the piece

A.3.12
visual requirements
visual grading requirements that are additional to machine sorting necessary to attain required structural and utility properties within a grade of timber

A.3.13
width
greater dimension perpendicular to the longitudinal axis of a piece of timber

Other features such as bow, cup, spring, twist and wane should be defined in the appropriate subclauses and by referencing the feature to an illustration.

A.4 Symbols and abbreviated terms

A.4.1 General notation

E modulus of elasticity

f strength

N sample size

CV coefficient of variation

A.4.2 Subscripts

0,05 5-percentile value

data value measured on data sample

mean mean value

m bending

target target or specified value for the grade

A.5 General

A.5.1 Machine strength-grading operations

The machine strength-grading operation shall be comprised of a machine and a visual grader sorting an input resource and sawn timber into output grades. Some of the timber may not meet the requirements of the minimum grade.

Structural and utility requirements are specified for the machine strength-graded timber.

A.5.2 Principles of quality control

The machine strength grading is one element of the quality control operations. This standard requires that the quality control be undertaken by placing checks on the four components of the strength-grading operation: the resource and sawn timber inputs, the machine operation, the structural and utility requirements, and the graded timber output.

A.6 Resource sawn timber input requirements

A.6.1 General

The input resources shall be identified in terms of all parameters that may affect the output of the machine grade sorting operation.

A.6.2 Input requirements

A.6.2.1 Resource

Parameters that shall be identified are

a) timber species or mixture of species,

b) log source,

c) log size,

d) silvicultural practices used,

e) cutting pattern used to manufacture sawn timber from logs, and

f) other parameters deemed to be important.

A.6.2.2 Sawn timber

Parameters that shall be specified are

a) seasoning condition at the time of machine and visual grade sorting,

b) moisture content: 10 % to 19 %,

c) width and thickness: 0 to +2 mm,

d) bow: 6 mm per metre,

e) spring: 3 mm per metre,

f) twist: 1 mm per 25 mm of width per metre of length, and

g) other parameters deemed to be important.

A.6.3 Control of inputs

A periodic check on the resource and sawn timber inputs should be defined and specified.

A.6.4 Reprocessing of previously graded material

If major reprocessing of previously graded material is undertaken that can reduce the structural design properties or lower the machine and/or visual (utility) grade, then re-grading of the material shall be required.

A.7 Machine strength-grading requirements

A.7.1 Machine requirements

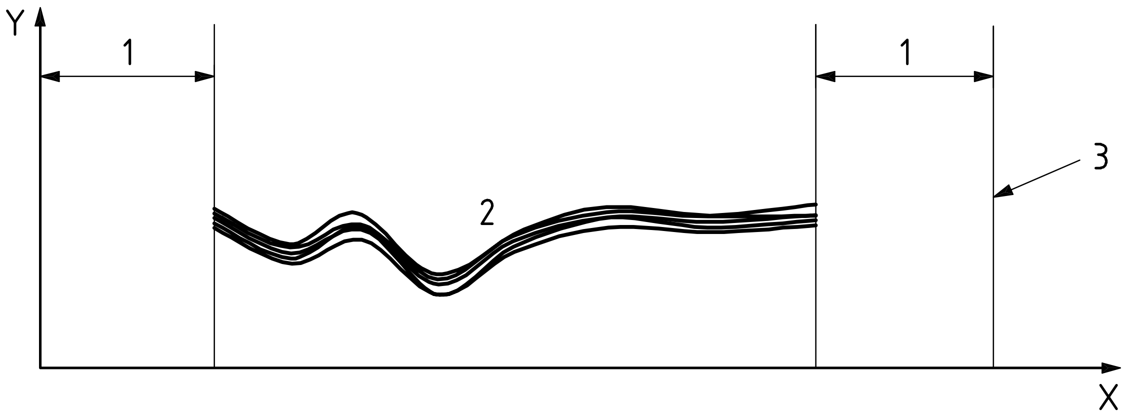
All machine checks, and the frequency of such checks, as specified by the machine manufacturer, shall be followed.

A.7.2 Machine grading requirements

Machine grading checks shall be based on the following principles.

A.7.2.1 Repeatability

At the start of each shift, one or more pieces of timber shall be sent through the machine five times (with the same leading edge and face directions). The criterion for acceptance shall be that the five overall individual pass scanner readings shall be measured at each data point and averaged along the whole piece of timber, shall not exceed 10 % of the grading modulus (see Figure A.1).



Key

X distance from start of piece

Y measured modulus of elasticity on flat

1 unscanned length

2 readings from 5 passes

3 end of piece

Figure A.1 — Repeatability check

A.7.2.2 Calibration

For calibration purposes, five pieces of timber shall be selected from the range of the timber to be graded. The timber shall be reasonably straight and shall have strength-reducing defects as defined in this standard.

First, each piece of timber shall be sent through the machine four times (with a different leading edge and face configuration [see Figure A.2 a)]. The criterion for acceptance shall be that the range of machine readings, measured at each data point and averaged along the whole piece of timber, shall not exceed 20 % of the grading modulus for the strength grade under consideration.

Next, the four scanner readings are averaged at each data point and this averaged set of values shall be compared with an independent calibration at a few critical points [see Figure A.2b)]. The calibration shall be made by comparison with a static measurement of the modulus of elasticity on flat (viz. centre point loading over a 900 mm span) at locations near the points of minimum grading moduli. The criterion for acceptance shall be that the minimum values obtained by the machine and by the static test shall not differ by more than 2 % of the static value.

The above calibration procedure shall be done at least every three months. Once the calibration sticks have been used to ensure that the machine calibration is accurate, they shall be passed through the machine at the commencement of each shift (see Figure A.3).

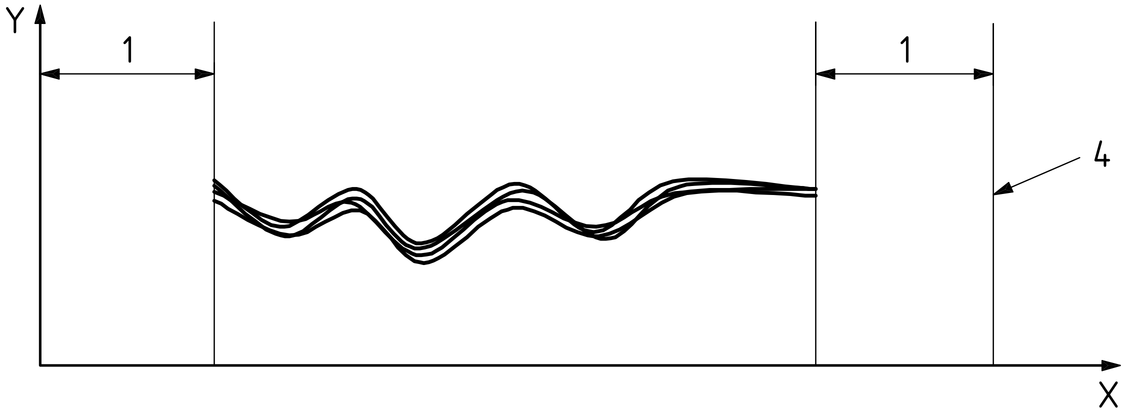
For the in-service calibration check, the data obtained with the calibration sticks at each shift shall be compared with the data obtained from the pass with the same leading edge and face configuration in the initial calibration check. The criterion for acceptance of the “in-service” calibration run shall be that the measured difference between the two sets of data at each point, averaged over the whole piece of timber, shall not differ by more than 15 % of the minimum modulus of the stick.

A.7.2.3 Consistency check

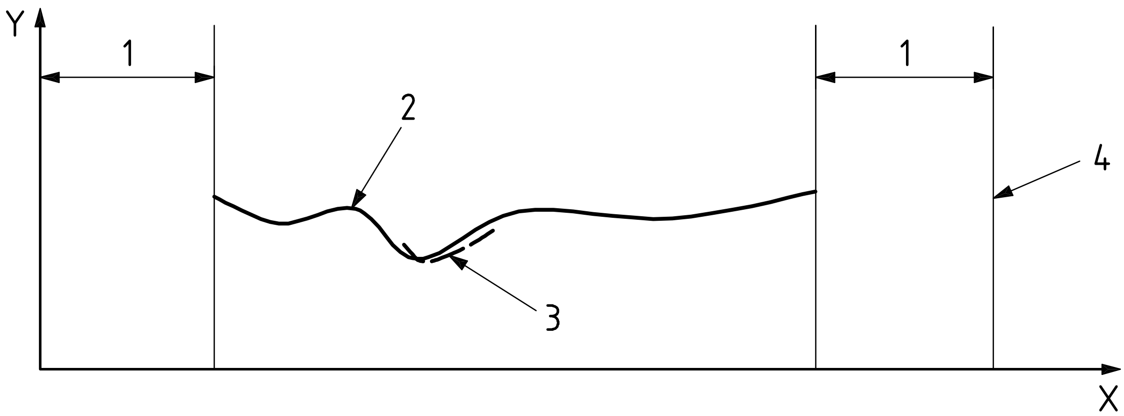
The procedure for undertaking a consistency check shall be to store the data obtained for 500 pieces of timber during a normal production run. The data from these 500 pieces shall be averaged as an ensemble, i.e. they are averaged for each location at a specified distance from the leading end (see Figure A.4). The criterion for acceptance of the consistency check shall be the value obtained by averaging the ensemble averages for all locations; the range shall not be more than 20 % of the average value.

Sometimes the criterion of acceptance of the “on flat output” of the consistency check cannot be obtained, even with a perfect machine, due to a bias in the input resource.

EXAMPLE This can occur if timber from butt logs is fed into the machine with the butt end entering first. Where such a bias exists then the effect of this particular bias can be overcome by choosing a random end of timber to enter the machine during the consistency check.



a) Output from 4-way scan



b) Calibration of scanner output

Key

X distance from end A

Y measured modulus of elasticity on flat

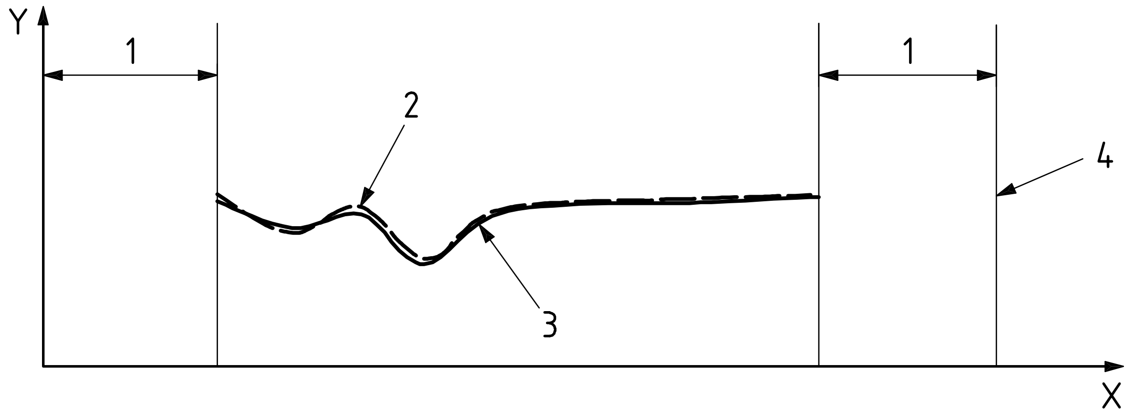
1 unscanned length

2 mean of a 4-way scan

3 independent calibration check

4 end of piece

Figure A.2 — Calibration of the scanner



Key

X distance from end A

Y measured modulus of elasticity on flat

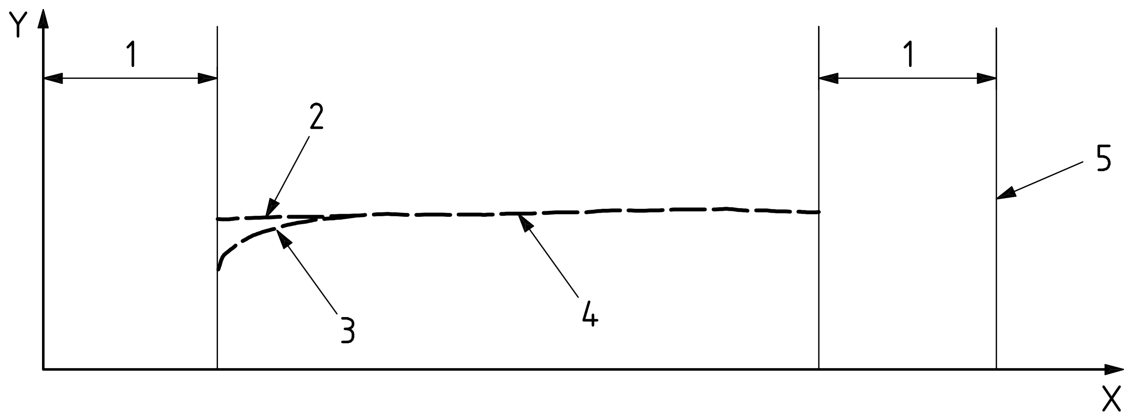
1 unscanned length

2 in-service mill run

3 initial calibration run

4 end of piece

Figure A.3 — Calibration check during an in-service mill run



Key

X distance from start of piece

Y measured modulus of elasticity on flat

1 unscanned length

2 machine in control

3 machine out of control

4 ensemble average of 500 pieces of timber

5 end of piece

Figure A.4 — Consistency check

A.7.3 Visual strength-grading requirements

A.7.3.1 Along the full length

The following limitations shall be applied to meet the visual requirements affecting strength along the full length:

a) edge knots appearing on the wide face shall not exceed 1/3 the width of the piece, and

b) through splits shall not exceed 1½ times the width of the piece.

A.7.3.2 Within the unscanned end lengths

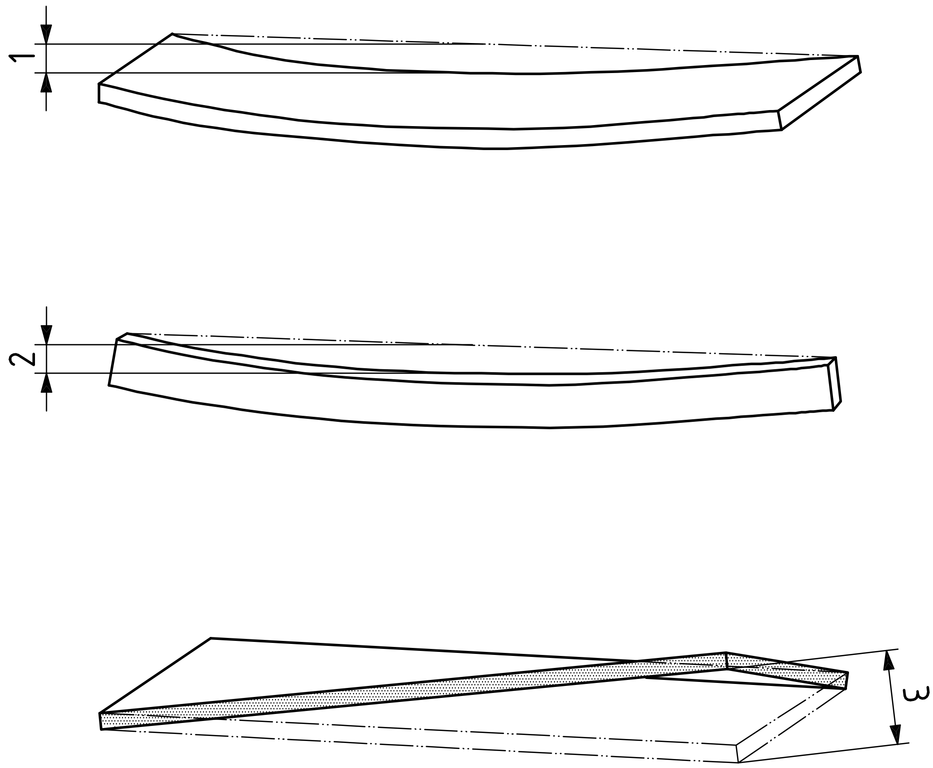
The following limitations shall be applied to meet the visual requirements affecting strength within the unscanned end lengths:

— any strength-reducing feature shall not exceed the maximum feature of that type in the scanned part of the timber, and

— any strength-reducing features shall not exceed the requirements given for the visual utility grading requirements in this standard.

The following limitations shall be applied to meet the visual requirements affecting utility:

a)	knot on wide face	1/2 width;
b)	width and thickness	0 to +2 mm;
c)	squareness	± 2 degrees;
d)	bow (see Figure A.5)	5 mm per meter of length;
e)	spring (see Figure A.5)	4 mm per metre of length;
f)	twist (see Figure A.5)	1 mm per 25 mm of width per metre of length;
g)	wane (see Figure A.6)	1/3 width of either face; and
h)	cup (see Figure A.7)	1 mm per 50 mm of width.



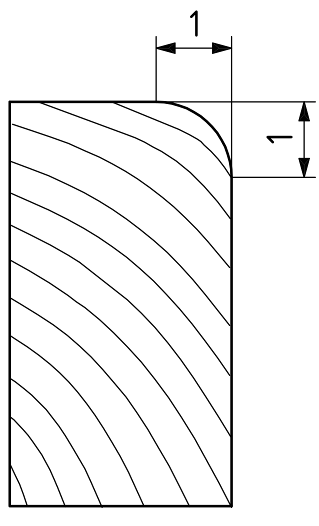
Key

1 bow

2 spring

3 twist

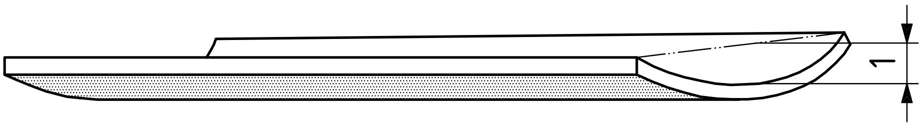
Figure A.5 — Measurement of bow, spring, and twist



Key

1 wane

Figure A.6 — Measurement of wane



Key

1 cup

Figure A.7 — Measurement of cup

A.7.4 Check on visual strength and utility grading process

During each production shift a check shall be made to assess the accuracy of the visual grading process. This shall be done by regrading a sample of graded timber. The pass criterion shall be that not more than 5 % of the pieces fall below the visual strength limitations and that not more than 20 % of the pieces fail the utility limitations.

If the checks indicate that the process is inadequate, then appropriate measures shall be undertaken to modify the process.

A.8 Structural properties

A.8.1 General

The critical properties of machine strength-graded timber are structural properties. These properties are defined and measured as specified in the test methods defined in ISO 13910.

A.8.2 Initial evaluation

Once the machine grading operation has been selected, evidence shall be provided that the resultant output grades have the required structural properties. This evidence shall be through direct measurement of structural properties of full-size timber (see Annex A, 8.1) or through the equivalent data from other similar grading operations.

For the case where a strength-grading operation in a mill commences with a grade sorting procedure and input resource that are equivalent to those already existing in other mills, no special initial evaluation is required as the evaluation data obtained from the other mills may be cited as initial evidence of properties of the graded timber.

For the case where the machine is similar to those that are used in existing mills, the species of timber graded is the same, but the source of timber and/or the cutting patterns used differ, then a limited check is required. A check shall be obtained by measuring the bending strength and modulus of elasticity for at least two sizes and two grades. The sample used for each size/grade should be $N = 200$.

If an existing machine is applied to a new species, then measurements of the graded material shall be made for at least the bending and tension strength and modulus of elasticity. All grades shall be evaluated and at least two sizes spanning the range of strength-graded timber to be produced.

For the case of a new machine, all specified grade properties and all grades shall be assessed. A minimum of three widths and two thicknesses, spanning the range of strength-graded timber to be produced, shall be assessed.

A.8.3 Daily evaluation

At each shift, one or more structural properties shall be measured on a limited sample of timber. The data obtained shall be applied to a CUSUM procedure and the results used to monitor the control of the strength-grading operation.

The CUSUM procedure described in Annex B should be used. For general information about CUSUM charts, see B.1.

NOTE The CUSUM procedure described in Annex B is simple to apply. However, it should be noted that the use of the attributes chart to control 5-percentile strength values is not effective for the case of high variability in strength coupled with sudden changes in the characteristic value of strength. The procedure is effective if the characteristic value changes slowly over a period of two or three months.

A.8.4 Periodic evaluations

Sampling for this purpose shall be undertaken during normal production. The sampling rate should be a minimum of 1 in 10 000 pieces of timber graded, and a rate of 1 in 1 000 when tight control is required. The timber shall be tested to measure bending strength and modulus of elasticity.

A check is made when the sample size for a given grade/size has the value N_o given by

$$N_o = 1\,000\ (\mathrm{CV})^2 \tag{A.1}$$

where CV is the coefficient of variation of the bending strength.

The 5-percentile of the bending strength data, denoted by $f_{m,0,05,\mathrm{data}}$ shall satisfy the following criterion

$$f_{m,0,05,\mathrm{data}} > 0{,}91\, f_{m,0,05,\mathrm{target}} \tag{A.2}$$

where $f_{m,0,05,\mathrm{target}}$ is the target 5-percentile for the grade/size.

If the sample fails to satisfy this criterion, then a second sample should be taken as soon as possible and tested according to the same criterion. If this second sample passes the criterion, then production may proceed without further delay. If, however, the second sample also fails, then there is a probability that there is an error in the grading process and action should be undertaken to determine and correct the cause.

The above procedure may also be applied to the tension strength if desired.

The mean value of modulus of elasticity, denoted by $E_{\mathrm{mean,data}}$ shall comply with the following criterion:

$$E_{\mathrm{mean,data}} > 0{,}96\, E_{\mathrm{mean,target}} \tag{A.3}$$

where $E_{\mathrm{mean,target}}$ denotes the target mean value for the grade/size.

If the sample fails to satisfy this criterion, then a second sample should be taken as soon as possible and tested according to the same criterion. If this second sample passes the criterion, then production may proceed without further delay. If, however, the second sample also fails, then there is a probability that there is an error in the grading process and action should be undertaken to determine and correct the cause.

In the use of this procedure, there is a risk that the producer will fail the test if the product has exactly the stated characteristic strength.

If desired, instead of using a test-to-failure, the timber used for strength evaluations may be proof-loaded to roughly the 10-percentile value of strength, and the unbroken pieces may be returned to production. However, some assessments shall be made to ensure that proof-loading does not cause any unacceptable damage for the species and grade of timber being evaluated.

NOTE This procedure is very effective where the timber testing is undertaken within a mill.

A.9 Product identification

Except for exceptional circumstances where the end use of the timber may require marking to be omitted for aesthetic reasons and where the customer specifically requests/orders timber to be free of marks, timber shall be marked to identify:

a) reference to this standard;

b) producer responsible;

c) grade and/or strength class;

d) certification body;

e) timber condition (stated/claimed moisture content at the time of grading); and

f) species or species mixture (group).

For those cases where the customer specifically requests/orders timber free of marks, each parcel/package of timber of a single grade/strength class shall be dispatched under the cover of a certificate of compliance stating the following information:

g) serial name and date of the certificate;

h) customer's name and address;

i) customer's purchase or order number;

j) species or species mixture (species group), grade, and dimensions and quantities, grade;

k) reference to this standard, timber condition (stated/claimed moisture content at the time of grading), and date the timber was graded; and

l) signature of the operator or of the grader.

A.10 Documentation

A quality manual shall include the following:

a) specifications of the resource and sawn timber input;

b) this standard;

c) definition of the grade sorting process;

d) specifications of the machine and visual structural and utility requirements;

e) specifications on controls for the grade sorting process;

f) specifications on the methods used to initially and periodically evaluate the properties of the timber;

g) specifications on control checks of graded timber;

h) specifications of the information marked on the timber or, where applicable for timber ordered free of marks, specifications for the certificate of compliance accompanying each parcel/package of timber;

i) allocation of responsibilities for quality control operations; and

j) specifications used by the certification body.

Annex B
(informative)

Use of the CUSUM procedure for daily evaluation

B.1 General

The two types of CUSUM[1)] charts are: 1) a *variables* chart; and 2) an *attributes* chart. The variables chart is used to assist in the control of a mean value and the attributes chart is used to assist in the control of a characteristic strength, in this case taken to be the lower 5-percentile value.

Normally, the *variables* chart is used to control the modulus of elasticity, and the *attributes* chart is used to control strength. However, there is no reason why both charts should not be applied to all properties and in fact this is recommended. Small sample sizes are used in the application of these charts; a typical sample size would be $N = 5$; hence the attributes chart is not very sensitive to sudden changes in 5-percentile strength. The attributes chart is most helpful when the changes to strength occur gradually over a period of several weeks.

B.2 Control constants

First a sample size N is chosen. Using the chosen sample size and the coefficient of variation of the structural property, control constants K, Y and Z are derived from Tables B.1 and B.2.

B.3 Incremental SUM

Usually one sample is taken at each shift, the specimens being selected at random at specified intervals of time. Immediately after collection of the total sample, the specimens are tested to measure their structural properties; the results are then used to compute an incremental SUM which in turn is used to evaluate the next step of a CUSUM control chart for that particular size and grade of timber. If only one sample is collected at each shift, it is usually tested to evaluate the bending strength and modulus of elasticity of the graded timber.

For the i-th step on a variables chart, a mean value M_i is computed and the corresponding $X_{\text{SUM},i}$ is given by

$$X_{\text{SUM},i} = X_{\text{CUSUM},i-1} + (K - M_i) \tag{B.1}$$

where $X_{\text{CUSUM},i-1}$ denotes the value of CUSUM at the previous step.

For the i-th step on an attributes chart, the value of SUM_i is given by

$$X_{\text{SUM},i} = X_{\text{CUSUM},i-1} + (d_i - K) \tag{B.2}$$

where d_i denotes the number of samples that failed to meet the target 3-percentile values.

1) CUSUM cumulative summation procedure for assessing structural quality trends from data sampled at intervals of time.

For strength properties in the absence of other information, the target 3-percentile value, denoted by $f_{0,03,\text{target}}$, may be taken to be given by

$$f_{0,03,\text{target}} = 0{,}9\, f_{0,05,\text{target}} \tag{B.3}$$

where $f_{0,05,\text{target}}$ denotes the target 5-percentile value.

B.4 Control chart

The control chart commences with a value of $X_{\text{CUSUM}} = 0$. Thereafter the X_{CUSUM} is incremented according to the following rules.

a) If $X_{\text{SUM},i} \leqslant 0$, then $X_{\text{CUSUM},i} = 0$.

b) If $0 < X_{\text{SUM},i} < Y$ and $X_{\text{CUSUM},i\text{-}1} \leqslant Y$, then $X_{\text{CUSUM},i} = X_{\text{SUM},i}$.

c) If $0 < X_{\text{SUM},i} < Y$ and $X_{\text{CUSUM},i\text{-}1} > Y$, then $X_{\text{CUSUM},i} = 0$.

d) If $X_{\text{SUM},i} = Y$ and $X_{\text{CUSUM},i\text{-}1} < Y$, then $X_{\text{CUSUM},i} = Z$.

e) If $X_{\text{SUM},i} = Y$ and $X_{\text{CUSUM},i\text{-}1} \geqslant Y$, then $X_{\text{CUSUM},i} = 0$.

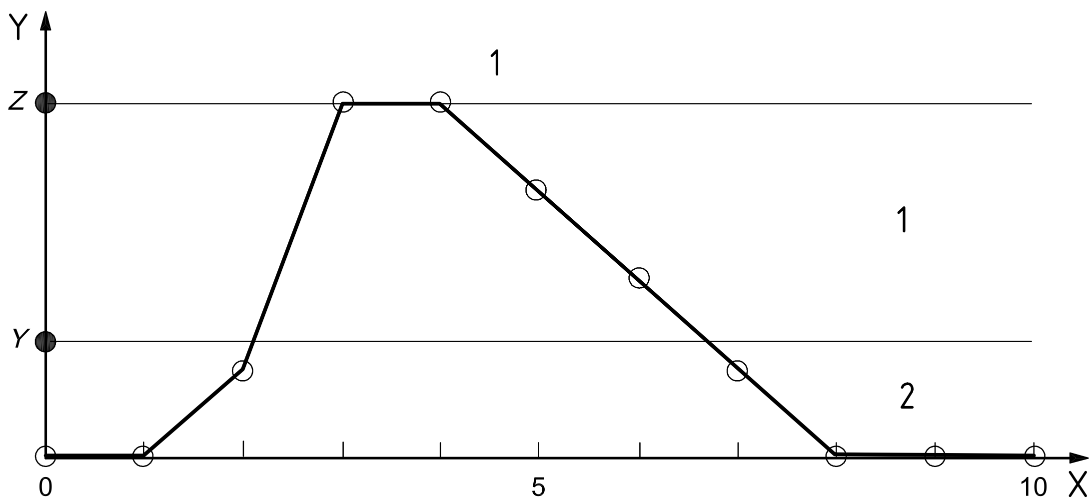
f) If $Y < X_{\text{SUM},i} < Z$ and $X_{\text{CUSUM},i\text{-}1} < Y$, then $X_{\text{CUSUM},i} = Z$.

g) If $Y < X_{\text{SUM},i} < Z$ and $X_{\text{CUSUM},i\text{-}1} \geqslant Y$. then $X_{\text{CUSUM},i} = X_{\text{SUM},i}$.

h) If $X_{\text{SUM},i} \geqslant Z$, then $X_{\text{CUSUM},i} = Z$.

These rules are summarised in Table B.3.

If the CUSUM is greater than Y, the process is deemed to be *"out of control"*; otherwise it is deemed to be *"in control"*. An illustration of a typical CUSUM chart is shown in Figure B.1.



Key

X sample number

Y CUSUM value

1 out-of-control

2 in-control

Figure B.1 — Illustration of typical CUSUM chart

B.5 Use of the Control Chart

If the process is deemed to be out-of-control, then a check is made on the grading operation to determine whether the process contains a fault. If a fault is found, then it is rectified.

If no fault is found, then a further six sets of samples are immediately taken and tested. The data is used to continue the CUSUM chart for a further six steps.

If at the end of these steps the machine is still out of control, then the grading operation is stopped and modified.

After the modification, a further six sets of samples are taken and tested; the CUSUM chart is then set to zero and the results of the test data used to plot six new points on the chart. If after this the process is in-control, then the production of graded timber is recommenced.

Table B.1 — Recommended control constants K, Y and Z for attributes CUSUM chart

Sample size	Control parameters		
	K	Y	Z
N = 5	1	1	6
N = 10	1	2	6
N = 20	1	4	7
N = 40	2	8	11
N = 60	4	8	15

Table B.2 — Control constants K, Y and Z for variables CUSUM chart

Coefficient of variation	Normalised constants* for N = 5			Normalised constants* for N = 10			Normalised constants* for N = 20		
	K	Y	Z	K	Y	Z	K	Y	Z
0,05	0,962 5	0,094	0,232	0,962 5	0,105	0,263	0,962 5	0,053	0,196
0,10	0,962 5	0,199	0,363	0,962 5	0,181	0,344	0,962 5	0,094	0,232
0,15	0,962 5	0,334	0,513	0,962 5	0,264	0,435	0,962 5	0,144	0,304
0,20	0,962 5	0,475	0,672	0,962 5	0,365	0,547	0,962 5	0,201	0,363
0,25	0,962 5	0,644	0,865	0,962 5	0,470	0,669	0,962 5	0,261	0,430
0,30				0,962 5	0,592	0,805	0,962 5	0,335	0,514
0,35				0,962 5	0,712	0,940	0,962 5	0,406	0,592
0,40							0,962 5	0,483	0,679
0,45									
0,50									

* All constants must be multiplied by the mean value of the variable.

Table B.3 — Rules for computing CUSUM

Previous X_{CUSUM}	**New** $X_{\text{CUSUM},i}$				
	$X_{\text{SUM},i} \leqslant 0$	$0 < X_{\text{SUM},i} < Y$	$X_{\text{SUM},i} = Y$	$Y < X_{\text{SUM},i} < Z$	$X_{\text{SUM},i} \geqslant Z$
$X_{\text{CUSUM},i\text{-}1} = 0$	0	SUM_i	Z	Z	Z
$0 < X_{\text{CUSUM},i\text{-}1} < Y$	0	SUM_i	Z	Z	Z
$Y < X_{\text{CUSUM},i\text{-}1} < Z$	0	0	0	SUM_i	Z
$X_{\text{CUSUM},i\text{-}1} = Z$	0	0	0	SUM_i	Z

$X_{\text{CUSUM},i} \leqslant Y$, process is in-control

$X_{\text{CUSUM},i} > Y$, process is out-of-control

* The condition $X_{\text{CUSUM}} = Y$ cannot occur.

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