BS EN 13231-3:2012

BSI Standards Publication

Railway applications — Track — Acceptance of works

Part 3: Acceptance of reprofiling rails in track

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National foreword

This British Standard is the UK implementation of EN 13231-3:2012. It supersedes BS EN 13231-3:2006, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee RAE/2, Railway Applications - Track.

A list of organizations represented on this committee can be obtained on request to its secretary.

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

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Bahnanwendungen - Oberbau - Abnahme von Arbeiten - Teil 3: Abnahme von reprofilierten Schienen im Gleis

This European Standard was approved by CEN on 20 August 2011.

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Foreword

This document (EN 13231-3:2012) has been prepared by Technical Committee CEN/TC 256 “Railway applications”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2012, and conflicting national standards shall be withdrawn at the latest by July 2012.

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

This document supersedes EN 13231-3:2006.

The changes with respect to the previous document (EN 13231-3:2006) include:

a) a reduced number of acceptance criteria for the longitudinal profile (only one instead of three) in line with current European practice;

b) reference points for interpretation of transverse profiles corresponding with the gauge recording points;

c) simplified methods to prove measurement systems (for reference and approved instruments as described in Annexes A and B);

d) introduction of a procedure to routinely demonstrate acceptability of approached instruments in Annex D;

e) integration of normative Annexes A, B, C and D.

This European Standard is one of the series EN 13231 "*Railway applications — Track — Acceptance of works*" as listed below:

— *Part 1: Works on ballasted track — Plain line, switches and crossings*

— *Part 3: Acceptance of reprofiling rails in track*

— *Part 4: Acceptance of reprofiling rails in switches and crossings*

NOTE Part 2 does not exist in this series.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

This European Standard specifies the technical requirements and the measurements to be made for the acceptance of work to reprofile longitudinally and/or transversely the heads of railway rails. For acceptance purposes, two classes of longitudinal profile and three classes of transverse profile tolerance are defined.

Annexes describe procedures to verify reference instruments to be used for these measurements as well as methods to approve non-reference instruments to be used for measurements.

This European Standard applies to reprofiled vignole railway rails 46 kg/m and above.

It does not apply for acoustic rail reprofiling.

A form of acceptance documentation that may be used is given in Annex E.

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.

EN ISO 3274, *Geometrical product specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments (ISO 3274:1996)*

EN ISO 3611, *Geometrical product specifications (GPS) — Dimensional measuring equipment: Micrometers for external measurements — Design and metrological characteristics (ISO 3611:2010)*

EN ISO 4287, *Geometrical product specifications (GPS) — Surface texture: Profile method — Terms, definitions and surface texture parameters (ISO 4287:1997)*

EN ISO 4288, *Geometrical product specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture (ISO 4288:1996)*

EN ISO 10360-2, *Geometrical product specifications (GPS) — Acceptance and reverification tests for coordinate measuring machines (CMM) — Part 2: CMMs used for measuring linear dimensions (ISO 10360-2:2009)*

3 Terms and definitions

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

3.1
angle of inclination of rail
nominal angle at which rail is laid (see Figure 1 b)), e.g. 0° (vertical rails), 2,86° (1:20 inclination), 1,91° (1:30 inclination), 1,43° (1:40 inclination), etc., inclined towards the centre of the track

NOTE For rail which is laid in non-canted track, the angle of inclination of the rail is equal to the angle between the vertical and the centre-line of the inclined rail.

3.2
approved instrument
instrument for measurement of longitudinal or transverse profile the usage of which is justified by correlation of its performance with that of a reference instrument in accordance with the defined procedure

NOTE For procedure to demonstrate correlation, see Annex B.

3.3
characteristic length
length on the rail travelled during one rotation of a grinding stone or milling wheel

3.4
class 1, class 2
classes of longitudinal profile differentiated by the proportion of a reprofiling site reaching a specified standard

NOTE For longitudinal profile, see 4.3.

3.5
class Q, class R, class S
classes of transverse profile differentiated by the proportion of a reprofiling site reaching a specified standard

NOTE For transverse profile, see 5.3.

3.6
cut-off wavelength
wavelength of a sinusoidal profile of which 50 % of the amplitude is transmitted by the profile filter

NOTE Profile filters are identified by their cut-off wavelength value, see EN ISO 11562.

3.7
deviation of the measured profile
deviation between the measured transverse profile and the reference rail, measured normal to the surface of the reference rail when the measured transverse profile and the reference rail are aligned at points A and B_1 or A and B_2, without rotation of either profile; the deviation is considered positive when the measured transverse profile is above the reference rail

NOTE For deviation, see Figure 3.

3.8
facet
approximately plane sector of the profile of a reprofiled rail produced by the reprofiling tool

3.9
filtered profile
profile which results from applying a profile filter to the primary profile

3.10
percentage exceedance
percentage length of a test site over which a measurement of the amplitude of the filtered profile exceeds a prescribed limit

3.11
phase correct profile filter
profile filter which does not cause phase shifts which lead to asymmetrical profile distortions

NOTE For profile filter, see EN ISO 11562.

3.12
primary profile
representation of the measured longitudinal profile before application of any profile filter

3.13
profile filter
electronic device or signal processing which separates profiles into long-wave and short-wave components, or into components within a specified wavelength range

3.14
rail crown line
that line on the rail head surface that is corresponding to the Y-Y axis of the rail profile

3.15
range of deviation
difference between the maximum and minimum values of the deviation of the measured transverse profile

NOTE For measured profile, see Figure 3.

3.16
reference instrument
instrument for the measurement of longitudinal or transverse profile the performance of which has been verified in accordance with the procedure defined in Annex A

3.17
reference line
line normal to the track's longitudinal axis and tangent to the heads of both rails

3.18
reference point A
point towards the gauge side of a reference rail at which the angle between the reference line and the tangent to the profile is equal to the specified angle of inclination

NOTE For specified angle of inclination, see Figure 1.

3.19
reference point B_1
point on the gauge face of a reference rail which lies 14 mm below that line that is parallel to the reference line and which passes through reference point A

NOTE For reference point, see Figure 1 a).

3.20
reference point B_2
point on the gauge corner of a reference rail at which a line which is tangent to the rail lies at an angle of 45° to the reference line

NOTE For reference point, see Figure 1 b).

3.21
reference profile
transverse profile to which rail is to be reprofiled, within the specified tolerances

3.22
reference rail
rail with the reference profile, at the desired angle of inclination relative to the reference line

NOTE For reference rail, see Figure 1 a).

3.23
reprofiling
action that is undertaken to modify the longitudinal or transverse profile of a rail

3.24
reprofiling site
continuous length of track where the rail is to be reprofiled excluding level crossings and switches and crossing work within the length of track

3.25
reprofiling zone
area of the railhead of a reference rail between the point at which the tangent to the rail lies at an angle of 70° to the reference line, measured towards the gauge side of the rail, and the point at which the tangent to the rail lies at an angle of 5° to the reference line, measured towards the field side of the rail

NOTE For side of the rail, see Figure 2.

3.26
sampling interval
distance between successive points on the rail at which a continuous record of the traced profile is sampled in order to produce the primary profile

3.27
test instrument
instrument whose use as a reference instrument or an approved instrument is being tested

3.28
traced profile
profile of the rail as recorded by the measuring system

3.29
transition length
initial or final section of a length of track where the validity of a measurement of longitudinal or transverse profile is questionable for a variety of reasons, including settling of electronic and digital components and circuits

4 Longitudinal profile

4.1 Principle

Measurements are made using either a reference instrument, see 3.16, or an approved instrument, see 3.2. Approved instruments do not offer the same accuracy as reference instruments but are generally adequate for the purpose of demonstrating compliance with the requirements of this European Standard.

NOTE An example of an approved instrument is the type of system used for routine corrugation measurement. Some of the systems used on reprofiling trains fall into this category.

In accordance with current practice, limits are set on the magnitude of the irregularities that can remain in track after a reprofiling operation. It is recognised, however, that it can be uneconomic to achieve 100 % compliance with these, particularly where isolated rail running surface defects, such as wheel burn, exist prior to reprofiling. Two classes are therefore offered, differentiated by the percentage of the reprofiled track meeting the specified criteria. Where isolated top faults exist, class 2 offers a lower cost option compared to class 1 as it will be achieved with fewer passes. However, a larger number of isolated non-compliant zones will remain in the reprofiled site.

Class 1 also includes limits for very short (10 mm to 30 mm) and very long (300 mm to 1 000 mm) wavelength residual irregularities; these are not included in class 2. Where it is required that corrugations in these shall be removed it will also be necessary to specify class 1.

For the necessary annual metrological check, see Annex D.

4.2 Measurements required

The longitudinal profile of the finished reprofiled rail shall be recorded continuously using either a reference instrument or an approved instrument. Where independent verification is required a reference instrument shall be used. All measurements undertaken in order to demonstrate compliance with 4.3 shall be recorded.

Longitudinal profile measurements shall be made within a distance of 15 mm laterally on the rail from the rail crown, to produce the traced profile.

NOTE It is recommended that a digital form of the traced profile, the primary profile, be used for subsequent analysis.

Measurements should be undertaken immediately after work. Measurements shall be undertaken at the latest within 8 days of reprofiling or before the track has carried 0,3 MGT (Million Gross Tonnes) of traffic, whichever occurs sooner.

4.3 Acceptance criteria for longitudinal profile

4.3.1 General

The acceptance of reprofiled sites shall be on the basis of percentage of irregularities shown in Table 1.

4.3.2 Peak-to-peak value

The percentage of any site in which the amplitude of the filtered profile exceeds the value specified in Table 1 shall be calculated.

The primary or traced profile shall be processed to provide a filtered profile within each of the wavelength ranges given in Table 2.

Table 1 — Acceptance criteria for longitudinal profile expressed in terms of allowable percentages of exceeding

Wavelength range (mm)	10 to 30	30 to 100	100 to 300	300 to 1 000
Class 1	5 %	5 %	5 %	5 %
Class 2	No requirement	10 %	10 %	No requirement

Table 2 — Acceptance criteria for peak to peak limits

Wavelength range (mm)	10 to 30	30 to 100	100 to 300	300 to 1 000
Limit of peak-to-peak values (mm)	± 0,010	± 0,010	± 0,015	± 0,075

The classification concerns the total length of each reprofiling section, where level crossings and switches and crossing work within the length of track are to be excluded.

5 Transverse profile

5.1 Principle

Measurements are made using either a reference instrument, see 3.16, or an approved instrument, see 3.2. Approved instruments do not offer the same accuracy as reference instruments but are generally adequate for the purpose of demonstrating compliance with the requirements of this European Standard.

Reprofiling can be undertaken for a variety of reasons. Where reprofiling is undertaken purely for the removal of corrugation, there may be less need for the rail to be reprofiled with precision. In other cases, it may be necessary for the reprofiled rail to match closely the ideal profile, represented by the reference rail, see 3.22. A range of classes is therefore included to enable the client to specify the level of precision that is appropriate for the site to be reprofiled.

NOTE Where reprofiling is undertaken to improve conicity, class Q, see 5.3, is likely to be appropriate.

The match between the reprofiled rail and the profile of the reference rail is determined by aligning the two at two points and measuring maximum difference between them, see Figure 3. For straight track, these points of alignment generally approximate to the rail crown and the gauge point. On the high rail of curves, this method is not applicable if side wear has occurred and an alternative method of alignment is therefore used.

For the necessary annual metrological check, see Annex D.

5.2 Measurements required

The rail's transverse profile shall be measured using either a reference instrument or an approved instrument. Where independent verification is required a reference instrument shall be used. All measurements undertaken in order to demonstrate compliance with 5.3 shall be recorded.

Measurements should be undertaken immediately after work. Measurements shall be undertaken at the latest within 8 days of reprofiling or before the track has carried 0,3 MGT (Million Gross Tonnes) of traffic, which ever occurs sooner.

NOTE It is preferable for measurements to be made immediately after reprofiling.

The transverse profile of each finished, reprofiled rail shall be measured sufficiently frequently to ensure compliance with the requirements stated in 5.3. The transverse profile shall be recorded at least once per reprofiling site or at an interval of not more than 500 m on a reprofiling site greater than 500 m long.

Where independent verification is required, measurements of each rail shall be made at an interval of not less than 10 m throughout the reprofiling site.

5.3 Acceptance criteria for the transverse profile

Each measured profile shall be aligned with the appropriate reference rail so that the reference points A and B_1, or A and B_2, on the reference rail coincide with points on the measured profile. The alignment shall be undertaken without rotation of either profile.

Reference points A and B_2 shall be used on side-worn rails and A and B_1 elsewhere.

The transverse reprofiling shall be specified as one of three classes as shown in Table 3. For each class one range of deviation and division of this range between a positive and negative tolerance shall also be specified. The percentage of measurements for which the deviation exceeds the stated range shall not exceed the value given in Table 3 for the class specified.

E.g. if reprofiling of class R and a tolerance range of 1,0 mm apportioned as + 0,4 mm/- 0,6 mm were specified, at least 85 % of measurements should deviate by less than + 0,4 mm/- 0,6 mm from the prescribed reference profile.

The maximum positive deviations shall be specified, e.g. for the range of deviation 0,6 mm: + 0,3 mm/- 0,3 mm, + 0,2 mm/- 0,4 mm.

Table 3 — Minimum proportion of measurements within the specified range

Range of deviation (mm)	0,6	1,0	1,7
Class Q	90 %	95 %	98 %
Class R	No requirement	85 %	98 %
Class S	No requirement	No requirement	75 %

On the field side of the rail outside the reprofiling zone, see 3.25, reprofiling shall be undertaking to – 0,8 mm tolerance.

6 Metal removal

6.1 Measurements required

Measurements of metal removal from the railhead are required only if there is a requirement in the contract to demonstrate a minimum or maximum depth of metal removal. All measurements undertaken in order to demonstrate compliance with 6.2 shall be recorded.

The height of the rail shall be measured using a micrometer whose accuracy is in accordance with EN ISO 3611.

The rail height or height of the rail-head shall be measured before and after reprofiling at a minimum of 5 positions on each rail at distance of no less than 0,5 m apart. Measurements shall be made within a month of reprofiling or one MGT what ever comes first. The rail shall be marked to ensure that measurements before and after reprofiling are made within a distance of 10 mm of each other along the rail. If the rail is initially corrugated, measurements shall be undertaken in the trough of the corrugation.

Measurement of the rail height or depth of the railhead shall be processed so as to provide the depth of metal removed within 15 mm transversely of the rail crown, or elsewhere on the railhead as agreed between client and contractor.

NOTE Measurements should be recorded once per week or as required by the contract.

6.2 Acceptance criteria for metal removal

The minimum or maximum depth of metal removed shall be as required by the contract at the minimum percentage of measurement positions specified by the contract.

7 Surface roughness

Roughness shall be measured using an instrument that complies with EN ISO 3274.

NOTE 1 Alternative instruments may be used for production control processes.

Measurements shall be made immediately after reprofiling along the rail's longitudinal axis within 15 mm of the rail crown. Where applicable, measurements shall be made on the same facet. A roughness sampling length, l_r = 2,5 mm and a roughness evaluation length, l_n = 12,5 mm, as defined in EN ISO 4288, shall be used.

At least 6 contiguous measurements shall be taken. Where applicable, sufficient measurements shall be made to cover at least one complete characteristic length on the facet.

The arithmetic mean surface roughness (R_a), as defined in EN ISO 4287, of each measured section, shall be calculated.

Unless specified otherwise in the contract, in no more than 16 % of the measured lengths (or 1 in 6, if only 6 measurements are made) shall R_a exceed 10 μm.

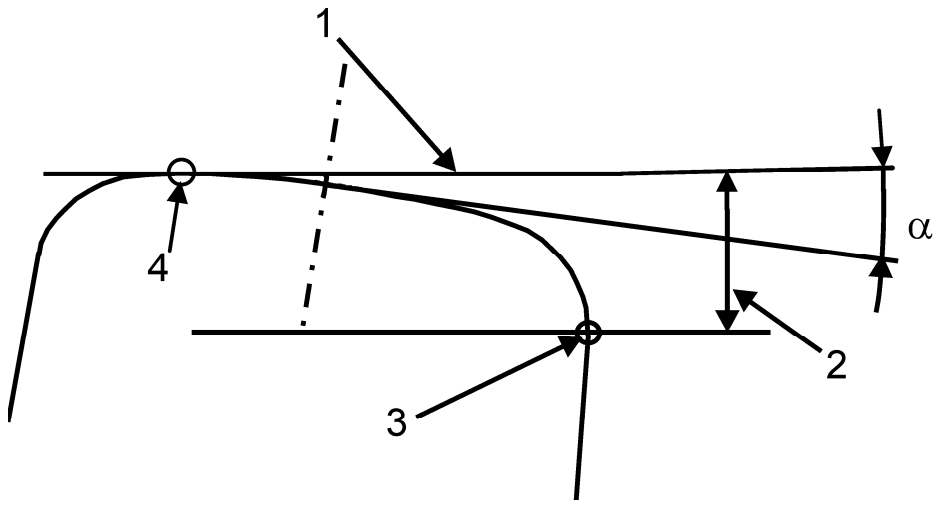
NOTE 2 Other values of surface roughness may be required where reprofiling is undertaken for the purpose of noise abatement or the improvement of adhesion.

8 Visual appearance: acceptance criteria

Where facets are produced by the reprofiling operation, the maximum facet width shall be 4 mm on the gauge corner, 7 mm on the shoulder and 10 mm within 10 mm of the rail crown. The reprofiling zone shall be blended smoothly into the parent rail.

The maximum variation in facet width over a 100 mm length of rail shall be 25 % of the maximum width of the facet.

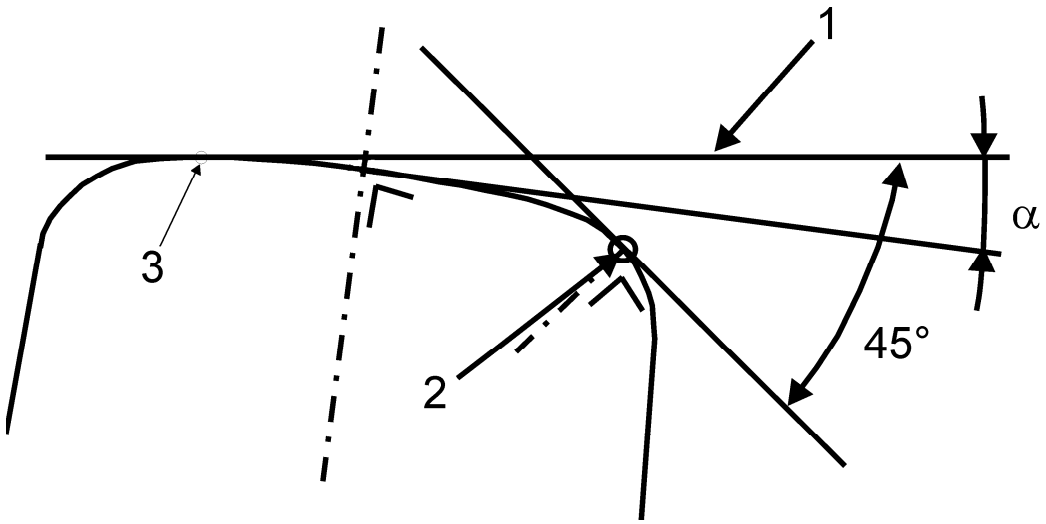
There shall not be continuous blueing in the reprofiling zone.



a) Detailed section of railhead, showing reference points A and B_1 (α: angle of inclination of the rail)

Key

1 reference line
2 14 mm
3 reference point B_1
4 reference point A

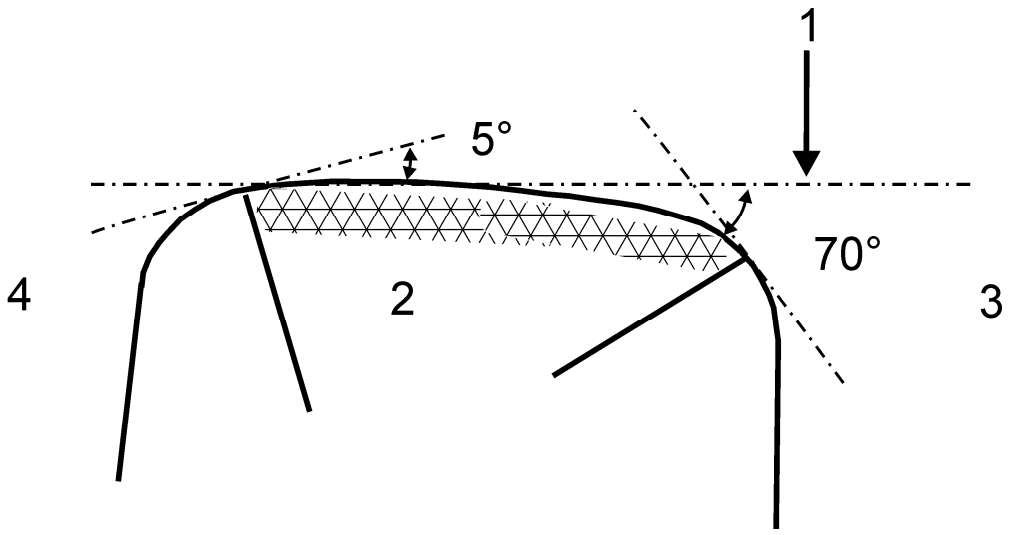


b) Detailed section of railhead, showing reference point A and B_2 (α: angle of inclination of the rail)

Key

1 reference line
2 reference point B_2
3 reference point A

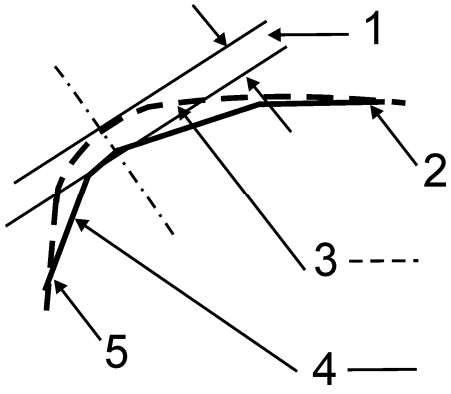
Figure 1 — Definition of terms, and determination of reference points A, B_1 and B_2 on the transverse profile



Key

1 reference line
2 re-profiling zone
3 gauge side
4 field side

Figure 2 — Reprofiling zone



Key

1 range of deviation
2 point A
3 reference profile - - -
4 measured profile ------
5 point B_1 or B_2

NOTE In this example, the range of deviation is negative (measured profile below the reference rail).

Figure 3 — Deviation of measured transverse profile from reference profile

Annex A
(normative)

Procedures to verify reference instruments

A.1 Longitudinal profile

A.1.1 Principle

The longitudinal profile of a machined strip on a purpose built beam is measured using both the test instrument and a Coordinate Measuring Machine (CMM). The test instrument is assessed for its ability to make peak amplitude measurements of the profile of the test strip.

The test instrument is deemed to be verified as a reference instrument for the acceptance of rails on the basis of peak values if there is satisfactory agreement between the peak values obtained using the test instrument and those made using the CMM.

A test instrument accepted as a reference instrument for the acceptance of rails on the basis of peak values is also deemed to be verified for the acceptance of rails on the basis of the percentage of irregularities exceeding a specified amplitude.

The procedure involves the assessment of the test instrument for all wavelength ranges and all rail acceptance criteria. Acceptance of the test instrument as a reference instrument may however be limited to specified wavelength ranges

NOTE Verification takes place at ambient temperature. Users of reference instruments are recommended to seek the guidance of the instrument manufacturer as to the temperature range over which the verification can be expected to remain valid.

A.1.2 Calibration beam

The machined strip on the calibration beam shall be not less than 20 mm wide and at least as long as the maximum wavelength for which the test instrument is to be verified.

Irregularities of the wavelength and peak to peak amplitudes shown in Table A.1 shall be present on the machined strip.

NOTE 1 An additional running-in length at each end of the machined strip may be desirable to avoid the possibility of transient effects corrupting the beginning of a profile record.

Table A.1 — Calibration beam irregularities

Wavelength range (mm)	10 to 30	30 to 100	100 to 300	300 to 1 000
Peak-to-peak amplitude (mm)	0,005 to 0,015	0,005 to 0,05	0,020 to 0,8	0,080 to 2,0

An example of a calibration beam suitable for the verification of instruments for wavelengths up to 1 000 mm is shown in Figure A.1. The longitudinal profile along the nominal centre-line of the machined strip of this beam is shown in Figure A.2. The longer wavelength irregularities can be produced by traversing the strip under a working (grinding) head and incrementing the working (grinding) head up and down. The shorter wavelength irregularities can be produced by linishing. The precise form of the irregularities is not critical.

A.1.3 Coordinate Measuring Machine (CMM)

The CMM shall be operated in accordance with the procedures in the manufacturer's operating manual. The maximum error *E* according to EN ISO 10360-2 shall not exceed 1 μm.

A.1.4 Measurement of the calibration beam using the CMM

Clamp the calibration beam in the CMM, taking care to minimize irregularities in the beam arising from the holding arrangement.

A measuring probe with a head diameter in the range 3 mm to 6 mm shall be used.

Sufficient time shall be allowed, before measurements are taken, for electronic systems to stabilize and for the calibration beam to come to thermal equilibrium with its surroundings.

Make three records of the traced profile of the calibration beam along nominally the same path in one direction.

A.1.5 Data analysis

Produce a primary profile from each of the traced profiles. The sampling interval along the calibration beam and the digitisation increment of the primary profile shall be recorded. The sampling interval shall be no greater

than 1 mm and the digitisation increment no greater than 1 μm.

A.1.6 Measurement of the calibration beam using the test instrument

Immediately following the measurement of the calibration beam using the CMM, the calibration beam shall be measured with the test instrument under same installation and temperature conditions. Make three records of the traced profile of the calibration beam along nominally the same path and same direction. Switch on the test instrument in sufficient time for its electronic circuits to stabilize before the measurements are taken. The measurement speed shall be constant to avoid kinematic failures.

A.1.7 Data analysis using the test instrument

Produce a primary profile from each of the traced profiles and compare the results of each traced profile with results of the CMM.

A.1.8 Acceptance criteria for reference instruments

For instruments for the measurement of peak-to-peak amplitude and for rail acceptance based on percentage of exceedances of specified peak-to-peak amplitudes the maximum difference between the measurements of the CMM and the test instrument shall be no greater than ± 2 μm and the total number of exceedances shall be no greater than 2 % of the total number of measurement points per measurement line.

A.1.9 Test report

The following shall be recorded:

— manufacturer and serial number or other means of identification of the CMM and the test instrument;

— temperature of test;

— CMM probe identification and head diameter;

— orientation of the beam relative to the x, y and z axes of the CMM;

— primary profiles obtained by both the CMM and the test instrument.

A.2 Transverse profile

A.2.1 Principle

Two rail sections are mounted in a calibration jig, which holds the sections at a known inclination. A support should be placed at the opposite side at a distance within the range of gauges for which a reference instrument would be used. The profile of one rail section is close to a reference profile, while that of the other differs significantly from the reference profile. The transverse profile of nominally the same line across the two rail sections is measured using both the test instrument and a Coordinate Measuring Machine (CMM), the accuracy of which has been verified. The test instrument is deemed to be verified as a reference instrument for measurement of the transverse rail profile if there is satisfactory agreement between measurements made using the test instrument and the CMM.

NOTE Verification should take place at ambient temperature. Users of reference instruments are recommended to seek the guidance of the instrument manufacturer as to the temperature range over which the verification can be expected to remain valid.

A.2.2 Calibration jig

The calibration jig shall consist of two short rail lengths. They shall be held to one another at nominally the same inclination, held sufficiently rigidly and should be long enough to hold the test instrument.

The transverse profile of one of the rails shall be such that it deviates from a reference rail of choice, at an inclination of choice, by less than $\pm$ 0,3 mm throughout the reprofiling zone. The transverse profile of the other rail shall be such that it deviates from the reference rail of choice, at the inclination of choice, by at least 0,5 mm at two or more points in the reprofiling zone.

A.2.3 Coordinate measuring machine (CMM)

The CMM shall be operated in accordance with the procedures in the manufacturer's operating manual. The maximum error E according to EN ISO 10360-2 shall not exceed1 μm, where L is the nominal dimension being measured in mm.

A.2.4 Calibration jig verification

Hold the calibration jig in the CMM rigidly. The two rails shall be measured using the CMM and a measuring probe with a head diameter in the range 3 mm to 6 mm. Sufficient time shall be allowed, before measurements are taken, for electronic systems to stabilize and for the calibration jig to come to thermal equilibrium with its surroundings.

The rails shall be shown to comply with the requirements of A.2.2.

A.2.5 Rail measurements using the test instrument

Immediately following the measurement of the jig using the CMM, the jig shall be measured with the test instrument under same installation and temperature conditions. Make three records of the traced profile of the jig.

Switch on the test instrument in sufficient time for its electronic circuits to stabilize before the measurements are taken. Remove the test instrument from the rail between measurements.

A.2.6 Acceptance of test instruments

From each traced profile, both those produced by the CMM and those produced by the test instrument, create a primary profile. The sampling interval when the CMM is used shall be no greater than 1,0 mm throughout the reprofiling zone and the digitisation increment no more than 10 μm.

Compare the primary profiles for each rail from the test instrument measurements with that from the CMM as though the latter were a reference rail. The maximum positive and negative deviations shall be less than 0,05 mm throughout the re-profiling zone. No exceedances are allowed.

A.2.7 Test report

The following shall be recorded:

— serial number and manufacturer or other means of identification of the CMM and the test instrument;

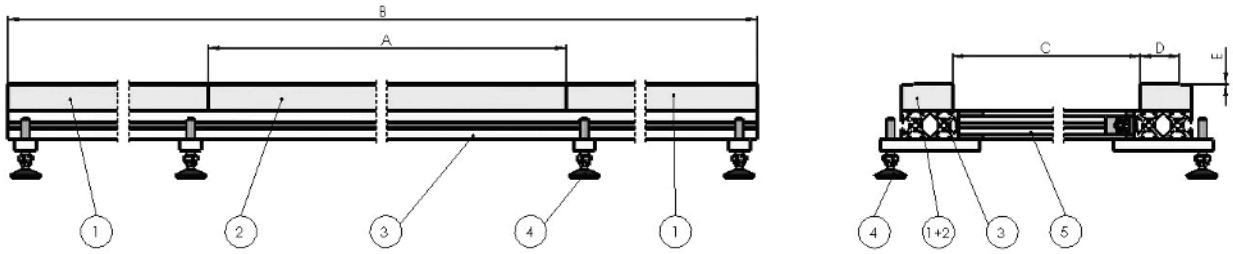
— temperature of test;

— CMM probe identification and head diameter;

— orientation of the calibration jig relative to the x, y and z axes of the CMM;

— primary profiles obtained by both the CMM and the test instrument;

— whether the test instrument complies with the requirements of A.2.6.

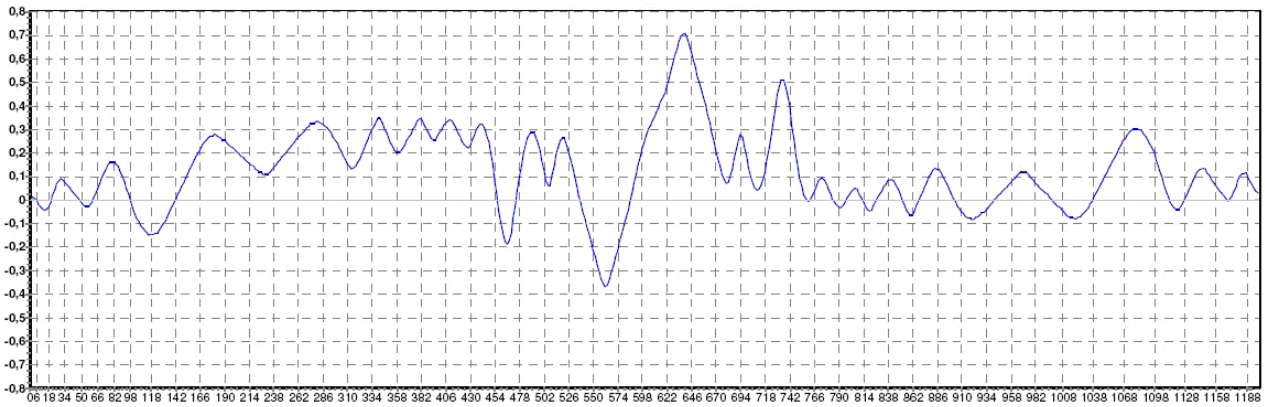


Key

A calibration beam
B total length of installation
C track gauge
D machined strip
E plane running surface

1 running-in track
2 calibration beam
3 support
4 level adjustment
5 transverse joint

Figure A.1 — Schematic diagram of a calibration beam for longitudinal profile measuring equipment



NOTE The values are shown in mm.

Figure A.2 — Longitudinal profile of a calibration beam

Annex B
(normative)

Procedures to demonstrate correlation of approved and reference instruments

B.1 Longitudinal profile

B.1.1 Principle

The train-borne systems used for the routine measurement of the rail's longitudinal profile are not normally accurate enough to enable compliance with this specification to be demonstrated directly. Their use is, however, the only practical option if extensive measurements are to be made. This annex sets out the procedure to be used for the approval of systems for routine measurements.

The basis of approval is that the use of such a system shall not generally lead to the acceptance of track that would have been rejected if a reference instrument had been used. To provide assurance of this, the performance of a test instrument for which approval is sought is compared to that of a reference instrument under a variety of test conditions. However, if acceptance of the test instrument as an approved instrument is only required for one speed and for one direction of train travel, testing may be limited to these conditions.

The procedure given involves the assessment of the test instrument for all wavelength ranges and for the acceptance of rails on the basis of peak amplitudes, in general see 4.3. As the test instrument will also be used to provide information on rail condition prior to re-profiling, a similar procedure to that described here shall be used to verify its suitability for that purpose but with measurements made on un-reprofiled sites.

NOTE The test instrument is approved on the basis of a comparison between measurements made on rails at ambient temperature. Users of approved instruments are recommended to seek the guidance of the instrument manufacturer as to the temperature range over which the instrument may reliably be used and whether other weather conditions could affect its performance.

B.1.2 Characteristics of the test sites

Three sites are required, as follows:

— (S1) straight track;

— (L1) a left hand curve of nominal radius no greater than 800 m;

— (R1) a right hand curve of nominal radius no greater than 800 m.

The length of each site shall be no less than 200 m.

NOTE Additional transition lengths at the beginning and the end of the measured length may be necessary.

All sites shall be shown to comply with the requirements of class 1 of 4.3 using a reference instrument.

B.1.3 Measurements required

Measurements shall be taken through the test sites for a continuous length of at least 200 m. If either the reference instrument or the test instrument requires a transition length at either the beginning or the end of the measurement, the transition length shall lie outside the measured length.

The longitudinal profile of both rails at each test site shall be recorded using a reference instrument.

The longitudinal profile of both rails at each test site shall be recorded using the test instrument at its maximum speed of use. Measurements shall also be made on site S1 at the minimum speed of use, if the test instrument is to be used at other than its maximum speed. If the test instrument is to be used with the train travelling both forwards and backwards, measurements shall be made with the train travelling in both directions.

All measurements shall be taken three times in both directions.

B.1.4 Data analysis

The primary profiles for each rail at each site obtained using the reference instrument shall be processed, as specified in Clause 4, to give peak amplitudes, for each wavelength range for which approval of the test instrument is sought.

The primary profiles obtained using the test instrument shall also be processed to give peak amplitudes using the electronics and software inherent in the test instrument.

For each filtered profile obtained by the test instrument and the reference instrument, the percentage of the measured length for which peak amplitudes exceeds the values respectively, shall be calculated.

B.1.5 Acceptance criteria for approved instruments

B.1.5.1 General

An instrument can be approved for all or a limited range of wavelengths, for one, specified, direction of train travel or for both. Within its specified limits of use, a test instrument is required to meet all the criteria set out below for all the profiles measured.

A test instrument which has only been shown to comply with the requirements of B.1.5 at its maximum speed of operation is deemed approved for that speed of operation only.

A test instrument which, additionally, complies at its minimum speed of operation is deemed to comply at both its maximum and minimum speeds and at all intermediate speeds.

B.1.5.2 Acceptance criteria for peak-to-peak measurements

For specified test conditions of speed and direction of travel, the percentage exceedance values obtained using the test instrument at the amplitudes given in Table B.1 for all the profiles recorded, shall not be less than those obtained using the reference instrument on the same measured lengths.

Table B.1 — Peak to peak amplitudes at which test instrument percentage exceedances are not less than those obtained using a reference instrument

Wavelength range (mm)	10 to 30	30 to 100	100 to 300	300 to 1 000
Amplitude (μm)	10	10	30	100

The percentage exceedances for the test instrument for each of the amplitudes given in Table B.1 shall also be included in a deviation range of at most 5 % of the exceedance percentage before rail reprofiling and 1 % exceedances after reprofiling rails obtained using the reference instrument.

B.1.6 Test report

The following shall be recorded:

— serial number and manufacturer or other means of identification of the reference instrument and the test instrument;

— nominal radii of sites L1 and R1;

— ambient temperature and weather conditions, including the relative humidity;

— direction of measurement with the reference instrument on each site and rail;

— direction(s) of measurement with the test instrument on each site and rail;

— speed(s) of measurement with the test instrument;

— primary and filtered profiles obtained by both the test and reference instrument.

If variable, the sampling interval, digitisation increment and filter characteristics of the test instrument during its evaluation.

The speed(s), direction(s) of travel and wave-length ranges for which the requirements of B.1.5.2 are complied with by the test instrument.

B.2 Transverse profile

B.2.1 Principle

The train mounted measuring systems used for the routine measurement of the rail's transverse profile are not normally accurate enough to enable compliance with this specification to be demonstrated directly. Their use is, however, the only practical option if extensive measurements are to be made. This annex sets out the procedure to be used for the approval of systems for routine measurements.

The basis of approval is that the use of such a system shall not generally lead to the acceptance of track that would have been rejected if a reference instrument had been used. To provide assurance of this, the performance of a test instrument for which approval is sought is compared to that of a reference instrument under a variety of test conditions. However, if acceptance of the test instrument as an approved instrument is only required for one speed and for one direction of train travel, testing may be limited to these conditions.

NOTE 1 The test instrument is approved on the basis of a comparison between measurements made on rails at ambient temperature. Users of approved instruments are recommended to seek the guidance of the instrument manufacturer as to the temperature range over which the instrument may reliably be used and whether other weather conditions could affect its performance.

NOTE 2 If the test instrument will also be used to provide information on rail condition prior to re-profiling, a similar procedure to that described here could be used to verify its suitability for that purpose but with measurements made on un-re-profiled sites.

B.2.2 Characteristics of the test sites

Two test sites are required, as follows:

— (S) straight track;

— (C) curve of nominal radius no greater than 800 m.

The measured length of each site shall not be less than 10 m.

NOTE 1 Additional transition lengths at the beginning and the end of the measured length may be necessary.

When measured using a reference instrument, the range of deviation of all sites shall be within the limits specified in 5.3 for class Q, and the maximum deviation shall be within the limits relative to the user-defined reference profile.

NOTE 2 Different user-defined reference profiles may be used for each site and rail.

B.2.3 Measurements required

Measurements shall be taken through the test sites for a length of at least 10 m after re-profiling. If the test instrument requires a transition length at either the beginning or the end of the measurement, the transition length shall lie outside the measured length.

Measurements with the test instrument shall be made at equal intervals in a range of 0,20 m to 0,30 m.

Measurements with the reference instrument shall be made using the same interval how did with the test instrument.

The profiles shall be recorded using the test instrument at its characteristically speed of use. If the test instrument is to be used with the train travelling both forwards and backwards, measurements shall be made with the train travelling in both directions.

All measurements shall be taken with the test instrument three times and with the reference instrument once.

B.2.4 Data analysis

The comparison of the measured profiles and the user-defined reference profile shall be done regarding to Figure B.1.

Determine the deviations of the measured profile and the user-defined reference profile for the railhead positions Y-30, Y-25 and Y+14 of each rail at each site both for measurements with the test instrument $\Delta Tn,m$ (with n – measurement point Nr.; m – Nr. of acquisition) and the reference instrument ΔRn (with n – measurement point Nr.).

Firstly, the averages $M\Delta Tn$ of all acquisitions m shall be calculated for each measurement point n and each railhead position shown in Table B.2.

After that the averages $MM\Delta T$ of all $M\Delta Tn$ and the averages $M\Delta R$ of all ΔRn shall be calculated for each railhead position of each rail and each site shown in Table B.3.

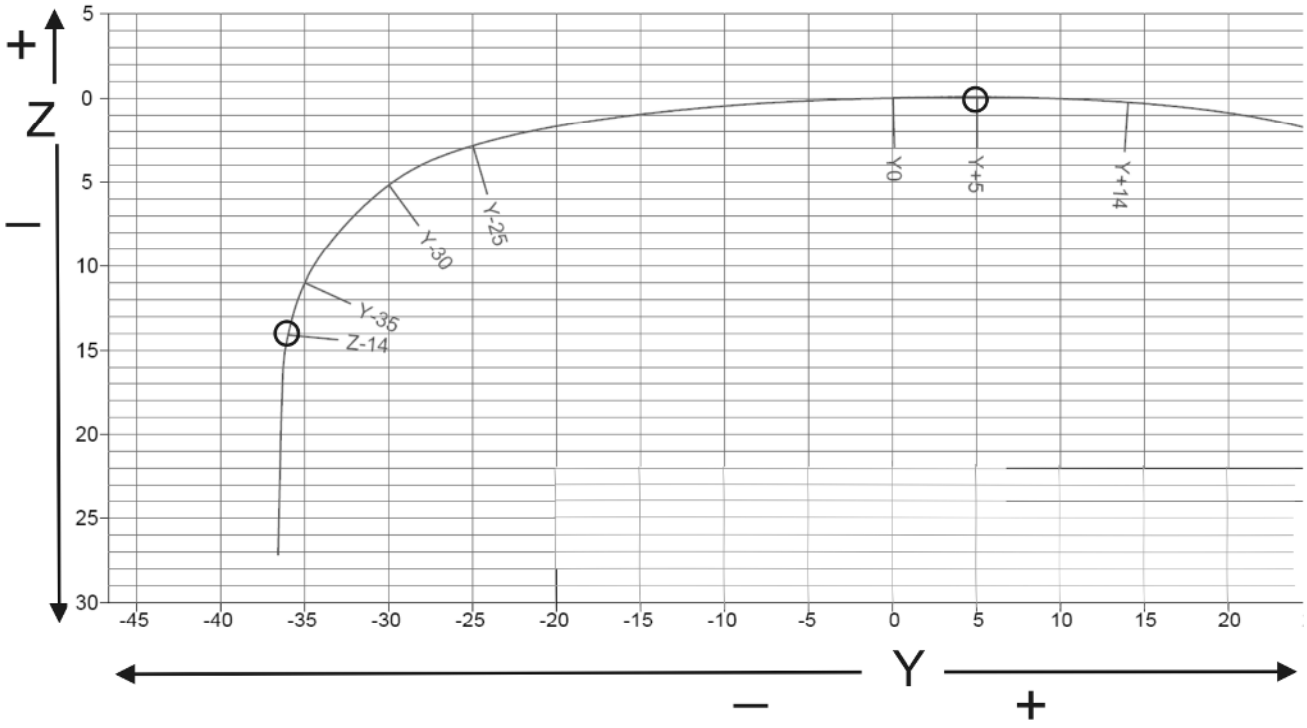


Figure B.1 — Reference profile

Table B.2 — Deviation of the measured profile and an user-defined reference profile for different rail head positions of a 10 m track section

Dimensions in millimetres

Measurement point / rail head position	Test instrument														Measurement point / rail head position	Reference instrument	
	left rail							right rail								left rail	right rail
	acquisitions							acquisitions									
	forwards			backwards				forwards			backwards						
	ΔTn,1f	ΔTn,2f	ΔTn,3f	ΔTn,1b	ΔTn,2b	ΔTn,3b	MΔTn	ΔTn,1f	ΔTn,2f	ΔTn,3f	ΔTn,1b	ΔTn,2b	ΔTn,3b	MΔTn		ΔRn	ΔRn
1															**30**		
Y-30	0,11	0,11	0,10	0,12	0,11	0,11	0,11	0,65	0,65	0,65	0,68	0,67	0,67	0,66	Y-30	0,18	0,67
Y-25	- 0,03	- 0,03	- 0,03	- 0,04	- 0,04	- 0,04	- 0,04	0,53	0,53	0,53	0,55	0,55	0,54	0,54	Y-25	- 0,07	0,50
Y+14	- 0,43	- 0,45	- 0,43	- 0,41	- 0,40	- 0,39	- 0,42	- 0,52	- 0,52	- 0,52	- 0,52	- 0,51	- 0,51	- 0,52	Y+14	- 0,38	- 0,45
2															**31**		
Y-30	0,11	0,11	0,10	0,12	0,11	0,12	0,11	0,64	0,64	0,64	0,66	0,66	0,66	0,65	Y-30	0,18	0,69
Y-25	- 0,05	- 0,05	- 0,05	- 0,06	- 0,05	- 0,05	- 0,05	0,53	0,52	0,52	0,54	0,54	0,53	0,53	Y-25	- 0,11	0,51
Y+14	- 0,41	- 0,45	- 0,41	- 0,41	- 0,41	- 0,40	- 0,42	- 0,50	- 0,50	- 0,51	- 0,50	- 0,50	- 0,50	- 0,50	Y+14	- 0,35	- 0,43
3															**32**		
Y-30	0,11	0,11	0,11	0,13	0,13	0,13	0,12	0,63	0,63	0,62	0,66	0,66	0,65	0,64	Y-30	0,19	0,70
Y-25	- 0,07	- 0,06	- 0,07	- 0,06	- 0,06	- 0,06	- 0,06	0,52	0,52	0,52	0,55	0,54	0,53	0,53	Y-25	- 0,06	0,51
Y+14	- 0,41	- 0,45	- 0,43	- 0,41	- 0,41	- 0,40	- 0,42	- 0,49	- 0,49	- 0,49	- 0,49	- 0,49	- 0,49	- 0,49	Y+14	- 0,34	- 0,44
…																	

Table B.3 — Average of the deviation of the measured profile and an user-defined reference profile for different rail head positions of a 10 m track section

Dimensions in millimetres

Measurement point / rail head position	Test instrument		Measurement point / rail head position	Reference instrument	
	left rail	right rail		left rail	right rail
	MMΔT	MMΔT		MΔR	MΔR
Y-30	0,22	0,65	Y-30	0,22	0,67
Y-25	0,00	0,52	Y-25	0,00	0,55
Y+14	- 0,37	- 0,57	Y+14	- 0,37	- 0,52

B.2.5 Acceptance criteria for approved instruments

The maximum deviations maxΔ for all railhead positions shall be less or equal than 0,1 mm between the averages MMΔT and the averages ΔR calculated for a 10 m track section:

$$\max\Delta = MM\Delta T - M\Delta R \leq 0{,}1 \text{ mm}$$

The difference between any measurement and any other measurement at the same measurement point and railhead position must not exceed 0,2 mm.

B.2.6 Test report

The following shall be recorded:

— serial number and manufacturer or other means of identification of the reference instrument and the test instrument;

— nominal radii of sites L1 and R1;

— ambient temperature and weather conditions, including the relative humidity;

— direction(s) of measurement with the test instrument on each site and rail;

— speed(s) of measurement with the test instrument;

— primary profiles obtained by both the test and reference instrument.

The test report shall state the speed(s) and direction(s) of travel, for which the requirements of B.2.5 are complied with by the test instrument.

Annex C
(normative)

Calculation of peak to peak values

C.1 Calculation of the percentage of exceedances

The percentage of exceedances is given by the routine:

z1(Y1, start, end, tolerance) =

s1 ← 0

for i ∈ start .. (end)

s1 ← s1 + 1 if $|Y1_i|$ > tolerance

s1

In the specific case shown per example:

z1(Y1,start,end,tolerance) = 38 — 38 samples are out of tolerance.

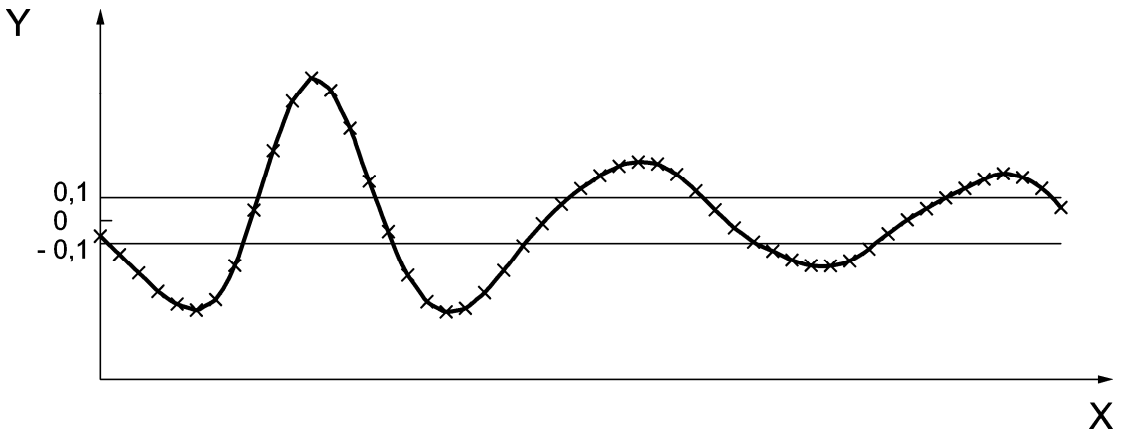
$$\text{percentage} = \frac{z1(Y1, \text{start}, \text{end}, \text{tolerance})}{(\text{end} - \text{start}) + 1} \cdot 100$$

In this example, the length is reduced to 51 samples.

percentage = 74,5 — 74,5 % of the measurements are out of tolerance.

NOTE Y1 profile.

Dimensions in millimetres



Key

X measured length (samples)

Y deviation

x = sample (e.g. 51 samples)

Figure C.1 — Percentage of exceedances

Annex D
(normative)

Method of periodic verification

D.1 Method of periodic verification of approved instruments

D.1.1 Principle

The approval of train mounted measuring system (approved instrument) is based on Annex B for every recording system and for an unlimited period. In order to keep the approval valid over time, every system shall undergo at least an annual metrological check or more frequently according to the demands of the client. The aim of these actions is to guarantee the correct functioning of the approved instrument, to prevent deviations and to undertake corrective actions in time. These metrological actions shall be designed in a way to be done on site with a simple instrumentation.

A quality controller, independent of the machine (internal or external according to e.g. EN ISO 9001), shall follow the correct execution of these metrological actions. The verifications shall be documented and accessible on board the machine. He also ensures that required corrective actions are undertaken within due time. At any moment, the client can ask to see the verification documents.

This confirmation interval is divided into two parts:

1) static metrological confirmation of the approved instrument;

2) dynamic metrological confirmation of the approved instrument.

The following chapters describe a method of verification, which might be adapted according to the specific requirements of each instrument.

D.1.2 Longitudinal profile

The verification of the approved instrument for longitudinal profile recording shall be done in two steps:

1) the static verification will allow ensuring the correctness of all the elements constituting the approved instrument such as probes, processing unit and reporting;

2) the dynamic verification will allow ensuring the repeatability of the approved instrument in its specific environment in both directions and at working speed.

D.1.3 Static verifications

D.1.3.1 Verification of measuring transducers

An appropriate metrological verification has to be established by the owner of the approved instrument in order to ensure, that each response of the measuring transducers is always correct. This verification needs to be documented.

D.1.3.2 Verification of processing chain

A simulator shall take the places of the measuring transducers in order to ensure, that the processing unit is always correct. This verification needs to be documented.

D.1.3.3 Documents of verification

The documents of verification shall be stored on the machine and made available for independent inspection for analyzing the conformity of the approved instrument.

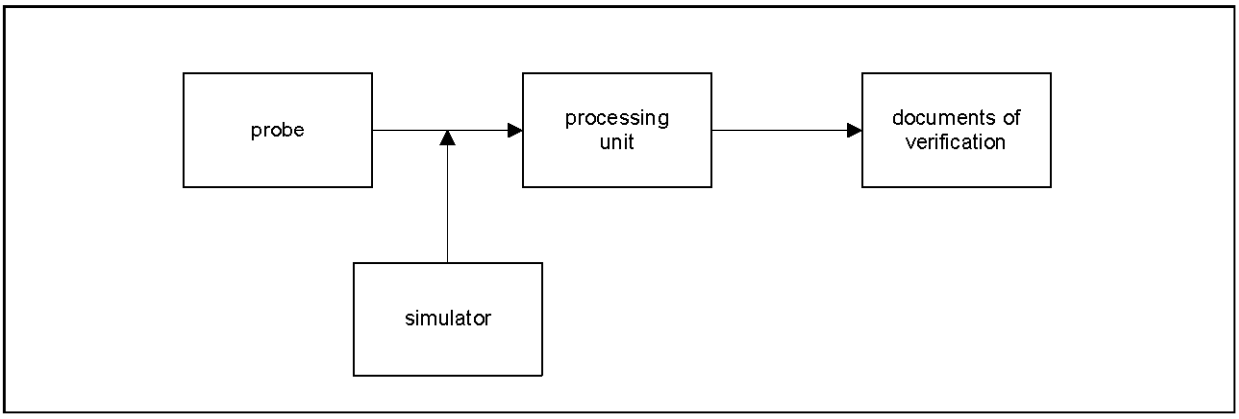


Figure D.1 — Process for documents of verification

D.1.4 Dynamic verification

D.1.4.1 General

The dynamic verifications shall be undertaken in track, both ground and not ground.

The recordings obtained in both working directions shall be compared either by comparison of the graphic outputs or electronically by comparison of the processed data.

D.1.4.2 Comparison of dynamic behaviour

One section of the track at least 300 m long shall be measured in both directions with the instrument(s) incorporated in the machine. A graphical superposition of the filtered profiles allows checking possible differences. In case of non-conformity a corrective action needs to be undertaken.

D.1.4.3 Comparison of statistical results

One section of the track at least 300 m long shall be measured once in each direction with the instrument(s) incorporated in the machine. Statistical analysis of the difference between the measured data for forward and backward measurement should be undertaken and if the data differs by more than 2 % corrective action is required.

The calculation of the exceedances should be undertaken according to Annex C and Table B.1.

Table D.1 — Example of comparison of statistical results

Wavelength range mm	10 to 30	30 to 100	100 to 300	300 to 1 000	10 to 30	30 to 100	100 to 300	300 to 1 000
Forward, 300 m	98	95	99	100	97	98	98	99
Backward, 300 m	97	97	95	100	98	99	99	94
Difference in %	1	2	4 [a]	0	1	1	1	5 [a]
[a] If the difference is greater than 2 %, a corrective action needs to be undertaken.								

D.2 Transverse profile

D.2.1 Principle

The verification of the approved instrument for transverse profile recording shall be done in two steps:

1) the static verification will allow ensuring the correctness of all the elements constituting the approved instrument such as probes, processing unit and reporting;

2) the dynamic verification will allow ensuring the repeatability of the approved instrument in its specific environment in both directions and at working speed.

D.2.2 Static verifications

D.2.2.1 Verification of probes and processing chain

The static verification is done by placing a reference profile under the approved instrument. The comparison of the reference profile against the measured profile within the range of the re-profiling angles used during work shall satisfy the correct conformity of the approved instrument and shall be documented.

D.2.2.2 Documents of verification

The documents of verification shall be stored on the machine and made available for independent inspection and for analyzing the conformity of the approved instrument.

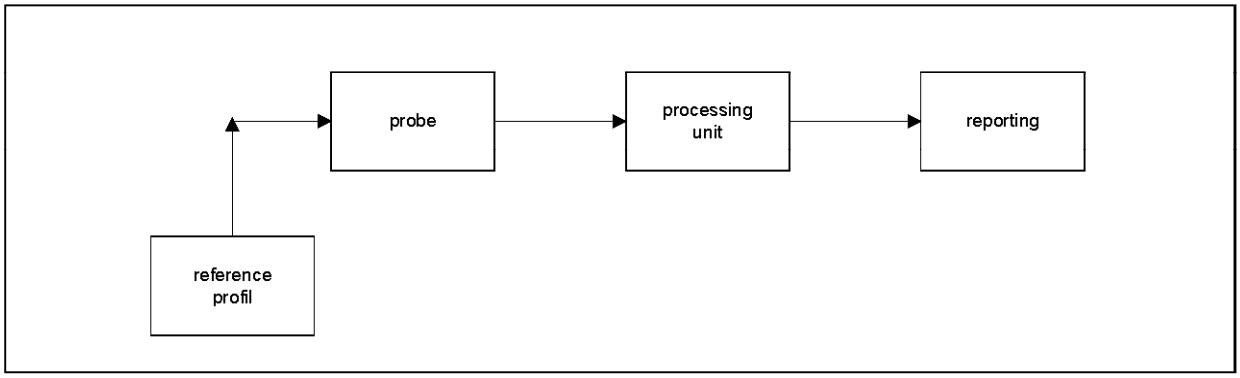
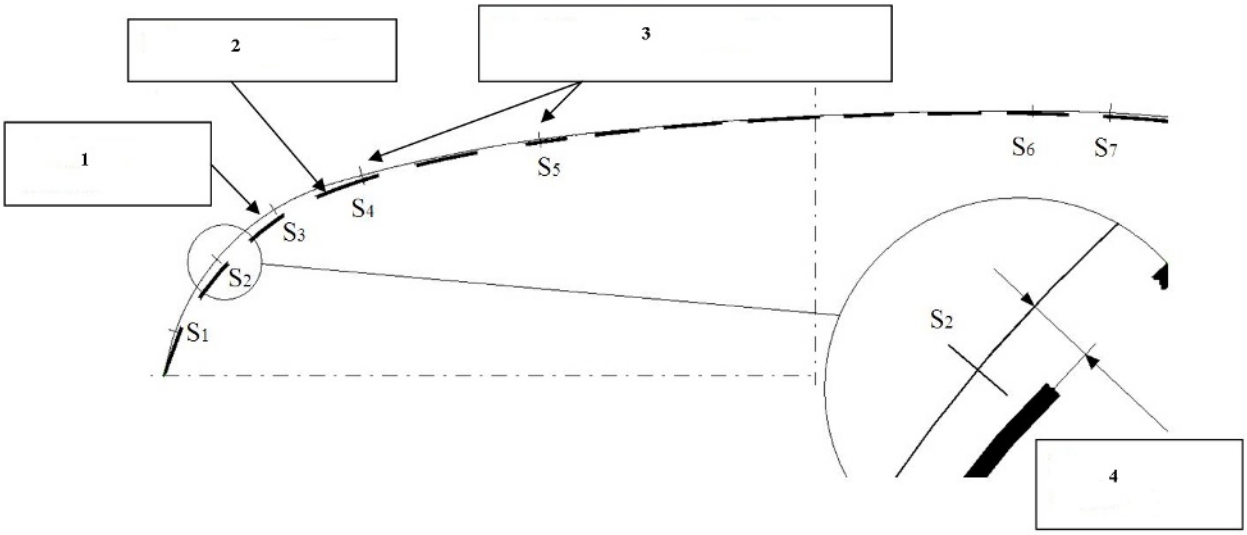


Figure D.2 — Process for reporting

D.2.3 Dynamic verification

The dynamic verifications shall be undertaken in track, either ground or not ground.

One section of the track at least 300 m long shall be measured once in each direction with the instrument(s) incorporated in the machine. Statistical analysis of the difference between the measured data for forward and backward measurement should be undertaken and if the data differs by more than 5 % corrective action is required as shown in Figure D.5.



Key

1 reference profile

2 measured profile

3 statistical reference points

4 range of deviation

Figure D.3 — Statistic interpretation for transverse profile

Measurements with the approved instrument shall be made at equal intervals in a range of 0,20 m to 0,30 m and shall be superimposed over the reference profile aligned at the reference points A and B.

The differences between the measured profiles and the reference profile are calculated for the points indicated as “statistical reference points.

The position of each statistical reference point is defined on the reference profile by its inclination or a coordinate of the railhead.

For every statistical reference point the average difference shall be calculated for every meter measured and only the biggest absolute value of all the average values taken is memorized in the statistic table. The principle is shown in Figure D.4.

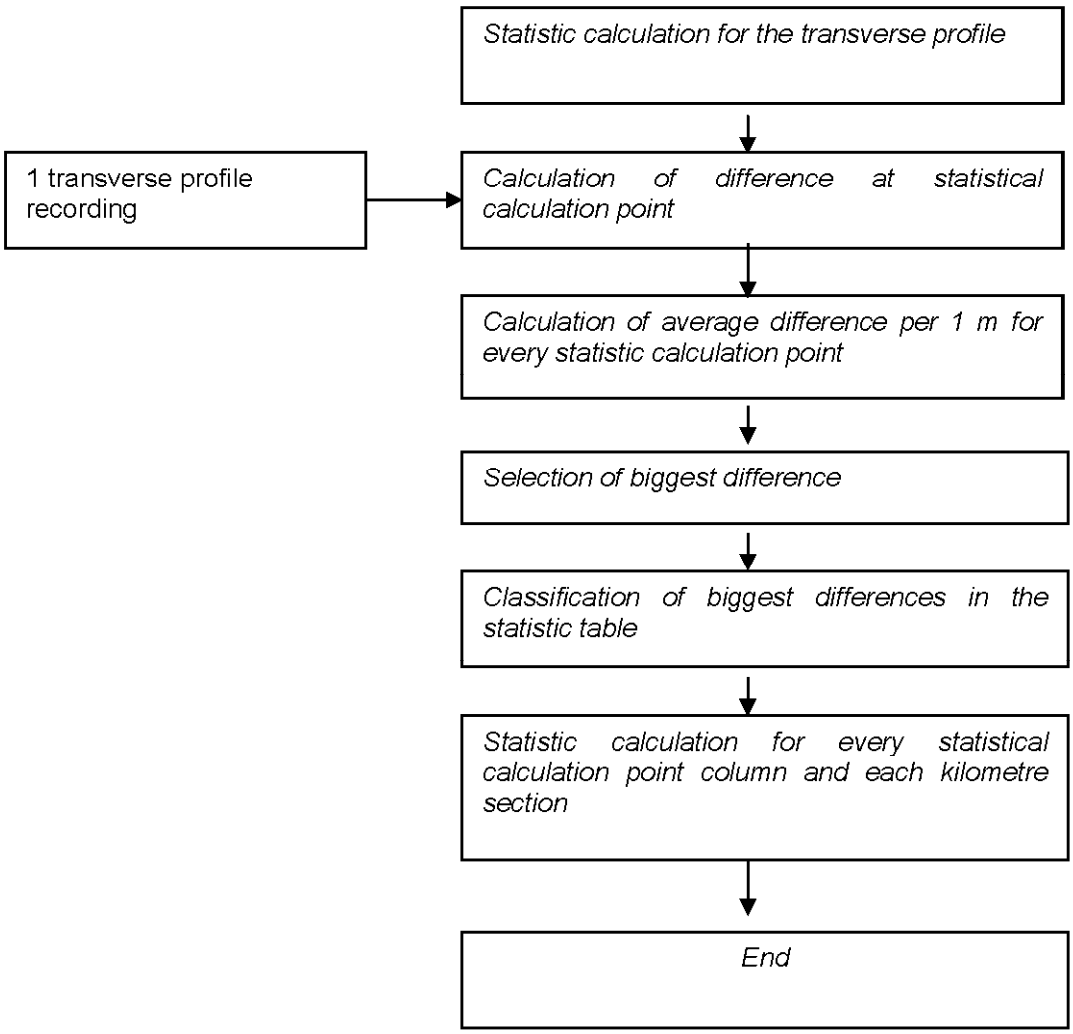


Figure D.4 — Principle of statistic verification

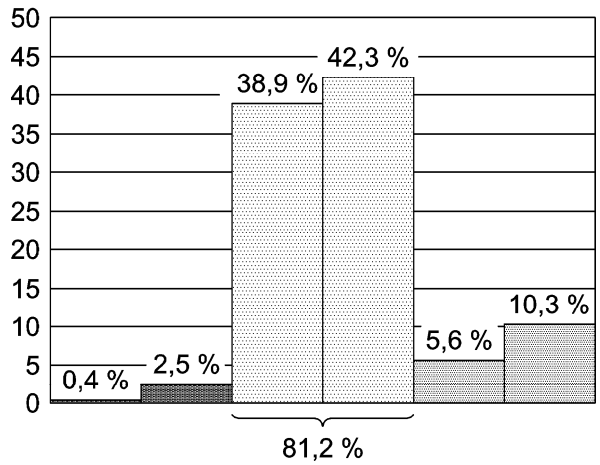
D.2.4 Report

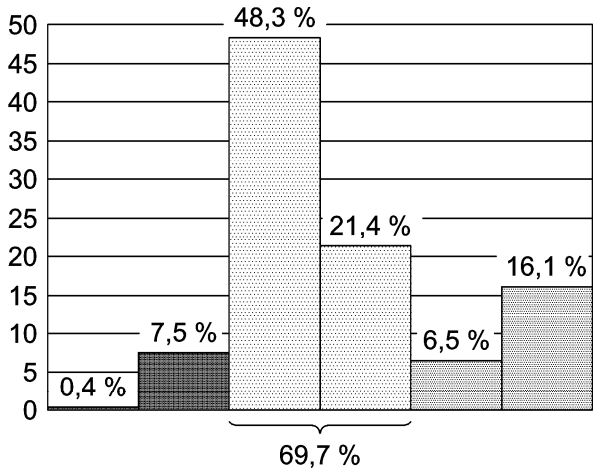
The results are classified in a table as shown in Figure D.5.

The differences calculated by the method described above are classified according to their values in the corresponding column and counted.

A histogram represents the results in graphic form.

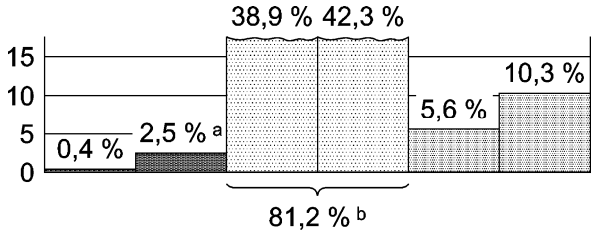
Interval km	Interval of tolerance mm											
	Left rail						Right rail					
	<-0,5	-0,5..-0,3	-0,3..0,0	0,0..0,3	0,3..0,5	>0,5	<-0,5	-0,5..-0,3	-0,3..0,0	0,0..0,3	0,3..0,5	> 0,5
45,000..45,100	0	4	24	68	4	0	0	10	78	12	0	0
45,100..45,200	0	0	40	58	2	0	0	2	74	24	0	0
45,200..45,300	0	7	50	31	10	2	3	24	63	10	0	0
45,300..44,400	1	1	5	50	14	29	1	12	51	24	4	8
44,400..44,500	1	0	23	56	5	15	0	2	30	31	8	29
44,500..44,600	2	3	11	30	16	38	0	0	0	6	6	88
44,600..44,700	0	8	54	36	2	0	0	8	2	32	22	36
44,700..44,800	0	3	52	45	0	0	0	0	100	0	0	0
44,800..44,900	0	2	51	38	0	9	0	4	49	37	10	0
44,900..45,000	0	0	54	36	0	10	0	4	30	36	16	14
45,000..45,100	0	0	64	17	9	10	0	16	54	23	5	2
……	..	..	..	..	..	..	..	..	..	..	..	..
……	..	..	..	..	..	..	..	..	..	..	..	..





Interval km	**Interval of tolerance** mm					
	< –0,5	–0,5.. –0,3	–0,3..0,0	0,0..0,3	0,3..0,5	> 0,5
	Number of differences taken for the tolerance interval of the length considered					
45,000 ..45,100	0	4	24	68	4	0
45,100 ..45,200	0	0	40	58	2	0
45,200 ..45,300	0	7	50	31	10	2
45,300 ..44,400	1	1	5	50	..	..
44,400 ..44,500	1	0	23	56	..	..
……	..	..	..	..	..	..
……..	..	..	..	..	..	..

Histogram



Key

a total percentage for the considered tolerance interval and for the total measured length

b total percentage for the two considered tolerance intervals and the total measured length

Figure D.5 — Result and interval

Annex E
(informative)

Example of acceptance documentation for rail reprofiling work

Network .....

Region .....

Protocol of acceptance

Re:

Track work

Type of work: .....
.....
Line: ..... from km ..... to km .....
Track: ..... from km ..... to km .....
Station: .....
Switch Nr.: .....
Maintenance unit: .....

Order Nr.: ..... dated: .....

Contractor: .....

Reception according to (Specification Nr.: ……..) Date: .....

Participants

For railway: .....

For contractor: .....

Result

Work has been accepted *
Work has been accepted, but shortcomings have been listed at back-side *

Shortcomings have to be corrected until: .....
Date

Requests with regard to shortcomings possible.

* Cross off, what does not apply.

Documented shortcomings:

Nr.	Place	Type	Explanation	To be corrected by	Corrected Name/Date	Remark

Accepted: ....., ...
Place Date

....
Signature Representative Railway Signature Representative Contractor

---

Correction of shortcomings confirmed:

....., ...
Place Date Signature Responsible Track

NOTE The user of this form is allowed to copy this present form.

Bibliography

[1] EN ISO 9001, *Quality management systems — Requirements*

[2] EN ISO 11562, *Geometrical product specifications (GPS) — Surface texture: Profile method — Metrological characteristics of phase correct filters (ISO 11562:1996 + Cor 1:1998)*

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