INTERNATIONAL STANDARD

ISO 5003

Second edition
2016-03-01

Flat bottom (Vignole) railway rails 43 kg/m and above

Rails Vignole de masse supérieure ou égale à 43 kg/m

Reference number
ISO 5003:2016(E)

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Foreword

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT), see the following URL: Foreword — Supplementary information.

The committee responsible for this document is ISO/TC 17, *Steel*, Subcommittee SC 15, *Railway rails, rail fasteners, wheels and wheelsets*.

This second edition cancels and replaces the first edition (ISO 5003:1980), which has been technically revised.

Flat bottom (Vignole) railway rails 43kg/m and above

1 Scope

This International Standard specifies the terms and definitions, information to be supplied by the purchaser, tolerances for dimensions, length, technical requirements, inspection rules, identification, certification, and a quality assurance system for as-rolled and heat-treated steel rails for railways.

This International Standard specifies flat bottom (vignole) railway rails with linear mass of 43 kg/m and above, for conventional and high-speed railway track usage.

There are 19 pearlitic steel grades specified, covering a 200 HBW to 400 HBW hardness range and including "non-heat-treated" carbon manganese steels, "non-heat-treated" alloy steels, "heat-treated" carbon manganese, and "heat-treated" low alloy steels.

2 Normative references

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

ISO 1099, *Metallic materials — Fatigue testing — Axial force-controlled method*

ISO 3887, *Steels — Determination of depth of decarburization*

ISO 4967, *Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams*

ISO 4968:1979, *Steel — Macrographic examination by sulfur print (Baumann method)*

ISO 4969:2015, *Steel — Etching method for macroscopic examination*

ISO 6506-1, *Metallic materials — Brinell hardness test — Part 1: Test method*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 12108, *Metallic materials — Fatigue testing — Fatigue crack growth method*

ASTM E45, *Standard test methods for determining the inclusion content of steel*

ASTM E399, *Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness Klc of Metallic Materials*

3 Terms and definitions

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

3.1
heat
liquid steel melt tapped out of a converter or electric arc furnace which includes, after continuous casting, a given number of blooms relating to the weight of the heat and the extension of the mixing zone

Note 1 to entry: In the case of sequence casting, the blooms belonging to the mixing zone should be clearly defined.

3.2
sequence
any number of heats, of the same steel grade, which undergo continuous casting in tundishes

Note 1 to entry: Tundishes can be used in parallel, if the caster has many strands.

3.3
heat-treated rail
rail that has undergone accelerated cooling from austenitizing temperature during the metallurgical transformation period

3.4
off-line heat-treated rail
all rolled rail that has undergone re-austenitization for heat treatment purposes

3.5
online heat-treated rail
heat-treated rail that has not undergone re-austenitization after rolling

3.6
rolling process
process between the blooms leaving the heating furnace and exiting the finishing pass

3.7
isothermal treatment process
process whereby blooms are held for a period of time at an elevated temperature for reducing the hydrogen content

Note 1 to entry: For maximum efficiency, this is as near to (but below) the pearlite to austenite transformation temperature as is practically possible.

Note 2 to entry: This process is sometimes referred to as "sub-critical" diffusion annealing.

3.8
rail running surface
curved surface of the rail head

Note 1 to entry: It may also refer to any area between both gauge corners (transition points of the head inclination and the first head radius).

4 Information to be supplied by the purchaser

The purchaser shall provide the supplier with the following information at the time of enquiry or order:

a) the rail profile (by submitting a drawing) and the profile tolerances as defined for the dimensions listed in Table 3;

b) the steel grade (see 7.2 and Annex A);

c) the straightness class "A" or "B" of rail (see Table 5);

d) the non-metallic inclusion determination method and if applicable: the class "1" or "2" of rail (see Table 13);

e) the determination of the macrostructure (see 5.10);

f) the lengths of rail (see Table 4 and 6.3);

g) undrilled or drilled rail ends to take fish bolts, and location and dimensions of holes when required (see Table 4);

h) paint code requirements (see 9.4.4).

5 Test methods

5.1 Test items, testing frequency and test methods

Test items, sampling position, sampling numbers and test methods shall be as given in Table 1 and Table 2.

Table 1 — Testing frequency for acceptance testing

Test items	As-rolled rails	Heat-treated rails	Relevant subclause
Chemical composition	One per heat	One per heat	5.2
Hydrogen	One per heat (two tests from first heat in sequence)	One per heat (two tests from first heat in sequence)	5.3
Total oxygen	One per sequence[a]	One per sequence[a]	5.4
Tensile	One per heat[a,b,d]	One per heat[a,c]	5.5
Hardness	One per heat[a,b]	One per heat[a,c]	5.6
Microstructure	Not required for grades HR200, HR220, HR235 and HR260A. One per 1 000 tons or part thereof for grades HR260B,HR280,HR310A, HR310B,HR320,HR325[a,b]	One per 100 tons of heat-treated rail[a,c]	5.7
Decarburization	One per 1 000 tons or part thereof[a,b]	One per 500 tons or part thereof[a,c]	5.8
Non-metallic inclusions	One per sequence[b]	One per sequence[b or c]	5.9
Macrostructure	One per 500 tons or part thereof[a,b]	One per 500 tons or part thereof[a,b or c]	5.10
Dimension	Whole length	Whole length	6.1
Straightness	Whole length	Whole length	6.2
Surface quality	Whole length	Whole length	7.9
Ultrasonic test	Whole length	Whole length	5.11

[a] Samples shall be taken at random. When different rail grades are casted in the same sequence, the samples shall be taken outside the mixing zone.

[b] Samples shall be cut after rolling.

[c] Samples shall be cut after heat-treating for heat-treated rails.

[d] One calculation per heat and one testing per 2 000 tons if agreed between purchaser and manufacturer

Table 2 — Testing frequency for periodic tests

Test items	As-rolled rails and Heat-treated rails	Relevant subclause
Residual stress	Tests shall be done for all grades at least once every 5 years or after any relevant change in the production process. The manufacturer shall only carry out testing on a 60 kg/m profile or the heaviest section produced.	5.12
Fracture toughness (K_{Ic})		5.13
Fatigue crack growth rate		5.14
Fatigue test		5.15
Longitudinal hardness test	Heat-treated rails	5.16

5.2 Chemical composition

The chemical composition shall be determined on the liquid.

When the solid chemical composition is to be checked as a requirement of the purchaser, this shall be carried out at the position of the tensile test piece shown in Figure 1.

5.3 Hydrogen content

The hydrogen content of the liquid steel shall be measured by determining the pressure of hydrogen in the steel using an online immersion probe system or the method agreed between the purchaser and manufacturer.

At least two liquid samples shall be taken from the first heat of any sequence using a new tundish and one from each of the remaining heats and analysed for hydrogen content (see Table 1). The first sample from the first heat in a sequence shall be taken from the tundish at the time of the maximum hydrogen concentration.

When testing of rails is required rail samples shall be taken at the hot saw at a frequency of one per heat at random. However on the first heat in a sequence, the rail sample shall be from the last part of a first bloom teemed on any strand. Hydrogen determination shall be carried out on samples taken from the centre of the rail head, and determined by automatic machine.

5.4 Total oxygen content

The total oxygen content can be determined in the liquid or solid.

If the total oxygen content is determined from the solid rail head, the testing positions are shown in Figure 2.

5.5 Tensile test

Test samples shall be taken from the rail head as shown in Figure 1.

The tensile properties shall be determined in accordance with ISO 6892-1 by using a round tensile test piece with the dimensions as follows:

— diameter 10 mm;

— gauge length 50 mm.

In the case of dispute, the tensile test pieces shall be maintained at a temperature of 200 °C for 6 h before testing.

For as-rolled rails, the tensile strength and elongation may be determined as agreed between the purchaser and manufacturer by a correlation to the chemical composition based on the statistical data analysis. The method to be applied is shown in Annex B.

5.6 Hardness

5.6.1 General requirements

Brinell hardness tests (HBW) shall be carried out in accordance with ISO 6506-1. The method used is at the discretion of the manufacturer.

In case of dispute, the test shall be done using HBW 2,5/187,5.

5.6.2 Surface hardness

The surface hardness shall be tested at position RS as shown in Figure 3.

The surface hardness shall be tested on the centre line of the rail head crown. 0,5 mm shall be removed from the running surface before a hardness impression is made. Surface quality must be according with ISO 6506-1.

5.6.3 Internal hardness

For heat-treated rails, the internal hardness shall be tested in accordance with ISO 6506-1 at the testing positions shown in Figure 3.

The internal hardness of heat-treated rails of any steel grade shall be determined on a transverse specimen cut from the end of the rail. The specimen shall be ground or milled so that the transverse surfaces are parallel.

5.7 Microstructure

The microstructure testing position in the rail head shall be as shown in Figure 1, and shall be determined at a magnification of 500x.

5.8 Decarburization

Decarburization depth shall be assessed by means of a hardness test using HBW 2,5/187,5 indentation. The test shall be performed at three points in the centre of the rail crown after minimal preparation of the rail head surface (less than 0,2 mm material removed). None of the hardness test results shall be more than 7 points lower than the minimum hardness of the specified grade (e.g. 253 HBW for 260 grade rail).

As an alternative or in the case of dispute decarburization depth shall be measured metallographically. The testing position in the surface of the rail head shall be as shown in Figure 4. The test shall measure the depth of closed ferrite network in accordance with ISO 3887. Photomicrographs showing examples of how to determine the depth of decarburization are shown in Figure 5.

5.9 Non-metallic inclusions

5.9.1 General requirements

Samples shall be taken from one of the last blooms of the last heat of the sequence. From each sample, two specimens shall be tested.

The non-metallic inclusions testing position in the rail head is shown in Figure 6.

5.9.2 Testing methods

The test shall comply with the method shown in Annex C.

If agreed between purchaser and manufacturer [see Clause 4 d)], alternative methods may be used, such as:

— ISO 4967:2013, Method A;

— ASTM E45, Method A.

5.10 Macrostructure

Macrostructure of transverse rail sections shall be tested in accordance with ISO 4969 or ISO 4968, as agreed between purchaser and manufacturer [information given by the purchaser in Clause 4 e)].

5.11 Ultrasonic test

5.11.1 Testing area

The minimum cross-sectional area examined by the ultrasonic technique shall be

— at least 70 % of the head,

— at least 60 % of the web, and

— the area of the foot to be tested shall be as shown in Figure 7.

By convention, these areas are based on projecting the nominal crystal size of the probe. The head shall be tested from both sides and from the running surface.

5.11.2 Sensitivity requirements

The sensitivity levels of the automated equipment used shall be a minimum of 4 dB greater than the level required to detect the reference reflectors described in 5.11.3. A rail giving an echo referring to a possible defect shall be separated by means of an automatic trigger/alarm level combined with a marking and/or sorting system. For possible retesting, the test sensitivity shall be increased to 6 dB, instead of 4 dB.

The system shall incorporate continuous monitoring of interface signals and, if present, backwall echo signals.

5.11.3 Calibration rails

There shall be a calibration rail for each profile to be tested ultrasonically. The positions of the artificial defects are given for the rail head, web and foot of the 60E1 profile (see Annex D) in Figures 8, 9 and 10 respectively. Calibration rails for other profiles with calibration defects similar to those in accordance with Figures 8, 9 and 10 for 60E1 shall be available.

Other methods of calibration may be used but these methods shall be equivalent to that described above.

5.12 Residual stress

5.12.1 Test sample rail

The manufacturer shall only carry out testing on a 60 kg/m profile or the heaviest section produced. For residual stress tests there shall be six sample rails, which shall be taken from finished roller straightened rails, and test pieces shall be taken from the full roller straightened part of the rail.

5.12.2 Test pieces

Each of the six test pieces from the rail section shall be 1 000 mm in length.

5.12.3 Test method

The residual stresses in the rail foot shall be determined in accordance with Annex E.

5.13 Fracture toughness (K_{Ic})

5.13.1 Test sample

The rails used for this test shall be of the same profile as used for 5.12.

Three rail test pieces shall be taken from the full roller straightened part of rails from three different heats and different strands.

From each of the three rail test pieces, a minimum of five samples shall be produced.

These samples shall not be subject to any further mechanical or thermal treatment.

5.13.2 Test pieces test method

Fracture toughness test shall be performed in accordance with Annex F.

5.14 Fatigue crack growth rate

5.14.1 Test sample rail

The rails used for this test shall be of the same profile as used for 5.12.

Three rail test pieces shall be taken from the full roller straightened part of rails from three different heats and different strands.

From each of the three rail test pieces, a minimum of three samples shall be produced.

These samples shall not be subject to any further mechanical or thermal treatment.

5.14.2 Test pieces

A three point bend, single edge notch test piece, of the dimensions and location within the rail shown in Figure 11 shall be used.

5.14.3 Test method

Tests shall be carried out in accordance with the general requirements of ISO 12108.

5.14.4 Number of tests and test conditions

A minimum of three tests from each sample rail shall be performed under the following conditions:

— test temperature shall be within +15 °C to +25 °C;

— R = 0,5 (R = minimum cyclic load/maximum cyclic load);

— 3-point bend test piece loading span shall be 4 W (see Figure 11);

— cyclic loading frequency shall be within 15 Hz to 40 Hz;

— laboratory environment.

5.15 Fatigue test

5.15.1 Test sample rail

The rails used for this test shall be of the same profile as used for 5.12.

Three rail test pieces shall be taken from the full roller straightened part of rails from three different heats and different strands.

From each of the three rail test pieces, a minimum of three samples shall be produced.

These samples shall not be subject to any further mechanical or thermal treatment.

5.15.2 Test pieces

The test pieces shall be machined from the sample rail as shown in Figure 12.

5.15.3 Test method

Constant amplitude fatigue tests shall be carried out in accordance with ISO 1099.

5.15.4 Number of tests and test conditions

A minimum of three test pieces shall be tested from each sample rail under the following conditions:

— test temperature shall be within +15 °C to +25 °C;

— control variable shall be axial strain amplitude;

— strain cycle shall be symmetrical about the initial, zero load.

5.16 Variation of centre line running surface hardness of heat-treated rails

This subclause only applies to heat-treated rails.

For the longest length of rail produced by the manufacturer, a one metre length of rail shall be taken from each end and at 20 m intervals from one end of the rail. These shall be hardness tested (HBW) in accordance with ISO 6506-1 along their length at 25 mm intervals on the centreline of the running surface after 0,5 mm has been ground away. The hardness results shall be no more than ±15 HBW from the mean result obtained.

6 Tolerances for dimension, shape, length and weight

6.1 Dimension, shape and length tolerance

The dimensions of the profile, which shall have certain tolerances, are given in Table 3. The reference points of the profile and gauge drawings are given in Annex G.

NOTE The tolerances shown in Table 3 in columns “X” and “Y” are informative for the 60E1 rail profile. For other profiles, the values for tolerances shall be given according to Clause 4 a).

The cut length and shorten length of rails shall be agreed upon by the purchaser and manufacturer [see Clause 4 f)]. The tolerances for cutting, drilling and length shall be as given in Table 4. The chamfer angle of drilled holes shall be 45° and 0,8 mm to 2,0 mm in depth.

6.2 Straightness, surface flatness and twist

Flatness testing of the body shall be performed automatically.

Tolerances for straightness, surface flatness and twist shall meet the requirements given in Table 3. Unless otherwise agreed, rails <54 kg/m are delivered with class B tolerances.

If the rail shows evidence of twist, this shall be checked in accordance with Figure 13 by inserting feeler gauges between the base of the rail and the rail skid nearest the rail end with the rail being laid head up on an inspection bed. If the gap exceeds 2,5 mm the rail shall be rejected.

Rotational twist in the end metre of the rail, as measured by the gauge illustrated in Figure 14, shall not exceed 0,2°.

Rejected rails may be subject to only one roller re-straightening.

In cases of dispute on the results of the automatic technique, rail flatness shall be verified using a straight edge as shown in Table 5.

6.3 Weight

Rails shall be delivered in theoretical weight. The density of 7,85 g/cm^3 shall be applied to calculate the rail theoretical weight.

Table 3 — Tolerances for profile dimension

*Reference points (see Figure D.1)		Profile class 60E1 rail profile (Annex D) (dimensions in millimetres, informative, the tolerances listed here shall be applied only for 60E1 rail profile)		Gauge, figure number (see Annex G)
Location/property	**Symbol**	**X**	**Y**	
Height of rail	*H	±0,6	±0,8	Figure G.3
Width of rail head	*WH	±0,5	±0,5	Figure G.4
Crown profile	*C			Figure G.5
– Class A straightness		+0,6 −0,3	+0,6 −0,3	
– Class B straightness		±0,6	±0,6	
Rail asymmetry	*AS	±1,2	±1,5	Figure G.6 and Figure G.7
Height of fishing	*HF	±0,6	±0,6	Figure G.8
Web thickness	*WT	+1,0 −0,5	+1,0 −0,5	Figure G.9
Width of rail foot	*WF	±1,0	+1,5 −1,0	Figure G.10
Foot toe thickness	*TF	+0,75 −0,5	+0,75 −0,5	Figure G.11
Foot base concavity		≤0,3	≤0,3	