

Railway applications — Track — Rail —

Part 1: Vignole railway rails 46 kg/m and above

ICS 45.080

National foreword

This British Standard is the UK implementation of EN 13674-1:2003+A1:2007. It supersedes BS EN 13674-1:2003 which is withdrawn. It also partially supersedes BS 11:1985 which has been amended accordingly.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to CEN text carry the number of the CEN amendment. For example, text altered by CEN amendment A1 is indicated by A1 A1.

BS EN 13674-1:2003 applies to all new installations of Vignole (flat bottom) rail sections of 46 kg/m and above. Other Vignole rails of 27 kg/m and above, switch and crossing rails and check rails have been covered by other parts of BS EN 13674.

BS 11:1985 has been declared obsolescent following the publication of the other parts of BS EN 13674. This was done in order to facilitate repairs and maintenance of existing track conforming to and unique to BS 11:1985.

The UK participation in its preparation was entrusted to Technical Committee RAE/2, Railway track components.

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

Additional information

In this standard rail grades are based on hardness whereas in BS 11 they are based on tensile strength. The approximate equivalence is shown as follows.

BS EN 13674-1 grade	BS 11 grade
R220	Normal
R260	Wearing resisting A
R260Mn	Wearing resisting B

In BS 11, rail sections are identified by a number which is the approximate mass per a unit length of rails in lb/yd. An approximate conversion to kg/m can be made by multiplying the value in lb/yd by 0,49.

NOTE The term “Vignole rail” is in common use elsewhere in Europe. It is derived from the name of Charles Blacker Vignoles, an early railway engineer who promoted the use of flat bottom rail.

The textual error set out below was discovered when the English language version of EN 13674-1 was adopted as the national standard. It has been reported to CEN/TC 256/SC 1 in a proposal to amend the text of the European standard.

— Table 5a) column headed “running surface” to be changed to “Sulfur content”.

The permitted range of sulfur content is shown as a percentage by mass in Table 5a) in the column incorrectly headed as “running surface”.

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

Compliance with a British Standard cannot confer immunity from legal obligations.

Amendments issued since publication

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English Version

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46 kg/m and above

Applications ferroviaires - Voie - Rails - Partie 1: Rails
vignole de masse supérieure ou égale à 46 kg/m

Bahnanwendungen - Oberbau - Schienen - Teil 1:
Vignolschienen ab 46 kg/m

This European Standard was approved by CEN on 28 February 2003 and includes Amendment 1 approved by CEN on 27 September 2007.

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Foreword

This document (EN 13674-1:2003+A1:2007) 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 May 2008, and conflicting national standards shall be withdrawn at the latest by May 2008.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see informative Annex ZA, which is an integral part of this document.

This document supersedes EN 13674-1:2003.

This document includes Amendment 1, approved by CEN on 2007-09-27.

The start and finish of text introduced or altered by amendment is indicated in the text by tags A1 A1.

This part of EN 13674 is the first of a series of standards for rails.

Railway applications – Track:

- *Part 1: Vignole railway rails 46 kg/m and above*
- *Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above*
- *Part 3: Check rails*
- *Part 4: Vignole railway rails from 27 kg/m to, but excluding 46 kg/m*

Other standards planned for publication include the following:

- Special purpose rail – Part 1: Grooved and associated construction.
- Flash butt welding of new rails R220 and R260 grade rails in a fixed plant.
- Flash butt welding of new R260Mn and R350HT grade rails in a fixed plant.
- Flash butt welding of new R220 and R260 grade rails by mobile welding machines at sites other than at a fixed plant.
- Flash butt welding of R220 and R260 grade reusable rails.
- Flash butt welding in association with crossing construction.
- Approval of aluminothermic welding processes.
- Tests for qualification of aluminothermic welders, approval of contractors and acceptance of welds.
- Restoration of rails by electric arc welding.

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, 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 and the United Kingdom.

Introduction

This Introduction provides an explanation of the concepts, and reasoning used in the production of this standard. Its inclusion also ensures that during future revisions restrictions are removed as technology progresses and to hold them where it has not, thus ensuring continued safety as new producers, products and technologies are introduced.

The most commonly used standards of the world for the supply of railway rails have been reviewed during the preparation of this standard. However, modern rail production technology and the requirements of high speed railways within the Community have demanded a completely new look at the philosophy and content of this part of EN 13674.

Whenever possible this part of EN 13674 is performance based, recognises the European Quality System standard EN ISO 9001 and requires manufacturers to offer the latest proven technology to consistently satisfy the demanding quality of the required product.

This part of EN 13674 has two major divisions:

- 1) qualifying tests;
- 2) acceptance tests.

The qualifying tests introduce a number of performance requirements not previously seen in national or international standards. They also include typical results from relevant acceptance tests.

Rail grading is based on hardness rather than tensile strength.

The acceptance tests have been designed to control those characteristics of the rail steel and rail that are of relevance to the production of high quality rails and the demands of the railway.

The steel grades covered by this part of EN 13674 reflect trends in railway usage and heat treated rails are included. The standard includes rail profiles for Vignole rails having a linear mass 46 kg/m and above.

To ensure the supply of high quality rails, some restrictions on production processes have been imposed.

The standard supersedes other standards covered by the scope and applies to all procurements falling inside the requirements of the European Procurement Directive (93/38/EEC of 14th June 1993). In addition CEN required, where possible, a performance based standard, taking into account safety implications and at the same time addressing modern production technology and the requirements of high-speed railways. As a result of the Directive it was recognised that there would be few opportunities (and these would have to be for transparent safety considerations) for derogation from the standard to operate between the user and the manufacturer.

The standard reflects this change in philosophy from the traditional content of rail standards. A review was undertaken of the most commonly used rail standards of the world. All relevant aspects important to both user and manufacturer were considered with the aim of ensuring that all of the content had specific usefulness and relevance. For example rail grading and much of the standard has been based on hardness rather than tensile strength. Whilst the two are directly related, hardness is very quick and cheap to carry out and provides more relevant guidance to the user particularly where properties vary in different parts of the profile.

Since many rail manufacturers would have not previously carried out proving trials, the standard includes a prerequisite for all manufacturers to prove conformity against a set of qualifying test criteria at the time of tendering. The Qualifying tests include all "normal" acceptance test results plus new "type-casting" features such as fracture toughness, fatigue and residual stress. To provide users with the necessary confidence, acceptance limits have been based on results from rail known to have performed well in demanding track installations.

One aspect of the standard which is a complete break from tradition is the inclusion of quality assurance and inspection clause as part of product integrity.

In order that quality management systems are consistent across all manufacturers and that users have the best assurance for the consistency of required product quality on this safety critical component of the track, this rail standard recommends that the manufacturers' quality assurance systems are at least equivalent to the requirements of EN ISO 9001. The inclusion of this requirement also reduces the need to incorporate detailed method and calibration descriptions on items such as normal chemical composition determination and the need to define more extensive testing.

Ideally, manufacturing techniques should not be referenced in a product standard. However, some rail attributes are either not known in an exact manner or are not measurable with satisfactory statistical significance. In such cases best practice manufacturing techniques have been included as a last resort. The equipment specified is that which gives the best probability of achieving the required product for use in track. In the future new technology can add to, but preferably will reduce or delete such items.

Examples of areas where the technological state of the art renders the standard less than complete include:

- oxide/oxygen relationships;
- hydrogen test techniques;
- roller straightening effects on residual stresses;
- roller straightening effects on contact scrub;
- measurement and effect of residual stresses throughout the rail.

1 Scope

This European Standard specifies Vignole railway rails of 46 kg/m and greater linear mass, for general and high speed railway track usage.

Seven pearlitic steel grades are specified covering a hardness range of 200 to 390 HBW and include non heat treated carbon manganese steels; non heat treated alloy steels; and heat treated carbon manganese and low alloy steels.

There are 21 rail profiles specified in this Standard.

Two classes of rail straightness are specified, differing in requirements for straightness, surface flatness and crown profile. Two classes of profile tolerances are specified.

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 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature*

EN 10163-1, *Delivery requirements for surface condition of hot rolled steel plates, wide flats and sections - Part 1: General requirements*

EN 10276-1, *Chemical analysis of ferrous materials - Determination of oxygen in steel and iron – Part 1: Sampling and preparation of steel samples for oxygen determination*

EN ISO 6506-1,  *Metallic materials - Brinell hardness test - Part 1: Test method (ISO 6506-1:2005)* 

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

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

BS 6835-1:1988, *Method for determination of the rate of fatigue crack growth in metallic materials - Fatigue crack growth rates of above 10^{-8} m per cycle*

DIN 50602:1985, *Microscopic examination of special steels using standard diagrams to assess the content of non-metallic inclusions*

ASTM E399:1991, *Standard test method for plane strain fracture toughness of metallic materials*

3 Terms and definitions

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

3.1

heat

one 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. 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. 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**re-heated rail**

all rolled rail that has undergone re-austenitization for heat treatment purposes

3.5**mill 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 diminishing the hydrogen content

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

NOTE 2 This process is sometimes referred to as sub critical diffusion annealing.

3.8**qualifying tests**

special tests and criteria which are relevant to some aspects of the service performance of rails. Acceptance tests also form part of the qualifying tests.

3.9**acceptance tests**

tests carried out as part of the process and product control system, normally on a heat, sequence or tonnage basis

4 Information to be supplied by the purchaser

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

- a) the rail profile (see annex A);
- b) the steel grade (see clause 5);
- c) the profiles class, 'X' or 'Y' (see 9.2.1);
- d) the straightness class 'A' or 'B' of rail as specified in 9.2.2;
- e) the lengths of rail (see 9.2.3 and Table 10);
- f) undrilled or drilled rail ends to take fish bolts, and location and dimensions of holes when required (see 9.2.3);
- g) any special treatments to be applied to bolt holes;
- h) tolerances for bolt holes to which special processes are to be applied;
- i) paint code requirements (see 7.4.4).

5 Steel grades

The seven steel grades are given in Table 1. The five hardness ranges of the steel grades shall conform to those given in Table 1.

The steel grade designations referred to in this standard are compared to those in EN 10027-1 and EN 10027-2 in informative annex F.

Table 1 — Steel grades

Grade ^a	Hardness range (HBW)	Description	Branding lines
R200	200 to 240	Carbon – manganese (C-Mn) Non heat treated	No branding lines
R220	220 to 260	Carbon – manganese (C-Mn) Non heat treated	_____
R260	260 to 300	Carbon – manganese (C-Mn) Non heat treated	_____ _____
R260Mn	260 to 300	Carbon – manganese (C-Mn) Non heat treated	_____ _____
R320Cr	320 to 360	Alloy (1 %Cr) Non heat treated	_____ _____ _____
R350HT	350 to 390 ^b	Carbon – manganese (C-Mn) Heat treated	_____ _____ _____
R350LHT	350 to 390 ^b	Low alloy, heat treated	_____ _____ _____
^a See Table 5 for chemical composition/mechanical properties.			
^b See Table 7 for hardness requirements.			

6 Profile drawings/properties/mass

Rail profiles, dimensions, properties and linear masses are given in annex A. The tolerances of certain dimensions shall be as given in Table 8. All other quantities are informative only.

NOTE Linear masses have been calculated based on the density of steel of 7850 kg/m³.

7 Manufacture

7.1 Product integrity

7.1.1 Factory production control

All Vignole rails shall be produced under a comprehensive system of factory production control which shall ensure confidence in the conformity of the finished product. The system shall address this European Standard to ensure that the finished products consistently comply with requirements to achieve the product integrity necessary to provide assurance of product safety in track.

Manufacturers shall demonstrate continuing compliance, including documented evidence, with the factory production control system required.

Manufacturers having a factory production control system which complies with EN ISO 9001 are recognised as satisfying the minimum requirements specified by this clause.

7.1.2 Best practice manufacture

The product shall be manufactured to the best practices as specified in 7.1.

NOTE This is to ensure that the rail attributes, described in the introduction, which are not known in an exact manner or are not practically measurable, achieve the required high level of product integrity in track.

7.2 Blooms

Blooms made from basic oxygen steel or electric arc furnace steel that has been secondary ladle arc refined, vacuum degassed and continuously cast, shall be used for the manufacture of rails.

7.3 Rails

7.3.1 The manufacturer shall operate a procedure for the effective removal of scale during the rolling and straightening processes.

7.3.2 The cross-sectional area of the rail shall not exceed one ninth that of the bloom from which the rail is rolled.

7.3.3 Rail straightening shall be by a two stage roller straightening process which straightens the rail about its XX and YY axes as defined in the rail profiles shown in annex A. End deviations or a localised deviation on the rail may be corrected using pressing.

NOTE Other mandatory processes are described in the relevant clauses within the standard.

7.4 Identification

7.4.1 Branding

Brand marks shall be rolled in relief on one side and in the middle of the web (see annex A) of each rail at least once every 4 m. The brand marks on the rails shall be clearly legible and shall be 20 mm to 25 mm high, raised between 0,6 mm and 1,3 mm.

The branding line(s) to denote grade shall be 50 mm in length for the long branding line and 25 mm in length for the short branding line.

The brand marks shall include:

- a) the identification of the mill;
- b) the steel grade as shown in Table 1;
- c) the last two figures of the year of manufacture;
- d) the rail profile identification as shown in annex A.

EXAMPLE

ROLLING MILL _____ 96 60 E 1

(60 E 1 profile rail rolled 1996 and 260 HBW carbon-manganese rail steel grade).

ROLLING MILL _____ 96 60 E 1

(60 E 1 profile rail rolled 1996 and 350 HBW heat treated carbon-manganese rail steel grade).

7.4.2 Hot stamping

In addition to the branding requirements of 7.4.1 each rail shall be identified by a numerical and/or alphabetical code system, hot stamped on the non-branded side of the rail web by machine and each rail shall be hot stamped at least once every 5 m.

If hot stamping every 5 m is not practical, the identity of the rail shall be applied by hot stamping or rotary burn near the end of the rail.

NOTE Subsequent cutting could result in more than one rail length having the same identity.

The figures and letters used shall be clearly legible and shall be 16 mm high. The stamped characters shall have a flat or radius face (1 mm to 1,5 mm wide) with bevels on each side. The letters and numbers shall be on a 10° angle from vertical and shall have rounded corners. The stamping shall be between 0,5 mm and 1,5 mm in depth along the centre of the web. The design shall be as shown in Figure 1.

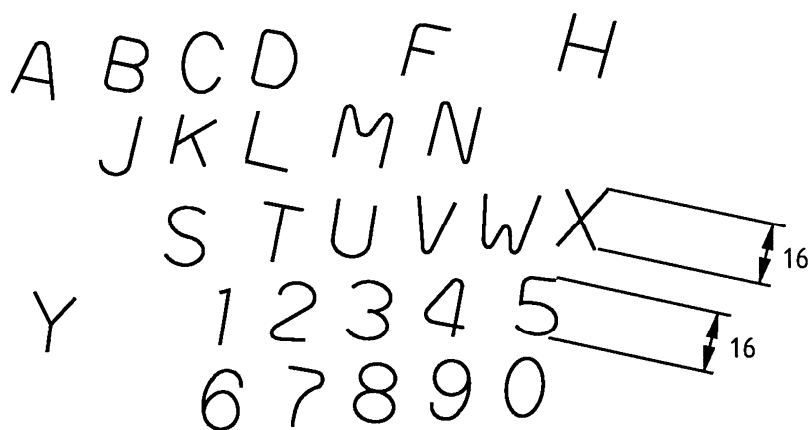


Figure 1 — Design of letters and numbers on a 10° angle for rail stamps

The identification system employed shall be such as to enable the hot stamped marking to be collated with:

- a) the number of the heat from which the rail has been rolled;
- b) the number of the strand and position of bloom within the strand;
- c) the position of the rail in the bloom (A, B ... Y).

In the event of identification marks having been removed, omitted or requiring alteration, re-identification of such marks shall be made by rotary burr.

7.4.3 Cold stamping

Cold stamping shall only be used on the cut face of the rail within the central portion of the head, at the request of the purchaser.

7.4.4 Other identification

Rails of straightness class A shall be identified with a green mark and the position of the green mark is to be specified by the purchaser. The steel grade may additionally be identified using paint. The purchaser shall specify the colour and position of the paint application.

8 Qualifying tests

8.1 Procedure

8.1.1 The manufacturer shall describe any bloom slow cooling or isothermal treatment process used to demonstrate compliance with the requirements of 9.1.2.2.

8.1.2 All qualifying tests as specified in 8.2 to 8.9 shall be undertaken at least once every five years and as a result of any significant production process change for all grades, with the exception of 8.7.1, where predictive equation approval is carried out on an ongoing basis. In addition the residual stress test shall be carried out on all available grades every 2 years.

The manufacturer shall only carry out testing on the 60 E 1 profile or the heaviest section produced.

All rail grades and profiles supplied shall conform to the qualifying criteria in accordance with 8.2 to 8.9.

The results for the grades to be supplied shall be provided at the time of tendering.

In the event of a manufacturer not having produced the rail grade prior to the tender enquiry he shall have the option of carrying out such tests on the first available sequence. When the qualifying criteria have been complied with, compliance with the standard is demonstrated and consequently the manufacturer is qualified.

8.1.3 The samples in accordance with 8.1.4 and 8.1.5 shall be removed from finished roller straightened rails. These samples shall not be subject to any further mechanical or thermal treatment (other than the treatment of ageing of the tensile test pieces as described in 9.1.8.3).

8.1.4 Test pieces for fracture toughness, fatigue crack growth rate and fatigue tests (see 8.2, 8.3 and 8.4 respectively) shall be taken from 3 sample rails at least 3 m from the cut ends of the rail. Sample rails shall be from different heats and different strands.

8.1.5 For residual stress tests (see 8.5) there shall be 6 sample rails and the test pieces shall be taken at least 3 m in from each rail end.

8.1.6 All tests should be carried out by a laboratory that operates an approved and audited quality assurance system conforming to requirements at least equivalent to EN ISO 9001.

8.1.7 The purchaser shall have access to all test records, calibrations and calculations that contribute to the final results.

8.1.8 All test results shall be reported to the purchaser.

8.2 Fracture toughness (K_{Ic})

8.2.1 Test pieces and test methods

Tests shall be performed in accordance with annex B.

8.2.2 Qualifying criteria

The value of K_{Ic} shall comply with Table 2.

Table 2 — Minimum single and minimum mean values of K_{Ic}

Steel grade	Minimum single value K_{Ic} (MPa m ^{1/2})	Minimum Mean K_{Ic} (MPa m ^{1/2})
R200 and R220	30	35
R260 and R260Mn	26	29
R320Cr	24	26
R350HT	30	32
R350LHT	26	29

NOTE In some circumstances k_Q^* values can be used for the purpose of qualification - see B.6.

8.3 Fatigue crack growth rate

8.3.1 Test method

Tests shall be carried out in accordance with the general requirements of BS 6835-1.

8.3.2 Test pieces

A three point bend, single edge notch test piece, of the dimensions and location within the rail shown in Figure 2 shall be used.

8.3.3 Number of tests and test conditions

A minimum of 3 tests from each sample rail shall be performed under the following conditions:

- test temperature shall be within the range + 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 2);
- cyclic loading frequency shall be within the range 15 Hz to 40 Hz;
- environment - laboratory air.

8.3.4 Qualifying criteria

Fatigue crack growth rates (m/Gc) shall not exceed the values given in Table 3.

Table 3 — Fatigue crack growth rates

Steel grades	$\Delta K = 10 \text{ MPa m}^{1/2}$	$\Delta K = 13,5 \text{ MPa m}^{1/2}$
All grades except R200 and R320Cr	17 m/Gc	55 m/Gc

8.4 Fatigue test

8.4.1 Test method

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

8.4.2 Test pieces

The test pieces shall be machined from the sample rail as shown in Figure 3.

8.4.3 Number of tests and test conditions

A minimum of 3 test pieces shall be tested from each sample rail under the following conditions:

- test temperature shall be within the range + 15 °C to + 25 °C;
- control variable shall be axial strain amplitude;
- the strain cycle shall be symmetrical about the initial, zero load.

8.4.4 Qualifying criteria

For a total strain amplitude of 0,00135, the life of each specimen shall be greater than 5×10^6 cycles.

NOTE Life is defined as the complete separation of the specimen.

8.5 Residual stress in rail foot

8.5.1 Test method

The residual stresses in the rail foot shall be determined in accordance with annex C.

8.5.2 Test pieces

Each of the 6 test pieces from the rail section shall be 1 m in length and shall be taken from rails as described in 8.1.3 and 8.1.5.

NOTE Only a small part of the test piece will be destroyed for the purpose of measuring residual stress; the remainder can be used for other qualifying approval tests.

8.5.3 Measurements

Longitudinal residual stress determinations shall be made on the rail foot of each of the 6 test pieces described in 8.5.2. The location of the measurements is shown in Figure C.1.

If data are available for straightness class A rails then class B rails of the same profile need not be tested.

8.5.4 Qualifying criteria

The maximum longitudinal residual stress in the foot shall be 250 MPa for all steel grades.

8.6 Variation of centre line running surface hardness of heat treated rails

This clause 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 EN 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.

8.7 Tensile strength and elongation

8.7.1 Predictive equations relating chemical composition to tensile strength and elongation shall be calculated using multiple regression analysis for all non heat treated rails produced. The following procedure shall be carried out:

- development of a predictive equation;
- confirmation of the predictive equation;
- periodic updating of the predictive equation;
- corrective action.

8.7.2 Manufacturers shall calculate, using multiple regression analysis for all naturally hard steel grades produced, predictive equations relating chemical composition to tensile strength and elongation. Each manufacturer shall derive its own predictive equations.

The predictive equations shall be produced from a minimum number of 100 heats and a maximum number of 200 heats.

The equations shall be created by carrying out one valid tensile test per heat. Tensile tests shall be carried out in accordance with 9.1.8.2 and 9.1.8.3.

The predictive equations shall produce results which are within a scatter band governed by the following limits:

tensile strength : 12,5 MPa (1 standard error);

elongation : 1,0 % (1 standard error).

8.7.3 The results of the predictive equations shall be compared with experimentally determined tensile strength and elongation results as described in 9.1.8. This comparison will be achieved by carrying out one valid tensile test every 2 000 tonnes or at least every tenth heat.

The experimental results shall be within plus or minus 25 MPa tensile strength and plus or minus 2 % elongation of those obtained from the predictive equations.

8.7.4 The results of the experimental tensile strength and elongation tests obtained from 8.7.3 shall be used to update the predictive equations. These results shall be accumulated and the equations updated annually. The updated equations shall be based on the last 200 results.

8.7.5 If results from the predictive equations or the experimental results are outside the limits set in 8.7.2 and 8.7.3 then actions a), b) and c) and when necessary action d) shall be taken:

- a) the manufacturer shall carry out an investigation;
- b) the problem will be resolved by the manufacturer taking appropriate corrective action;
- c) the manufacturer shall report the findings of a) and b) to the purchaser;
- d) if the problem cannot be resolved to the satisfaction of the purchaser, the manufacturer or potential manufacturer shall have failed the approval requirements as specified in 8.1.1. If the physical tests themselves are within the requirements of Table 5 a) the product is satisfactory.

8.8 Segregation

Full section transverse test pieces shall be sulfur printed in accordance with ISO 4968. For this purpose rail sulfur prints shall be taken from each strand from the beginning of every heat, excluding the mixing zone, for five heats.

The samples shall be assessed and classified according to the limiting figures of annex D. For the process to be accepted, all samples shall be classified as acceptable.

8.9 Other qualifying requirements

In addition to the results of the tests described in 8.2 to 8.8 inclusive the manufacturer shall provide a complete set of results for the acceptance tests described in 9.1. Samples for these tests shall be taken from the rails used for the qualifying tests as described in 8.1.3.

9 Acceptance tests

9.1 Laboratory tests

9.1.1 General

Laboratory tests shall be performed, during production, at frequencies as stipulated in Table 4. Results for each laboratory test shall comply with the limiting values shown in Table 5. Additional information and other acceptance tests not covered by Table 5 shall comply with the requirements of 9.1.2 to 9.1.8 inclusive. All rails supplied shall meet the requirements of clauses 8 and 9.

9.1.2 Chemical composition

9.1.2.1 General

The liquid chemical composition shall be determined for each heat. When the solid chemical composition is checked, this shall be carried out at the position of the tensile test piece. Liquid and solid chemical composition shall conform to the requirements of Table 5 a).

9.1.2.2 Hydrogen

The hydrogen content of the liquid steel shall be measured by determining pressure of hydrogen in the steel using an on-line immersion probe system.

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 4). The first sample from the first heat in a sequence shall be taken from the tundish at the time of the maximum hydrogen concentration.

The heats shall be assessed for hydrogen content in accordance with Table 6.

The blooms from group 1 heats shall be deemed to be satisfactory.

The blooms from group 2 heats shall be slowly cooled or isothermally treated and all heats shall be tested in the rail form.

Table 4 — Testing frequency

Test on	Relevant subclause	Steel grades	
		R200, R220, R260, R260Mn, R320Cr	R350HT, R350LHT
Chemical composition	9.1.2	One per heat	One per heat
Hydrogen	9.1.2.2	One per heat (two from first heat in sequence)	One per heat (two from first heat in sequence)
Total oxygen	9.1.2.3	One per sequence ^a	One per sequence ^a
Microstructure	9.1.3	Not required for grades 200, 220 and 260 One per 1000 tonnes or part thereof for grades 260 Mn and 320 Cr	One per 50 tonnes of re-heated ^{a,c} One per 100 tonnes of mill heat treated ^{a,c}
Decarburisation	9.1.4	One per 1000 tonnes or part thereof ^{a,b}	One per 500 tonnes of re-heated and mill heat treated ^{a,c}
Oxide cleanness	9.1.5	One per sequence ^{a,b}	One per sequence ^{a,b} or ^c
Sulfur print	9.1.6	One per 500 tonnes or part thereof ^{a,b}	One per 500 tonnes or part thereof ^{a,b} or ^c
Hardness	9.1.7	One per heat ^{a,b}	One per 50 tonnes of re-heated ^{a,c} One per 100 tonnes of mill heat treated ^{a,c}
Tensile	8.7 & 9.1.8	One calculation per heat/one per 2 000 tonnes ^{a,b}	One per 1 000 tonnes ^{a,c}
^a Samples shall be taken at random but only rails from blooms outside the mixing zone between heats when continuously cast in sequence. ^b Samples shall be cut after rolling. ^c Samples shall be cut from heat treated rails.			

Table 5 a) — Chemical composition/mechanical properties

Steel sample grade		% By mass									10 ⁻⁴ % ppm max. by mass		R _m min. MPa	min. elong A %	Centre line
		C	Si	Mn	P max	running surface ^c	Cr	Al max.	V max.	N max.	O ^a	H ^b			
R200	Liquid	0,40/0,60	0,15/0,58	0,70/1,20	0,035	0,008/0,035	0,15 max	0,004	0,030	0,009	20	3,0			
	Solid	0,38/0,62	0,13/0,60	0,65/1,25	0,040	0,008/0,040	0,15 max	0,004	0,030	0,010	20	3,0	680	14	200/240
R220	Liquid	0,50/0,60	0,20/0,60	1,00/1,25	0,025	0,008/0,025	0,15 max	0,004	0,030	0,008	20	3,0			
	Solid	0,50/0,60	0,20/0,60	1,00/1,25	0,025	0,008/0,025	0,15 max	0,004	0,030	0,008	20	3,0	770	12	220/260
R260	Liquid	0,62/0,80	0,15/0,58	0,70/1,20	0,025	0,008/0,025	0,15 max	0,004	0,030	0,009	20	2,5			
	Solid	0,60/0,82	0,13/0,60	0,65/1,25	0,030	0,008/0,030	0,15 max	0,004	0,030	0,010	20	2,5	880	10	260/300
R260 Mn	Liquid	0,55/0,75	0,15/0,60	1,30/1,70	0,025	0,008/0,025	0,15 max	0,004	0,030	0,009	20	2,5			
	Solid	0,53/0,77	0,13/0,62	1,25/1,75	0,030	0,008/0,030	0,15 max	0,004	0,030	0,010	20	2,5	880	10	260/300
R320 Cr	Liquid	0,60/0,80	0,50/1,10	0,80/1,20	0,020	0,008/0,025	0,80/1,20	0,004	0,18	0,009	20	2,5			
	Solid	0,58/0,82	0,48/1,12	0,75/1,25	0,025	0,008/0,030	0,75/1,25	0,004	0,20	0,010	20	2,5	1080	9	320/360
R350 HT	Liquid	0,72/0,80	0,15/0,58	0,70/1,20	0,020	0,008/0,025	0,15 max	0,004	0,030	0,009	20	2,5			
	Solid	0,70/0,82	0,13/0,60	0,65/1,25	0,025	0,008/0,030	0,15 max	0,004	0,030	0,010	20	2,5	1175	9	350/390
R350 LHT	Liquid	0,72/0,80	0,15/0,58	0,70/1,20	0,020	0,008/0,025	0,30 max	0,004	0,030	0,009	20	2,5			
	Solid	0,70/0,82	0,13/0,60	0,65/1,25	0,025	0,008/0,030	0,30 max	0,004	0,030	0,010	20	2,5	1175	9	350/390
^a See 9.1.2.3.															
^b See 9.1.2.2.															
^c See Figure 10.															

Table 5 b) — Maximum residual elements

All values in M by mass

	Mo	Ni	Cu	Sn	Sb	Ti	Nb	Cu & 10 Sn	Others
R200, R220, R260, R260Mn	0,02	0,10	0,15	0,030	0,020	0,025	0,01	0,35	0,35 (Cr + Mo + Ni + Cu + V)
R320Cr	0,02	0,10	0,15	0,030	0,020	0,025	0,01	0,35	0,16 (Ni + Cu)
R350HT	0,02	0,10	0,15	0,030	0,020	0,025	0,04	0,35	0,25 (Cr + Mo + Ni + Cu + V)
R350LHT	0,02	0,10	0,15	0,030	0,020	0,025	0,04	0,35	0,20 (Mo + Ni + Cu + V)

Table 6 — Hydrogen content of heats

Heats	Hydrogen content 10 ⁻⁴ % (ppm)	
	Steel grades R200 and R220	All other steel grades
Group 1	≤ 3,0	≤ 2,5
Group 2	> 3,0	> 2,5

If the hydrogen contents of the first samples of a first heat or the heat sample of a second or further heat do not comply with the requirements of Table 5 a) then the blooms made before those samples are taken shall be slowly cooled or isothermally treated. This applies also to all blooms made before the hydrogen content eventually complies with the requirements in Table 5 a) shall be slowly cooled or isothermally treated.

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.

If any test result fails to meet the requirements stated in Table 5 a) the heat shall be rejected.

9.1.2.3 Determination of total oxygen content

9.1.2.3.1 General

Total oxygen content shall be determined in the liquid steel, following solidification of the sample, or from the solid rail head, in the positions shown in Figure 4, and at the frequency shown in Table 4.

For orders in excess of 5 000 tonnes at least 95 % of heats shall have a total oxygen content of less than 20 ppm. No more than 5 % of heats shall have a total oxygen content of up to 30 ppm. Heats with a total oxygen content greater than 30 ppm shall be rejected.

For orders less than 5 000 tonnes, only one sample with total oxygen greater than 20 ppm, but less than 30 ppm, is allowed. Heats with total oxygen greater than 30 ppm shall be rejected. Any heats with total oxygen above 20 ppm shall require that all subsequent heats be tested until values below 20 ppm are achieved.

9.1.2.3.2 Preparation of the sample

The thickness of the transverse rail slice shall be 4 mm.

Samples shall be prepared in accordance with EN 10276-1.

9.1.2.3.3 Measurement

The measurement of oxygen shall be made using an automatic machine.

9.1.3 Microstructure

9.1.3.1 General

Microstructures shall be determined at a magnification of x 500.

The microstructure shall be verified for R260Mn, R320Cr and heat treated rails in accordance with the requirements of Table 4.

The testing position in the rail head shall be as shown in Figure 5.

9.1.3.2 Grades R200, R220

The microstructure shall be a mixture of pearlite and grain boundary ferrite. There shall be no martensite, bainite or grain boundary cementite.

9.1.3.3 Grade R260, R260Mn

The microstructure shall be pearlitic but grain boundary ferrite may occur in these grades. The maximum grain boundary ferrite permitted is shown in Figure 6. There shall be no martensite, bainite or grain boundary cementite.

9.1.3.4 Grade R320Cr

The microstructure shall be fully pearlitic with no martensite, bainite or grain boundary cementite.

9.1.3.5 Grades R350HT, R350LHT

The microstructure shall be pearlitic with no martensite, bainite or grain boundary cementite. The maximum grain boundary ferrite permitted is shown in Figure 6.

9.1.4 Decarburisation

No closed ferrite network shall be observed below 0,5 mm depth measured anywhere on the rail head surface. The decarburisation depth will be assessed by means of a hardness test at a frequency shown in Table 4. After a minimum of preparation of the rail surface (polishing) a hardness test according to the method indicated in 9.1.7 will be performed in three points. None of the results of hardness obtained shall be lower than the minimum value specified of the grade, reduced by 7HBW (example : 253HBW for grade R260).

Photomicrographs showing the depth of decarburisation allowed are shown in Figure 7 and Figure 8 defines the rail head surface for decarburisation checks.

9.1.5 Oxide cleanliness

Samples shall be prepared and assessed in accordance with DIN 50602. For orders less than 5 000 tonnes, only one sample with a K3 greater than 10 and less than 20 is allowed. Samples shall be taken from one of the last blooms of the last heat of the sequence but from each sample 2 specimens shall be tested.

The following limits shall apply.

Total index $10 < K3 < 20$ for a maximum of 5 % of samples.

$K3 < 10$ for a minimum of 95 % of samples.

The testing position in the rail head is shown in Figure 9.

9.1.6 Sulfur prints

Sulfur prints of transverse rail sections shall be prepared in accordance with ISO 4968 at the frequency shown in Table 4.

All samples, including those intended for repeat test, shall be taken from outside the mixing zones of the heat. When part or all of an adjacent heat has been withdrawn due to non-conformance, tests shall be made in the mixing zones to determine the first conforming blooms.

The sulfur prints shall conform to the requirements of annex D.

9.1.7 Hardness

Brinell hardness tests shall be carried out in accordance with EN ISO 6506-1 at the frequency shown in Table 4. The test conditions shall be as follows:

- tungsten carbide ball;
- ball diameter 2,5 mm;
- load 1,839 kN;
- period of application 15 s.

Other measurement techniques, for example Rockwell or Vickers hardness testing, may be used, but in case of dispute Brinell hardness testing in accordance with EN ISO 6506-1 shall be used.

The hardness values measured shall meet the requirements given in Table 7 for the relevant grade.

In the case of the heat treated grades the mean value of position 2 shall be greater than the value of position 3 + 0,4 [(mean value of position 1) minus (value of position 3)]. Also the difference between any of the three position 1 s shall be no more than 30 HBW. The testing positions are shown in Figure 10.

The hardness on the centre line of the head crown shall not vary by more than 30 HBW on any individual rail.

For the steel grades R200, R220, R260, R260Mn and R320Cr the hardness shall only be tested for position RS. For heat treated rails hardness shall be tested in accordance with the positions shown in Figure 10.

0,5 mm shall be ground from the running surface before a hardness impression is made.

Table 7 — Hardness testing positions and requirements

Position	Rail Steel Grade						
	R200	R220	R260	R260Mn	R320Cr	R350HT	R350LHT
RS ^a 1 2 3 4	Hardness (HBW)						
	200-240	220-260	260-300	260-300	320-360	350-390 ^b	350-390 ^b
						340 min	340 min
						331 min	331 min
						321 min	321 min
						340 min	340 min
^a RS = Point on the centre line running surface. ^b If the hardness exceeds 390HBW, the rail is acceptable provided the microstructure is confirmed to be pearlitic, and the hardness does not exceed 405 HBW.							

9.1.8 Tensile tests

9.1.8.1 Steel grades R200, R220, R260, R260Mn, R320Cr

For rail steel grades R200, R220, R260, R260Mn and R320Cr the tensile strength and elongation shall be determined by the predictive equation described in 8.7.2.

If a manufacturer is temporarily unqualified, or if limited production quantities prevent qualification, then tensile testing shall be one per heat.

The values determined by the predictive equation shall not be less than those quoted in Table 5 a).

9.1.8.2 Steel grades R350HT and R350LHT

For rail steel grades R350HT and R350LHT tensile tests shall be carried out at a frequency given in Table 4. Test samples shall be removed from the rail as shown in Figure 5. Results obtained shall comply with the values given in Table 5.

9.1.8.3 Method of test

The manufacturer shall determine the tensile properties in accordance with EN 10002-1 using a round tensile test piece with the dimensions as follows:

- diameter 10 mm;
- original cross-sectional area 78,5 mm²;
- original gauge length 50 mm;
- minimum parallel length 55 mm.

Before testing the tensile test pieces should be at a temperature of 200 °C for up to 6 h. In the case of dispute, before testing the tensile test pieces should be at a temperature of 200 °C for 6 h.

9.1.9 Retest procedures

If any test fails to meet the requirements of 9.1.2 to 9.1.8 (but excluding hydrogen) then two tests shall be performed on samples from rails in close proximity to the original. Should either retest fail then rails shall be progressively tested until acceptable material is found. The failed material shall be rejected or in the case of heat treated material re-treated and tested. For hydrogen and oxygen testing refer to the 9.1.2.2 and 9.1.2.3 respectively.

If the results of an investigation under 8.7.5 or the qualification procedure, or the predictive equation indicate that certain rails are out of specification, then acceptance of such rails shall be based on experimental tensile test results. The minimum values in Table 5 shall apply in such cases.

9.2 Dimension tolerances

9.2.1 Profile

The nominal dimensions of the rail profile (see annex A) and the actual dimensions anywhere on any rail shall not differ by more than the tolerances given in Table 8.

Table 8 — Profile tolerances

* Reference points (see Figure E.1)	Profile class (dimensions in mm)		Gauge figure number (see annex E)
	X	Y	
Height of rail ^a *H < 165 mm ≥ 165 mm	± 0,5 ± 0,6	+ 0,5 - 1,0 + 0,6 - 1,1	E.3
Crown profile *C Class A straightness Class B straightness	+ 0,6 - 0,3 ± 0,6	+ 0,6 - 0,3 ± 0,6	E.4
Width of rail head *WH	± 0,5	+ 0,6 - 0,5	E.5
Rail asymmetry *As	± 1,2	± 1,2	E.6,E.7
Inclination of fishing surfaces (on the basis of 14 mm parallel to the inclined theoretical fishing surfaces) ^b *IF	± 0,35	± 0,35	E.8
Height of fishing *HF < 165 ≥ 165	± 0,5 ± 0,6	± 0,5 ± 0,6	E.8
Web thickness *WT	+ 1,0 - 0,5	+ 1,0 - 0,5	E.9
Width of rail foot *WF	± 1,0	+ 1,5 - 1,0	E.10
Foot toe thickness *TF	+ 0,75 - 0,5	+ 0,75 - 0,5	E.11
Foot base concavity	0,3 max	0,3 max	
^a The total height variation over any rail length shall not be greater than 1 mm for rails < 165 mm and 1,2 mm for rails ≥ 165 mm.			
^b The maximum fishing tolerance on the head and on the foot is 0,35 mm but the total tolerance allowed is also ± 0,35 mm.			

9.2.2 Straightness, surface flatness and twist

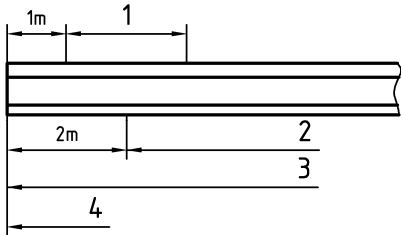
Flatness testing of the body shall be performed automatically.

Tolerances for straightness, surface flatness and twist shall meet the requirements given in Table 9. Rejected rails may be subject to only one roller re-straightening.

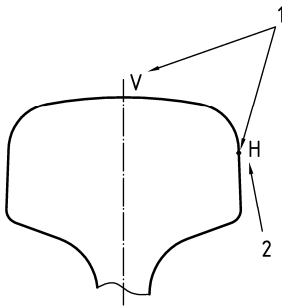
In cases of dispute on the results of the automatic technique, rail flatness shall be verified using a straight edge as shown in Table 9.

When measuring sidesweep the rail shall be stood vertically on a suitable support that allows the rail to be unrestrained. If a measurement technique other than that given above is used, only the above shall be used in the case of dispute.

Table 9 — Straightness, surface flatness and twist tolerances

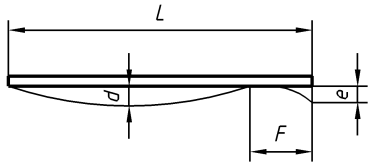
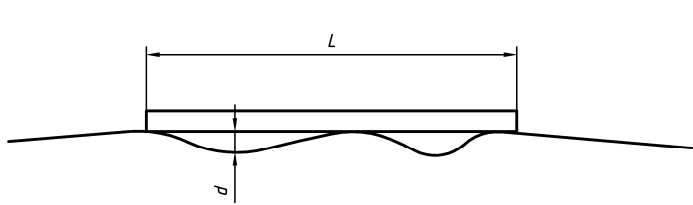


- Key**
- 1 Overlap
 - 2 Body
 - 3 Whole rail
 - 4 End "E"

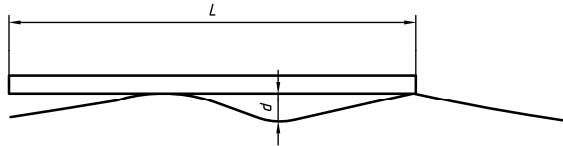


- Key**
- 1 V and H. Location of flatness measurements
 - 2 The position of H is nominally 5 mm - 10 mm below the gauge corner on the side of the head

		Class B		Class A	
		<i>d</i>	<i>L</i>	<i>d</i>	<i>L</i>
BODY ^a	Vertical flatness V	≤ 0,4 mm	3 m ^c	≤ 0,3 mm	3 m ^c
	Horizontal flatness H	≤ 0,3 mm and ≤ 0,6 mm	1 m ^c and 1,5 m ^c	≤ 0,2 mm and ≤ 0,45 mm	1 m ^c and 1,5 m ^c
ENDS ^a	End "E"	1,5 m		2 m	
	Vertical straightness	≤ 0,5 mm	1,5 m	≤ 0,4 mm and ≤ 0,3 mm and <i>e</i> ≤ 0,2 mm	2 m and 1 m ^d and <i>e</i> ≤ 0,2 mm
	Horizontal straightness	≤ 0,7 mm	1,5 m	≤ 0,6 mm and ≤ 0,4 mm	2 m and 1 m ^d

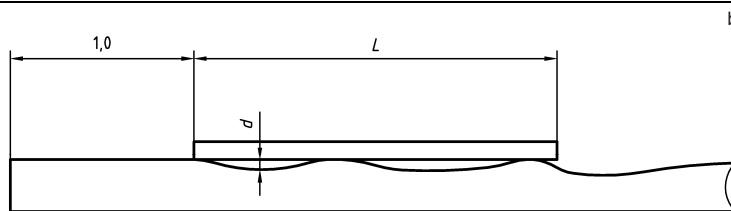
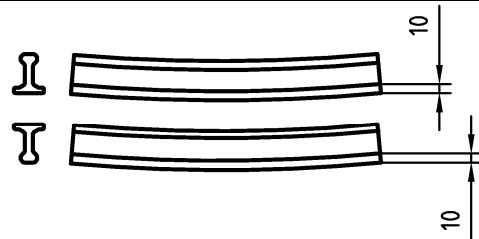


If *e* > 0 *F* ≥ 0,6 m



"to be continued"

Table 9 (concluded)

		Class B		Class A		
		<i>d</i>	<i>L</i>	<i>d</i>	<i>L</i>	
OVERLAP ^a	Length of overlap	1,5 m		2 m		
	Vertical flatness V	≤ 0,4 mm	1,5 m ^c	≤ 0,3 mm	2 m ^c	
	Horizontal flatness H	≤ 0,6 mm	1,5 m ^c	≤ 0,6 mm	2 m ^c	
WHOLE RAIL	Upsweep and downsweep	10 mm ^e		10 mm ^e		
	Side sweep	Curve radius <i>R</i> > 1500 m		Curve radius <i>R</i> > 1500 m		
	Twist	See Figures 11 and 12		See Figures 11 and 12		
NOTE It is unlikely that the manufacturer can supply rails < 54 kg/m for class A tolerances.						
^a Automatic measurement equipment shall measure as much of the rail as possible but, at least the body. If the whole rail satisfies the body specifications, then measurement of end and overlap is not mandatory.						
^b Automatic measurement techniques are complex and are therefore difficult to define but the finished rail flatness shall be capable of being verified by straight edge as shown in the above drawings.						
^c 95 % of delivered rails shall be within limits specified, with 5 % of rails allowed outside the tolerances by 0,1 mm.						
^d Reference L sliding over end E.						
^e The ends of the rails shall not be up more than 10 mm when the rail is on its foot or on its head when standing on an inspection bed.						

9.2.3 Cutting and drilling

The size and location of drilled holes, the squareness of rail ends and rail lengths shall be within the tolerances given in Table 10.

Drilled holes and rail ends shall be deburred. For holes that are to be subject to special treatments the tolerances shall be in accordance with 4.h).

9.3 Gauges

The gauges required for manufacture are as shown in annex E.

If other measurement techniques than those given in annex E are used, only those in annex E shall be used in case of dispute.

9.4 Inspection requirements/tolerances for internal quality and surface quality

9.4.1 Ultrasonic test requirements

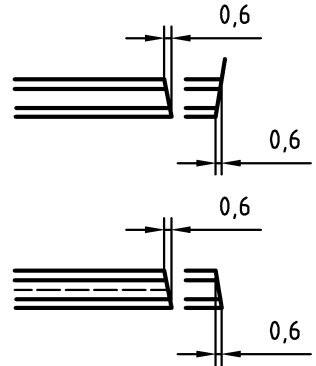
9.4.1.1 All rails shall be ultrasonically tested by a continuous process ensuring that the entire rail length and specified cross-sectional area are inspected.

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

- at least 70 % of the head;
- at least 60 % of the web;
- the area of the foot to be tested shall be as shown in Figure 16.

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.

Table 10 — Drilling and cutting tolerances

Number	Dimensional requirement	Tolerance
1	Drilling Diameter ≤ 30 mm > 30 mm Centring and positioning of the holes vertically and horizontally	$\pm 0,5$ mm $\pm 0,7$ mm The horizontal position of the holes is checked using a gauge as shown in Figure E.12 which has a stop designed to come into contact with the end of the rail and pins designed to enter the holes. The diameter of the pins for horizontal and vertical clearances is smaller than the diameter of the holes by: - 1,0 mm for holes less than or equal to 30 mm in diameter; - 1,4 mm for holes greater than 30 mm in diameter; - the distances between the centre lines of the pins and the stop are equal to the nominal distances from the centre line of the holes to the end of the rail; - the gauge pins shall be able to enter the holes at the same time while the stop is touching the end of the rail. The vertical centring of the holes can be checked using a gauge as shown in Figure E.13. The side of the hole, left or right, is determined by proceeding from the side with the relief markings.
2	Squareness of ends	0,6 mm in any direction 
3	Length^a - both ends drilled ≤ 24 m > 24 m ≤ 40 m - other (undrilled or one end drilled)	± 3 mm ± 4 mm ± 1 mm/per metre of rail (max. ± 30 mm on any rail) For special purpose undrilled rails the length tolerance is ± 6 mm up to 24 m and ± 10 mm for > 24 m rail.
The given rail lengths apply for $+ 15$ °C. Measurements made at other temperatures are to be corrected to take into account expansion or contraction of the rail.		

9.4.1.3 The sensitivity levels of the automatic equipment used shall be a minimum 4dB greater than the level required to detect the artificial defects described in 9.4.1.4. An echo giving a possible defect indication shall be re-tested, using an increased sensitivity of 6dB in place of 4dB.

Rails giving signals over the threshold in the rail using the increased sensitivity shall be rejected or cut back to remove the defective portion.

The system shall incorporate continuous monitoring of interface and intermediate echo signals.

9.4.1.4 There shall be a calibration rail for each profile ultrasonically tested and the positions of the artificial defects are given for the rail head, web and foot of the 60 E 1 profile in Figures 13, 14, and 15 respectively. Calibration rails for other profiles shall be based upon the 60 E 1 calibration rail and detailed drawings shall be made available to the purchaser.

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

The calibration rail shall be used to test the equipment at production speed at the beginning and once every 8 h of testing a particular profile.

9.4.2 Surface quality

9.4.2.1 General

All rails shall be visually or automatically inspected on all faces for surface imperfections. In addition, the underside of the rail foot shall be inspected automatically in accordance with 9.4.2.6. All rails shall comply with the criteria defined at 9.4.2.2 and 9.4.2.3. Assessment and dressing of imperfections shall be in accordance with 9.4.2.5.

9.4.2.2 Hot marks, protrusions and seams

All protrusions on the running surface or the underside of the foot shall be dressed. Any protrusions affecting the fit of the fishplate at less than 1 m from the extremity of the delivered rail shall be dressed to shape.

The depth of hot marks and seams, as defined in EN 10163-1, shall not exceed:

- 0,35 mm for the running surface;
- 0,5 mm for the rest of the rail.

In the case of longitudinal guide marks, there shall be a maximum of two, to the depth limits specified, at any point along the length of the rail but no more than one of these shall be on the rail running surface. Recurring guide marks along the same axis are accepted as a single guide mark.

The maximum width of guide marks shall be 4 mm. The width to depth ratio of allowable guide marks shall be a minimum 3:1.

In the case of hot formed marks originating from the vicinity of the mill rolls, those which are recurrent along the same axis, at a distance equal to the roll circumference, shall be accepted as a single mark. They can be removed by dressing except those marks on the rail crown where a maximum of 3 per 40 m is allowed.

9.4.2.3 Cold marks

Cold marks are longitudinal or transverse cold formed scratches.

The discontinuity depth shall be not larger than:

- 0,3 mm for the rail running surface and underside of foot;
- 0,5 mm for the rest of rail.

NOTE It is difficult, or impossible to detect in track fatigue cracks initiating and propagating from the underside of the foot; therefore all practicable efforts should be made to avoid cold transverse marks in this area.

9.4.2.4 Surface microstructural damage

Any sign of surface microstructural damage resulting in martensite or white phase shall be dressed or the rail rejected. The dressed area shall be proved by suitable hardness testing. The hardness shall not be more than 50 HBW greater than the surrounding material.

9.4.2.5 Proving and dressing of surface imperfections

If the imperfection depth cannot be measured it shall be investigated by depth proving, and subsequently dressed to the criteria below, using a rotary burr, lamellar flap tool or grinding belt, providing the rail microstructure is not affected by the operation and the work is contour blended.

The depth of dressing shall be not larger than:

- 0,35 mm for the rail running surface;
- 0,5 mm for the rest of rail.

No more than three defects within a length of 10 m of rail and, over the whole length, a maximum of one defect per 10 m rail length shall be dressed or proved. After dressing profile tolerances shall be in accordance with Table 8 and flatness tolerances shall be in accordance with Table 9.

9.4.2.6 Automatic foot inspection

The rail shall be automatically inspected on the underside of the foot along its entire length.

The equipment used shall be able to detect artificial imperfections with sizes as shown in Table 11. The artificial imperfections shall have a tolerance of $\pm 0,1$ mm.

Table 11 — Dimensions of test imperfections

Depth (mm)	Length (mm)	Width (mm)
1,0	20	0,5
1,5	10	0,5

An edge loss for the automatic technique is permitted for the extreme 5 mm of the flat portion of the foot width at each side.

A suitable test rail containing artificial imperfections requires to be run every 8 h.