INTERNATIONAL STANDARD

ISO 5003

Second edition
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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

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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	

Table 4 — Tolerances for cutting, drilling and length

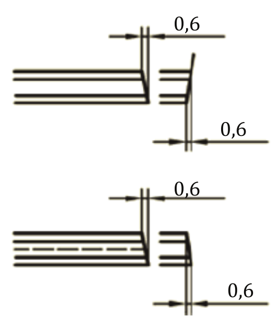
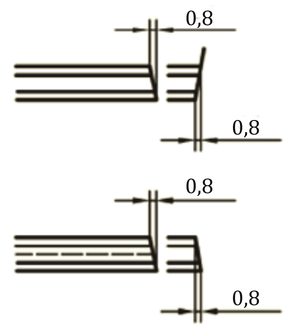
<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="2">Profile class
dimensions in millimetres
(the tolerances listed here shall be applied only for 60E1 rail profile)</th><th rowspan="2">Gauge, figure number
(see Annex G)</th></tr>
<tr><th>X</th><th>Y</th></tr>
<tr><td colspan="2">Squareness of ends</td><td>0,6 mm in any direction
</td><td>0,8 mm in any direction
</td><td></td></tr>
<tr><td rowspan="2">Bolts</td><td>Diameter</td><td>±0,7</td><td>±0,8</td><td>Figure G.12</td></tr>
<tr><td>Position
Centring and positioning of the holes vertically and horizontally</td><td colspan="2">The horizontal position of the holes is checked using a gauge as shown in Figure G.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 ≤30 mm in diameter;
— 1,4 mm for holes >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 G.13.
The side of the hole, left or right, is determined by proceeding from the side with the relief markings.</td><td>Figure G.12, Figure G.13</td></tr>
<tr><td rowspan="3">Length[a]</td><td>Rails drilled both ends ≤25 m</td><td>±6</td><td>±6</td><td></td></tr>
<tr><td>Rails undrilled ≤25 m</td><td>±10</td><td>±10</td><td></td></tr>
<tr><td>Rails undrilled or drilled on one end >25 m</td><td>±1 mm/1 m</td><td>±1 mm/1 m</td><td></td></tr>
<tr><td colspan="5">[a] The given rail lengths apply for +20 °C. Measurements made at other temperatures are to be corrected to take into account expansion or contraction of the rail.</td></tr>
</table>

Table 5 — Straightness, surface flatness and twist tolerances

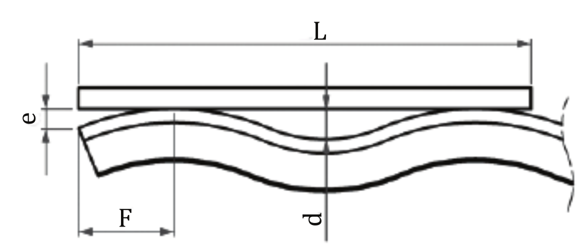
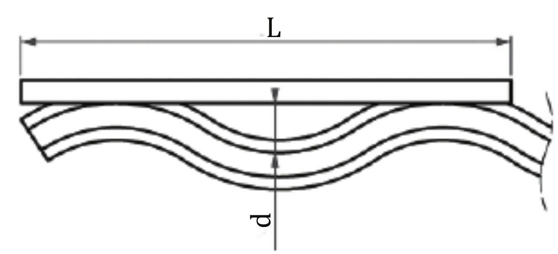
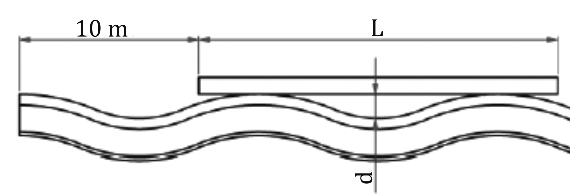
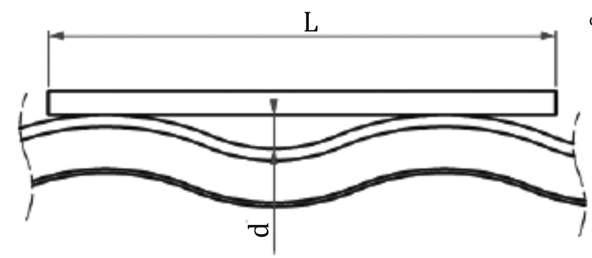
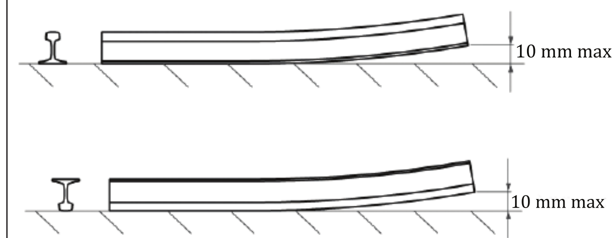
Location/Dimensional properties		Class A[e]		Class B		
		d	**L**	**d**	**L**	
Ends[a,c]	End "E"	2 m		1,5 m		[d] 
	Vertical straightness-up (V[b])	≤0,4 mm and ≤0,3 mm	2 m 1 m[f]	≤0,5 mm	1,5 m	if e > 0 F ≥ 0,6 m
	Vertical straightness-down (V)	and e ≤0,2 mm		and e ≤0,2 mm		
	Horizontal straightness (H[b])	≤0,6 mm and ≤0,4 mm	2 m 1 m[f]	≤0,7 mm	1,5 m	[d] 
Overlap[a,c]	Length of overlap	2 m		1,5 m		[d] 
	Vertical flatness (V)	≤0,3 mm	2 m[e]	≤0,4 mm	1,5 m[e]	
	Horizontal flatness (H)	≤0,6 mm	2 m[e]	≤0,6 mm	1,5 m[e]	

Table 5 *(continued)*

Location/Dimensional properties		Class A[e] d	Class A[e] L	Class B d	Class B L	
Body[a,c]	Vertical flatness (V)	≤0,3 mm and ≤0,2 mm	3 m[e] 1 m[e]	≤0,4 mm and ≤0,3 mm	3 m[e] 1 m[e]	
	Horizontal flatness (H)	≤0,45 mm	1,5 m[e]	≤0,6 mm	1,5 m[e]	
Sweep (whole rail)	Upsweep and downsweep	10 mm[g]		10 mm[g]		
Twist	Whole rail	Maximum gap of 2,5 mm				See 6.2 and Figure 13
	End (1 m)	Maximum rotational twist of 0,2° and maximum relative twist of 0,003 5 × *c*				See 6.2 and Figure 14

a

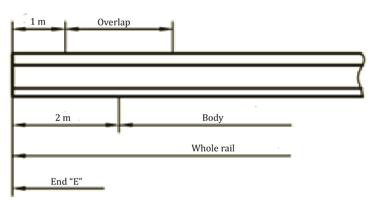
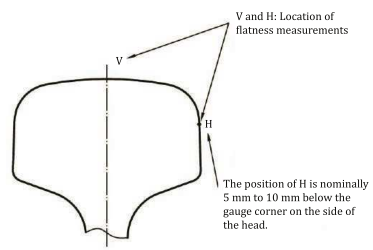


Table 5 *(continued)*

Location/Dimensional properties	Class A[e]		Class B		
	d	L	d	L	

b



c 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.

d 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.

e 95 % of delivered rails shall be within limits specified, with 5 % of rails allowed outside the tolerances by 0,1 mm.

f Reference L sliding over end E.

g 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.

7 Technical requirements

7.1 Manufacturing methods

7.1.1 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.

7.1.2 The manufacturer shall operate a procedure for the effective removal of scale during the rolling process.

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

7.1.4 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. End deviations or a localized deviation on the rail may be corrected using pressing.

7.2 Chemical composition

7.2.1 General

The liquid chemical composition shall fulfil the requirements of Tables 6 and 7, and liquid residual elements shall fulfil the requirements of Table 8.

The content of nitrogen shall not exceed 90 × 10^{-4} % in the liquid for all steel grades.

Table 6 — Chemical composition of as-rolled (HR) rails (in mass %)

Steel grade	C	Si	Mn	P max.	S max.	Cr	Al_t max.	V
HR200	0,40–0,60	0,15–0,58	0,70–1,20	0,035	0,025	≤0,15	0,004	≤0,030
HR220	0,50–0,60	0,20–0,60	1,00–1,25	0,025	0,025	≤0,15	0,004	≤0,030
HR235	0,63–0,75	0,15–0,30	0,70–1,10	0,030	0,025	≤0,15	0,004	≤0,030
HR260A	0,62–0,80	0,15–0,58	0,70–1,20	0,025	0,025	≤0,15	0,004	≤0,030
HR260B	0,55–0,75	0,15–0,60	1,30–1,70	0,025	0,025	≤0,15	0,004	≤0,030
HR280	0,71–0,80	0,50–0,80	0,70–1,05	0,025	0,025	≤0,15	0,004	0,04–0,12
HR310A	0,74–0,86	0,10–0,60	0,75–1,25	0,020	0,020	≤0,30	0,004	≤0,030
HR310B	0,72–0,82	0,10–0,50	0,80–1,10	0,020	0,020	0,25–0,40	0,004	≤0,030
HR320	0,60–0,80	0,50–1,10	0,80–1,20	0,020	0,025	0,80–1,20	0,004	≤0,18
HR325	0,72–0,82	0,10–1,00	0,70–1,25	0,020	0,020	0,40–0,70	0,004	≤0,030

Table 7 — Chemical composition of heat-treated (HT) rails (in mass %)

Steel grade	C	Si	Mn	P max.	S max.	Cr	Al_t max.	V
HT320	0,72–0,82	0,10–0,55	0,70–1,10	0,030	0,020	≤0,20	0,004	≤0,030
HT330	0,72–0,82	0,10–0,65	0,80–1,20	0,030	0,020	≤0,25	0,004	≤0,030
HT340	0,71–0,80	0,50–0,80	0,70–1,05	0,025	0,020	≤0,15	0,004	0,04–0,12
HT350A	0,72–0,80	0,15–0,58	0,70–1,20	0,020	0,025	≤0,15	0,004	≤0,030
HT350B	0,72–0,80	0,15–0,58	0,70–1,20	0,020	0,025	≤0,30	0,004	≤0,030
HT370A	0,74–0,86	0,10–0,60	0,75–1,25	0,020	0,020	≤0,30	0,004	≤0,030
HT370B	0,72–0,82	0,10–1,00	0,70–1,25	0,020	0,020	0,40–0,70	0,004	≤0,030
HT370C	0,70–0,82	0,40–1,00	0,70–1,10	0,020	0,020	0,40–0,60	0,004	≤0,030
HT400	0,90–1,05	0,20–0,60	1,00–1,30	0,020	0,020	≤0,30	0,004	≤0,030

Table 8 — Maximum residual elements (%)

Steel grade	Nb	Mo	Cu	Ni	Sn	Sb	Ti	Cu+10Sn	others
HR200, HR220 HR235, HR260A, HR260B	0,01	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,35 (Cr+Mo+Ni+Cu+V)
HR280	0,01	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,35 (Cr+Mo+Ni+Cu)
HR310A	0,01	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,20 (Mo+Ni+Cu+V)
HR310B, HR325	0,01	0,02	0,40	0,15	0,030	0,020	0,025	–	–
HR320	0,01	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,16 (Ni+Cu)
HT320, HT330, HT350B HT370A, HT370C, HT400	0,04	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,20 (Mo+Ni+Cu+V)
HT340	0,04	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,35 (Cr+Mo+Ni+Cu)
HT350A	0,04	0,02	0,15	0,10	0,030	0,020	0,025	0,35	0,25 (Cr+Mo+Ni+Cu+V)
HT370B	0,04	0,02	0,40	0,15	0,030	0,020	0,025	–	–

7.2.2 The solid chemical composition tolerances shall conform to the requirements of Table 9.

Table 9 — Solid chemical composition tolerance on the upper and lower limits (%)

Elements	Under (Minimum)	Over (Maximum)
C	0,02	0,02
Si	0,02	0,02
Mn	0,05	0,05
P	–	0,005
S	–	0,005
N	–	0,001
Cr[a]	0,03	0,03
V[b]	0,02	0,02

[a] This is suitable only for HR310B, HR320, HR325, HT370B, and HT370C.

[b] This is suitable only when V content in liquid steel is greater than or equal to 0,04 %.

NOTE Tolerance beyond limits of specified chemical composition.

7.2.3 For all grades other than HT370C and HT400, the hydrogen contents of the liquid steel shall not exceed 2,5 × 10^{-4} %, or the hydrogen contents of solid rails shall not exceed 2,0 × 10^{-4} %. For the grades of HT370C and HT400, the hydrogen contents of the liquid steel or solid rails shall not exceed 1,7 × 10^{-4} %.

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 these requirements, 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 these requirements; in these cases, all heats shall be tested in the rail form. In case of dispute, the hydrogen content shall be tested in the rail form.

If any test result after corrective treatment fails to meet these requirements the heat shall be rejected.

7.2.4 Total oxygen content of liquid steel or product rail shall not exceed 20 × 10^{-4} %.

For orders greater than 5 000 tons at least 95 % of samples shall have a total oxygen content of less than 20 × 10^{-4} %. No more than 5 % of samples shall have a total oxygen content of up to 30 × 10^{-4} %. Heats with samples having a total oxygen content greater than 30 × 10^{-4} % shall be rejected.

For orders less than 5 000 tons, only one sample with total oxygen greater than 20 × 10^{-4} %, but less than 30 × 10^{-4} %, is allowed. Heats with samples having a total oxygen greater than 30 × 10^{-4} % shall be rejected. Any heats with samples having a total oxygen above 20 × 10^{-4} % shall require that all subsequent heats be tested until values below 20 × 10^{-4} % are achieved.

7.3 Mechanical properties

The tensile strength, elongation and surface hardness of as-rolled and heat-treated rail shall meet the requirements as shown in Tables 10 and 11. The surface hardness shall not vary by more than 30 HBW on any individual rail.

The internal hardness of heat-treated rails shall meet the requirements as shown in Table 12.

Table 10 — Tensile strength, elongation and surface hardness of as-rolled (HR) rails

Steel grade	Tensile strength Rm (MPa)	Elongation A (%)	Surface hardness (HBW)
HR200	≥680	≥14	200–240
HR220	≥770	≥12	220–260
HR235	≥800	≥10	235–275
HR260A, HR260B	≥880	≥10	260–300
HR280	≥980	≥10	280–320
HR310A, HR310B	≥980	≥9	310–350
HR320	≥1 080	≥9	320–360
HR325	≥1 080	≥8	325–365

Table 11 — Tensile strength, elongation and surface hardness of heat-treated (HT) rails

Steel grade	Tensile strength Rm (MPa)	Elongation A (%)	Surface hardness (HBW)
HT320	≥1 080	≥10	320–375
HT330	≥1 130	≥10	330–390[a]
HT340	≥1 175	≥10	340–400[b]
HT350A, HT350B	≥1 175	≥9	350–390 [a]
HT370A, HT370B	≥1 175	≥9	370–410 [c]
HT370C	≥1 280	≥9	370–410[c]
HT400	≥1 280	≥9	400–440[d]

[a] If the hardness exceeds 390 HBW, the rail is acceptable provided the microstructure is confirmed to be pearlitic, and the hardness does not exceed 405 HBW.

[b] If the hardness exceeds 400 HBW, the rail is acceptable provided the microstructure is confirmed to be pearlitic, and the hardness does not exceed 415 HBW.

[c] If the hardness exceeds 410HBW, the rail is acceptable provided the microstructure is confirmed to be pearlitic, and the hardness does not exceed 425 HBW.

[d] If the hardness exceeds 440HBW, the rail is acceptable provided the microstructure is confirmed to be pearlitic, and the hardness does not exceed 455 HBW.

Table 12 — Internal hardness of heat-treated (HT) rails

Steel grade	Internal hardness (HBW)			
	Point 1	Point 2	Point 3	Point 4
HT320	≥321	≥311	≥301	≥321
HT330	≥331	≥321	≥311	≥331
HT340	≥331	≥321	≥311	≥331
HT350A, HT350B	≥340	≥331	≥321	≥340
HT370A, HT370B	≥350	≥341	≥331	≥350
HT370C	≥360	≥350	≥340	≥360
HT400	≥390	≥380	≥370	≥390

7.4 Microstructure

For HR200, HR220, HR235, HR260A and HR260B, the microstructure shall be pearlitic, but grain boundary ferrite may occur. For other grades, the microstructure shall be fully pearlitic.

All grades including heat-treated grades, the microstructure shall be with no martensite, bainite or grain boundary cementite.

7.5 Decarburization

Where decarburization is assessed metallographically, the depth of continuous ferrite networks as assessed according to ISO 3887 shall not exceed 0,5 mm measured on the rail head surface.

Where decarburization is assessed by the hardness method, the minimum hardness measured at the centre of the rail crown shall not be more than 7 HBW below the minimum bulk hardness for the grade tested.

7.6 Non-metallic inclusions

If the method shown in Annex C is applied, the total index K3 shall comply with:

— 10 < K3 ≤ 20 for a maximum of 5 % of samples;

— K3 ≤ 10 for a minimum of 95 % of samples.

For orders less than 5 000 tons, only one sample with a K3 greater than 10 and less than or equal to 20 is allowed.

If alternative methods are used (see 5.9), the following limits shall apply.

— If the method of ISO 4967 is applied, the non-metallic inclusions of rails shall comply with the requirements of Table 13 according to the information on the class applied as given by the purchaser [see Clause 4 d)].

Table 13 — Non-metallic inclusions assessment according to ISO 4967

Type	Class 1	Class 2
A	≤2.0	≤2,5
B	≤1,5	≤2,0
C	≤1,5	≤2,0
D	≤1,5	≤2,0

— In ASTM E45, Method A, each individual metallographic sample shall have a maximum average rating of 2 and a maximum individual rating of 3 for any inclusion type, thin or heavy.

7.7 Macrostructure

The transverse macrostructures of acid etch rail test pieces shall comply with the requirements of Annex H (see ISO 4969) or Annex I (see ISO 4968).

7.8 Ultrasonic test

All rails shall be ultrasonically tested by a continuous process ensuring that the entire rail length and specified cross-sectional area are inspected. Rails giving signals exceeding the threshold in the rail using the increased sensitivity shall be rejected or cut back to remove the defective portion.

7.9 Surface quality

7.9.1 All rails shall be visually or automatically inspected on all faces for surface imperfections. All rails shall comply with the criteria defined in 7.9.2 through 7.9.5. Assessment and dressing of imperfections shall be in accordance with 7.9.6.

7.9.2 The rail surface shall be free of cracks, when assessed by visual inspection.

7.9.3 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.

7.9.4 The depth of hot marks and seams shall not exceed

— 0,35 mm for the running surface, and

— 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 and may be removed by dressing. On the running surface a maximum of three marks per 40 m is allowed. Statements concerning dressing are given in 7.9.6.

7.9.5 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, and

— 0,5 mm for the rest of rail.

7.9.6 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, provided 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, and

— 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 3 and flatness tolerances shall be in accordance with Table 5.

7.9.7 Any sign of surface microstructural damage resulting in martensite or bainite shall be dressed or the rail rejected.

7.10 Residual stress

The maximum longitudinal residual stress in the foot shall not be greater than 250 MPa for all steel grades.

7.11 Fracture toughness

The value of K_{Ic} shall comply with Table 14.

Table 14 — Minimum single and minimum mean values of K_{Ic}

Steel grades	Minimum single value K_{Ic} (MPa m$^{1/2}$)	Minimum mean value K_{Ic} (MPa m$^{1/2}$)
HR200, HR220, HR235	30	35
HR260A, HR260B, HR280 HR310A, HR310B	26	29
HR320, HR325	24	26
HT320, HT330, HT340	26	29
HT350A	30	32
HT350B, HT370A, HT370B HT370C, HT400	26	29

NOTE In some circumstances K^*_Q values can be used, see F.5.

7.12 Fatigue crack growth rate

Fatigue crack growth rates (m/Gc) shall not exceed the values given in Table 15.

Table 15 — Fatigue crack growth rates

Steel grade	ΔK = 10 MPa·m$^{1/2}$	ΔK = 13,5 MPa·m$^{1/2}$
All grades except HR200 and HR320	17 m/Gc	55 m/Gc

7.13 Fatigue test

For a total strain amplitude of 0,001 35, the fatigue life of each specimen shall be greater than 5×10^6 cycles.

NOTE Life is defined as the number of cycles up to the complete separation of the specimen.

8 Inspection requirements

8.1 Inspection and acceptance

The inspection and acceptance tests shall be the responsibility of the manufacturer.

8.2 Retest and justification

When the initial test results failed to comply with the requirements, retest and justification shall comply with the following requirements.

If any test result fails to meet the requirements, this rail should be rejected. Further tests shall be performed on samples from two other rails from the same heat. These samples should be representative of the cast and rolling batch and should be from separate caster strands. If the results of both retests are in accordance with the specification requirements, the remaining rails from this heat shall be accepted.

Should be either retest fail to meet the specification requirements, then rails from this heat and batch shall be either rejected or re-heat treated depending on the specification.

Alternatively, rails from this heat and batch may be accepted on the basis that acceptable results are obtained by testing the individual rails to be supplied.

9 Identification

9.1 Branding

Brand marks shall be rolled in relief on one side and in the middle of the web 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 30 mm high, raised between 0,5 mm and 1,5 mm.

The brand marks shall include

a) the identification of the mill,

b) the rail profile identification,

c) the steel grade,

d) the last two figures of the year of manufacture.

The order of the information given in a) to d) shall be given by the manufacturer.

9.2 Hot stamping

In addition to the branding requirements of 9.1, 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 10 m.

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 15.

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

a) number of the heat from which the rail has been rolled,

b) number of the strand and position of bloom within the strand, and

c) position of the rail in the bloom (A, B ... Y).

9.3 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.

9.4 Other identification

9.4.1 The brand marks or hot stamping on the web can also be identified by the manufacturer and the purchaser.

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

9.4.3 The rail shall not be delivered when no marks are present or marks cannot be clearly identified.

9.4.4 Painting of rail identification shall be agreed by the purchaser and the manufacturer.

10 Certification

When specified in the purchase order or contract, a certificate shall be furnished, including the following information:

a) name of the manufacturer;

b) name of the purchaser;

c) rail profile(s);

d) contract number;

e) number of this International Standard, i.e. ISO 5003;

f) steel grade(s);

g) quantity and length of the rail;

h) heat;

i) date of issue;

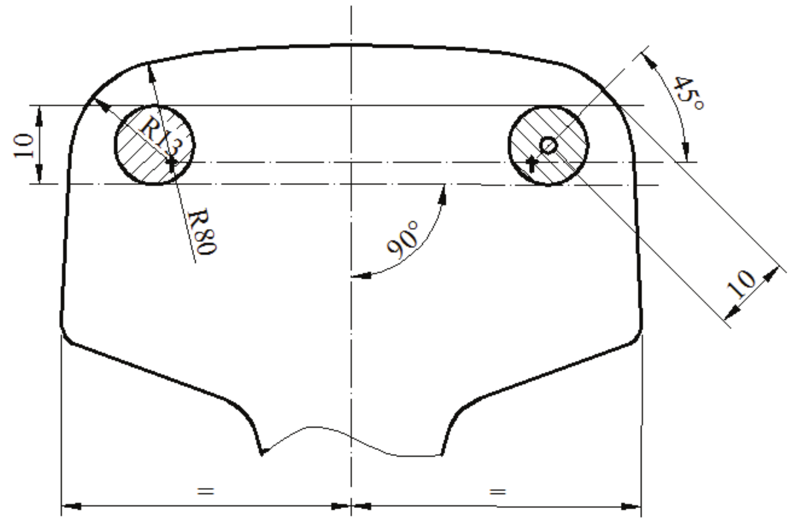
j) all the test results specified in 7.2 to 7.7.

The issue of a certificate according to this International Standard confirms compliance with all technical requirements of the standard.

11 Quality assurance system

A quality system shall be applied by the supplier.

Dimensions in millimetres



Key

- ✝ intersecting point of the *R*13 and *R*80 radii (60E1 section)
- o location at the centre of the tensile test piece
- ▨ area to be checked for microstructure

Figure 1 — Location of tensile test piece and microstructure checks

Dimensions in millimetres

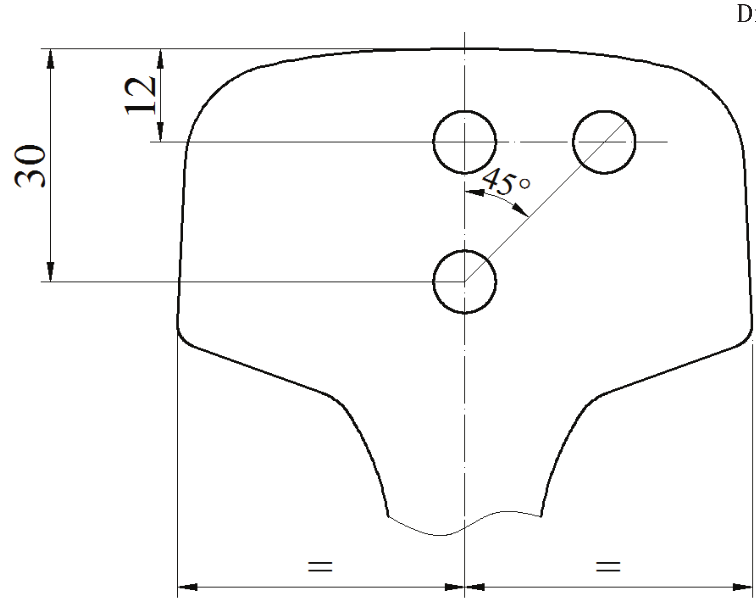
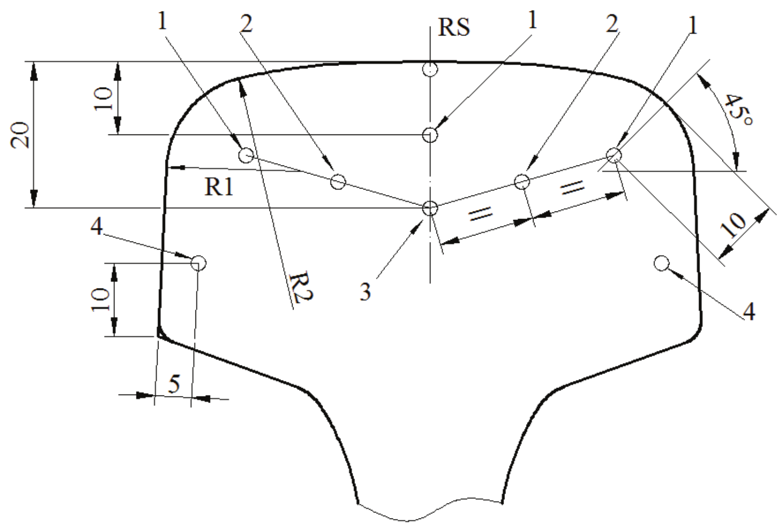


Figure 2 — Sampling positions in rail for total oxygen determination

Dimensions in millimetres

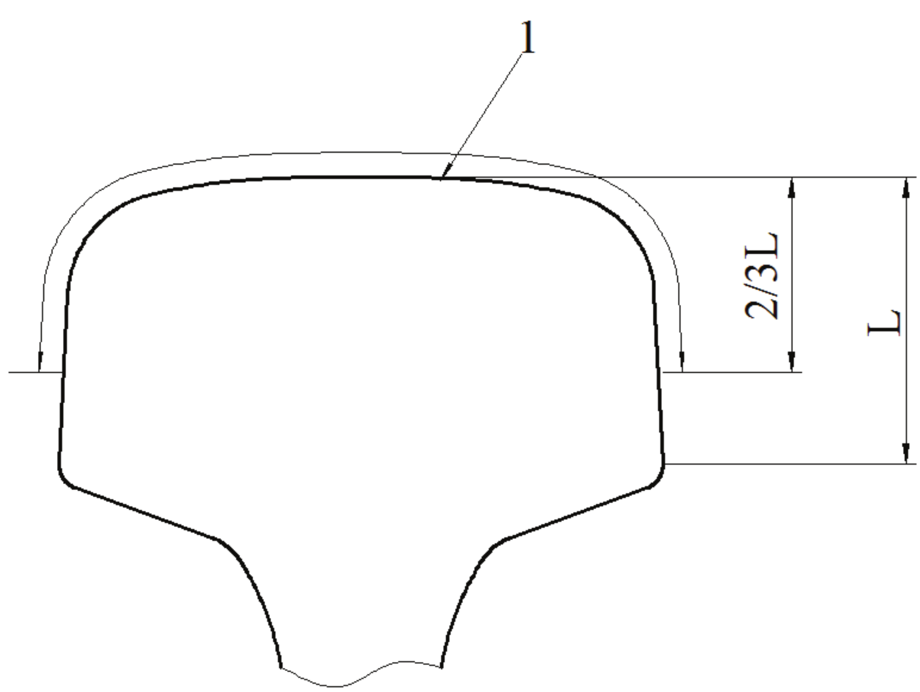


Key

1, 2, 3, and 4 location of hardness testing (see Table 12)

● exact intersection points of the radii

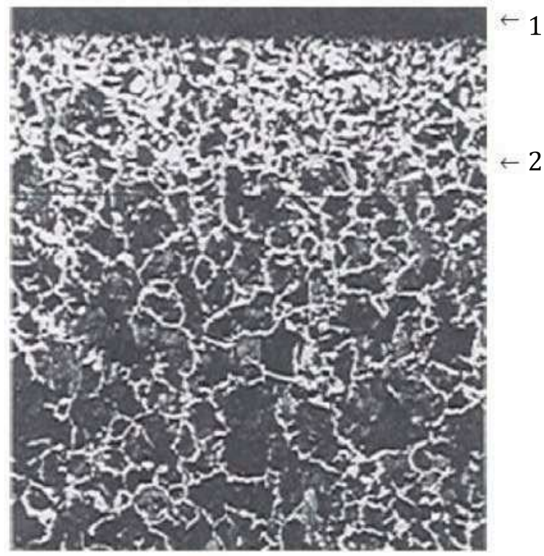
Figure 3 — Hardness testing positions



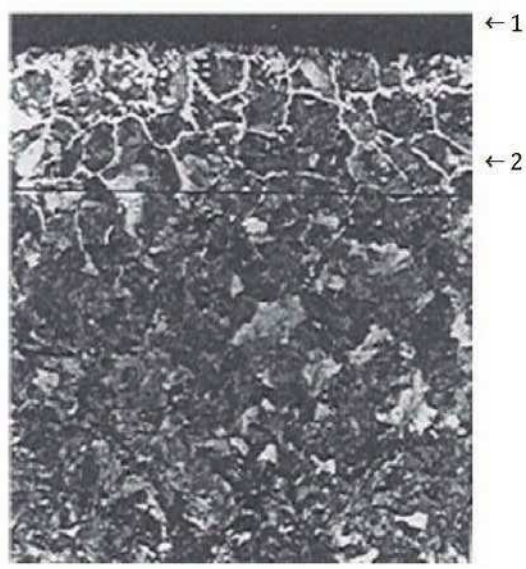
Key

1 decarburization limits apply to this part of rail head

Figure 4 — Range of extent of rail head surface for decarburization checks



a) Grades HR200 and HR220



b) All grades other than Grades HR200 and HR220

Key

1 surface of rail

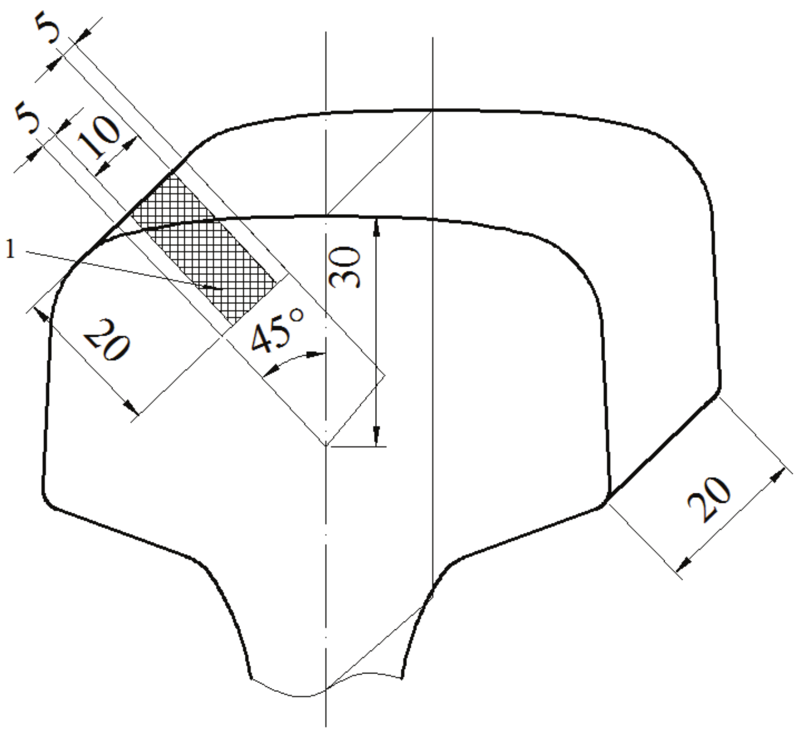
2 limit of continuous ferrite network

NOTE 1 Figure 5 a) shows decarburization to a depth of 0,28 mm.

NOTE 2 Figure 5 b) shows decarburization to a depth of 0,25 mm.

Figure 5 — Photomicrographs (100x) showing examples how to determine the depth of decarburization allowed on the rail wear surface

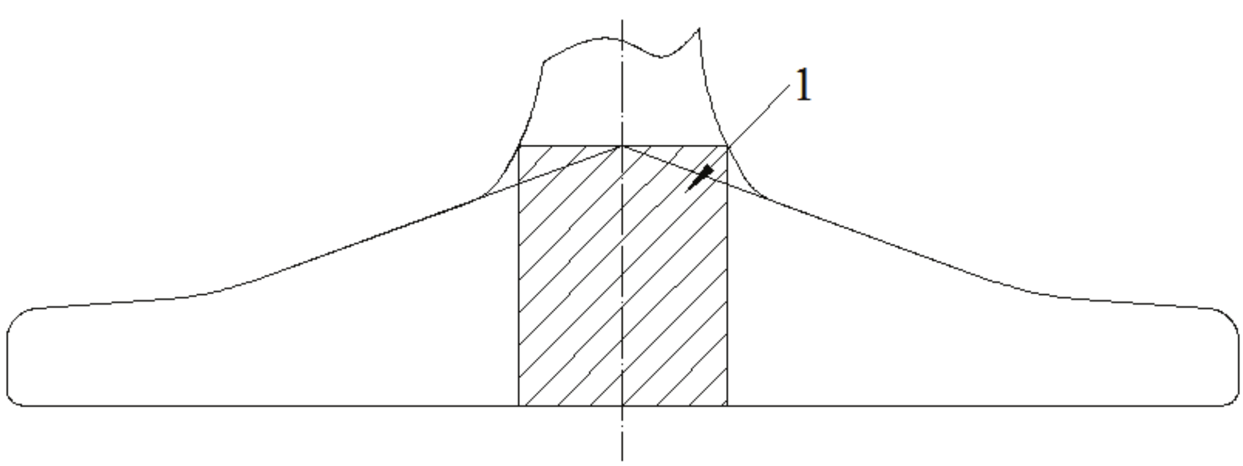
Dimensions in millimetres



Key

1 face to be examined

Figure 6 — Non-metallic inclusions sampling position in rail head

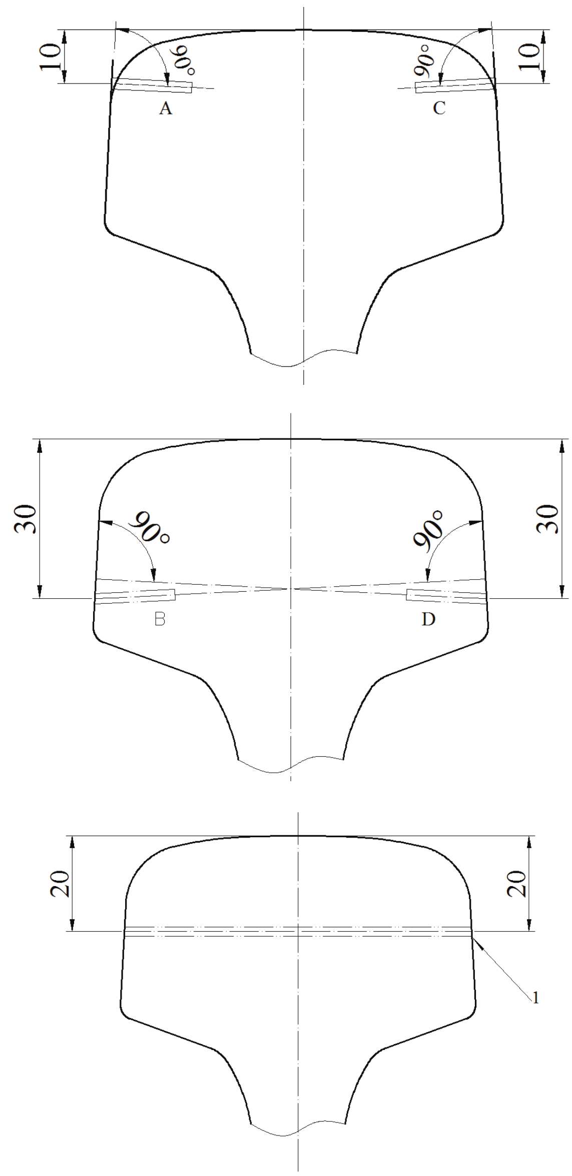


Key

1 area to be tested

Figure 7 — Area to be tested in rail foot of 60E1 profile

Dimensions in millimetres



Key

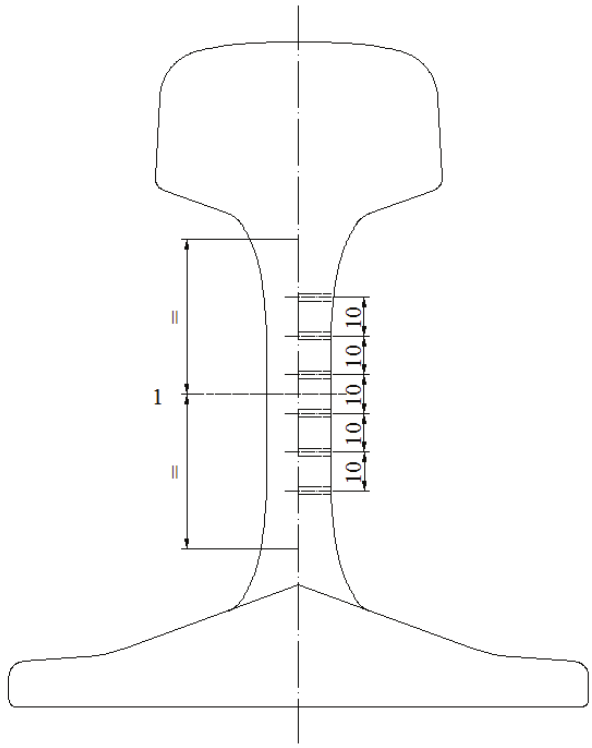
A, B, C, D flat bottom holes

1 2 mm diameter through hole

NOTE Flat bottomed holes are 2 mm in diameter and 15 mm deep.

Figure 8 — Location of artificial defects in rail head of 60E1 profile

All dimensions in millimetres measured from the centreline



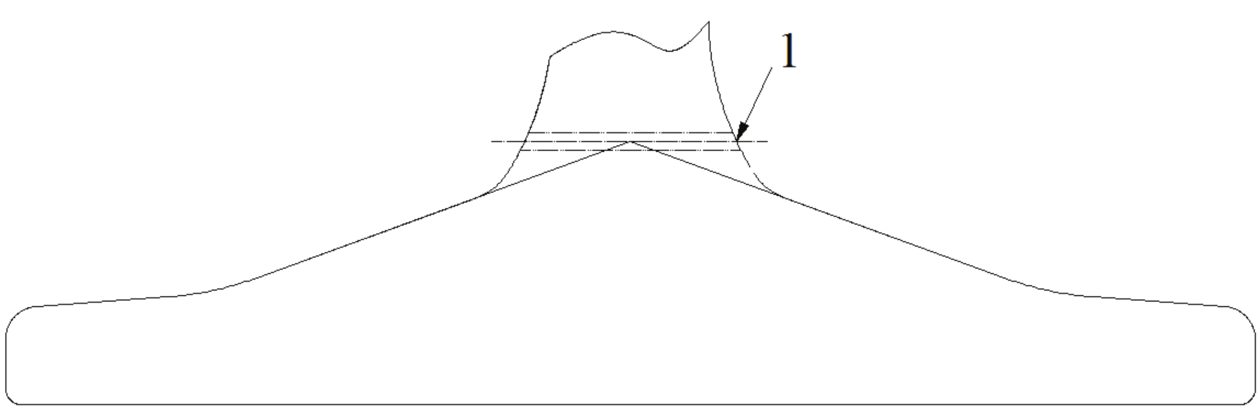
Key

1 centreline of web

NOTE 1 Flat bottomed holes are 2 mm in diameter drilled through the centreline of the web.

NOTE 2 Flat bottomed holes are allowed to be ±1° from horizontal.

Figure 9 — Location of artificial defects in rail web of 60E1 profile

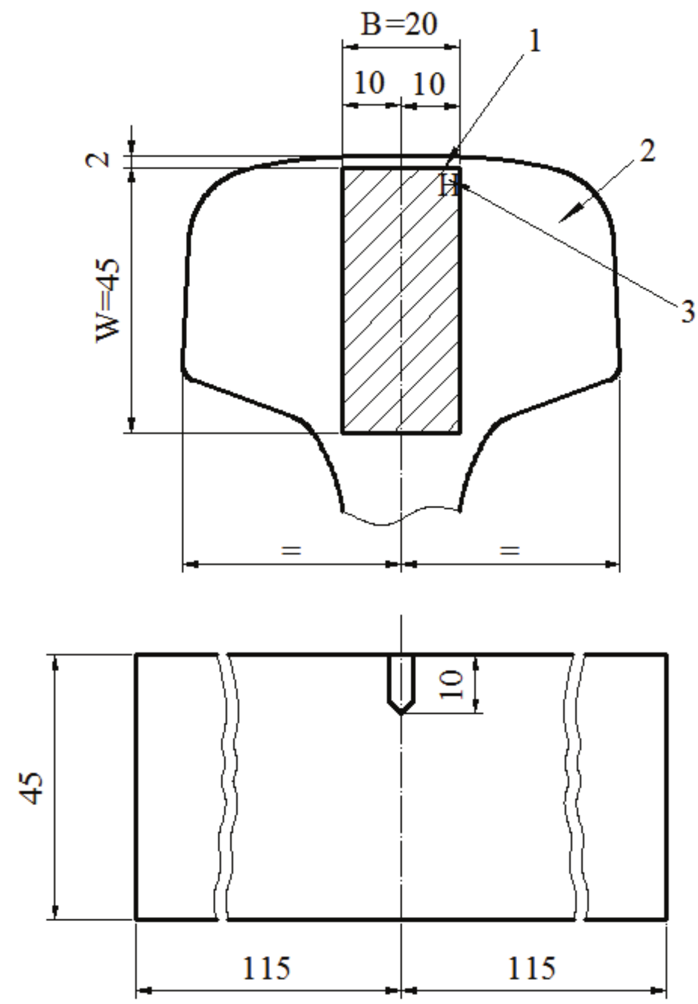


Key

1 2 mm diameter through hole

Figure 10 — Location of artificial defect in rail foot of 60E1 profile

Dimensions in millimetres



Key

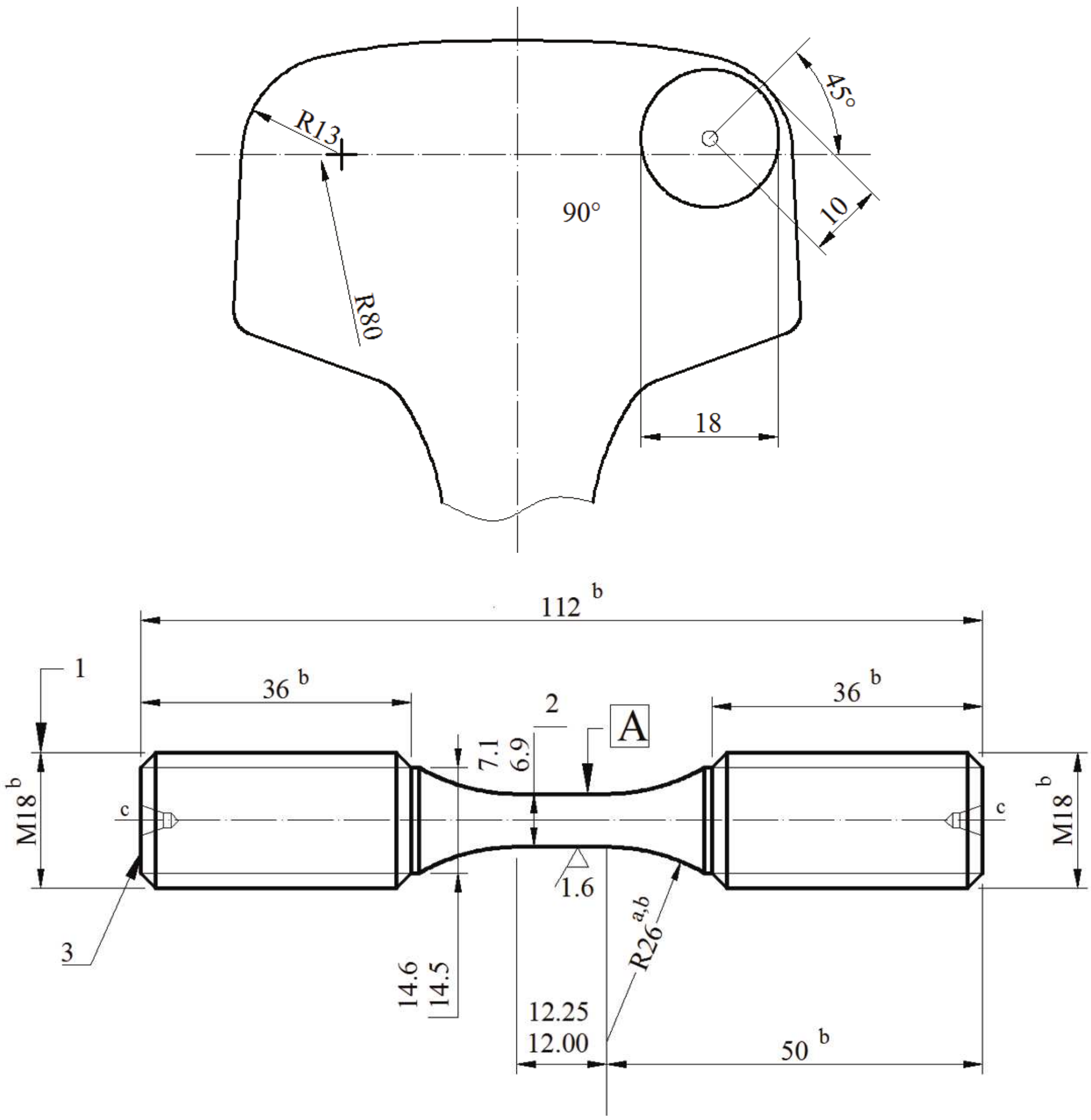
1 notch machined into this face

2 section through rail head

3 letter “H” to be stamped on end face of test piece as shown

Figure 11 — Location and dimensions of fatigue crack growth test pieces

Dimensions in millimetres



Key

✝ intersecting point of the *R*13 and *R*80 radii (60 E1 section)

○ location of the centre of the test piece

1 screw threads (both ends) to be concentric with Ø *A* within 0,005 mm

2 cylindrical within 0,005 mm

3 centre drill

a 26 mm radius shall run tangential with gauge diameter (datum dia "*A*") without undercutting or leaving a shoulder.

b General tolerance to be ±0,2 mm unless otherwise stated.

c Specimen to be identified on each end.

NOTE Different forms of screw threads (without threaded heads of test pieces) may also be used.

Figure 12 — Specimen for determining fatigue initiation life

Dimensions in millimetres

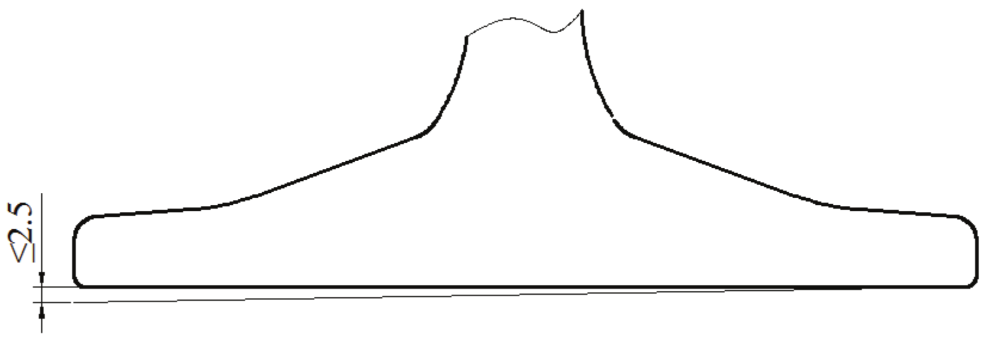
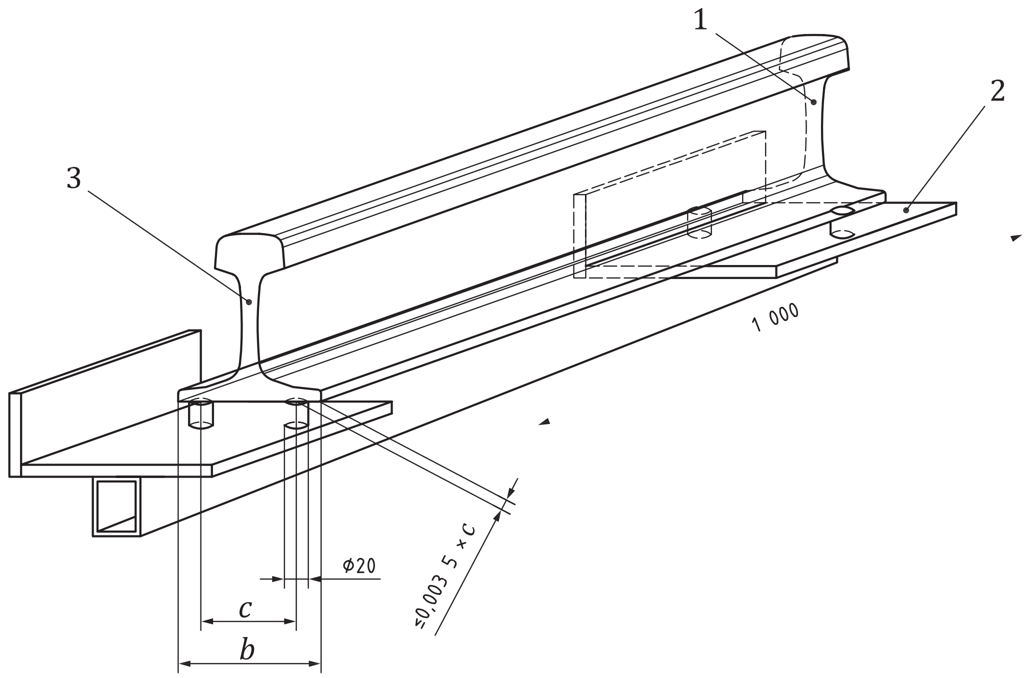


Figure 13 — Whole rail twist

Dimension in millimetres



Key

1 cross-section 1 m away from the rail end

2 gauge

3 cross-section at the rail end

Foot width *b*	Distance between contacts[a] *c*
$b < 130$	90
$130 \leq b < 150$	110
$b \geq 130$	130

[a] Diameter of contact surfaces: 20 mm.

NOTE The relative twist between the cross-sections at the rail ends, and the cross-sections 1 m away from each end should be measured with a specific gauge (1 m long) on each rail end, using points on the under surface of the foot as measuring references, as explained above.

Figure 14 — Rail end twist

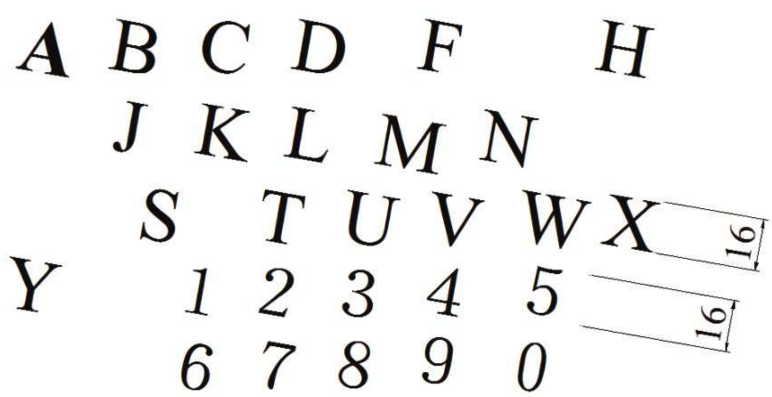


Figure 15 — Design of letters and numbers on a 10° angle for rail stamps

Annex A
(normative)

Steel grades

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

Table A.1 — Steel grades

Steel grade[a,b]	Hardness range (HBW)	Description
HR200	200–240	Non-alloy (C-Mn) Non-heat-treated
HR220	220–260	Non-alloy (C-Mn) Non-heat-treated
HR235	235–275	Non-alloy (C-Mn) Non-heat-treated
HR260A	260–300	Non-alloy (C-Mn) Non-heat-treated
HR260B	260–300	Non-alloy (C-Mn) Non-heat-treated
HR280	280–320	Micro-alloy (0,08 %V) Non-heat-treated
HR310A	310–350	Non-alloy (C-Mn) Non-heat-treated
HR310B	310–350	Alloy (0,35 %Cr) Non-heat-treated
HR320	320–360	Alloy (1 %Cr) Non-heat-treated
HR325	325–365	Alloy (0,55 %Cr) Non-heat-treated
HT320	320–375	Non-alloy (C-Mn) Heat-treated
HT330	330–390	Non-alloy (C-Mn) Heat-treated
HT340	340–400	Micro-alloy (0,08 %V) Heat-treated

[a] See Tables 6, 7 and 8 for chemical composition.

[b] See Tables 10 and 11 for mechanical properties.

Table A.1 *(continued)*

Steel grade[a,b]	Hardness range (HBW)	Description
HT350A	350–390	Non-alloy (C-Mn) Heat-treated
HT350B	350–390	Non-alloy (C-Mn) Heat-treated
HT370A	370–410	Non-alloy (C-Mn) Heat-treated
HT370B	370–410	Alloy (C-Mn) Heat-treated
HT370C	370–410	Alloy (C-Mn) Heat-treated
HT400	400–440	Non-alloy (C-Mn) Heat-treated

a See Tables 6, 7 and 8 for chemical composition.

b See Tables 10 and 11 for mechanical properties.

Annex B
(normative)

Method for determination of tensile strength and elongation for as-rolled rails by a correlation

B.1 Procedure

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.

B.2 Method

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.

The equations shall be created by carrying out one valid tensile test per heat. Tensile tests shall be carried out in accordance with 5.5 and 7.3.

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

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

— elongation: 1,0 % (1 standard deviation).

B.3 Confirmation of the predictive equation

The results of the predictive equations shall be compared with experimentally determined tensile strength and elongation results as described in 5.5 and 7.3. This comparison will be achieved by carrying out one valid tensile test every 2 000 tons.

The one standard deviation of the experimental results compared with the results obtained from the predictive equations shall be 12,5 MPa for the tensile strength and 1,0 % for the elongation.

B.4 Periodic updating of the predictive equation

The results of the experimental tensile strength and elongation tests 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 a minimum of the last 100 results.

B.5 Corrective action

If results from the predictive equations are outside the limits set in 7.3, then the following actions shall be taken.

a) Manufacturer carries out an investigation.

b) Manufacturer resolves the problem by taking appropriate corrective action.

c) Manufacturer reports its findings on actions a) and b).

If the results of an investigation 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.

Annex C
(normative)

Microscopic examination of rail steels using standard diagrams to assess the content of non-metallic inclusions

C.1 General

C.1.1 Degree of purity

The degree of purity (index K3) is a value indicating the content of non-metallic inclusions in the form of oxide inclusions in the product. The K3 index is a value indicating the content of such oxides by the determination of the percentage area of non-metallic inclusions in the structure, i.e. the sum obtained by counting inclusions weighted according to their area, starting from a specified size of inclusion upwards, and referred to an area of 1 000 mm^2.

C.1.2 Standard Diagram Plate No. 1

The standard Diagram Plate No. 1 is a set of diagrams constructed line by line on the basis of a 2n geometrical series for the area of non-metallic inclusions, containing forms of inclusion typical for steel, the inclusion area doubling from one diagram to the next in each column. Inclusions of equal area but differing in length × width or frequency are shown on the same line next to the basic column for each type of inclusion.

C.2 Preparation of specimens

In polishing the specimens, the inclusions shall not be torn out or be changed in their form and no particles of grinding or polishing agent shall be pressed into the polished surface. If necessary, the surface of the section has to be hardened. For this reason, the specimens are to be carefully ground and then polished for the shortest period of time as possible.

C.3 Structure and use of standard Diagram Plate No. 1

C.3.1 Use of Diagram Plate No. 1

Diagram Plate No. 1 (Figure C.1) includes three basic columns giving the most commonly observed shapes of inclusions designated by numbers 3, 6 and 8, each consisting of nine diagrams with inclusion rating numbers 0 to 8. The magnification to be used with the diagrams in Figure C.1 is 100:1.

NOTE The diameters of the circles in Figure C.1 corresponds to 0,8 mm on the sample surface.

The following types of inclusion are distinguished:

Inclusion type OA: oxide inclusions of fragmented type (aluminium oxides);

Inclusion type OS: oxide inclusions of elongated type (silicates);

Inclusion type OG: oxide inclusions of globular type.

The derived columns 2, 4, 5, 7 and 9 are described in C.3.2 and C.3.3.

The nine diagrams of a column with the rating numbers 0 to 8 show under rating number 0 the smallest microscopic inclusion that can be evaluated at a magnification of 100:1, and under rating number 8 in some cases inclusions that are already in the macroscopic range for the type of inclusion concerned. The area of the inclusions shown doubles from one diagram to the next, forming a 2n geometric series where n is the rating number.

The length of the inclusion to be considered increases from diagram to diagram by a factor of 1,5 with a simultaneous increase in the average inclusion width, thus conforming to the basic formula for the increase in area of the inclusions. The length, and in column 6 also the width, are marked in Figure C.1 in order to facilitate measurement. By the same width, the length of an oxide inclusion in case of OA inclusions is greater than the length of an inclusion in case of OS inclusions; otherwise the area would be different, for a given rating number.

Rating number 9 is reserved for macroscopic inclusions, which are not shown in diagrammatic form, because they would extend beyond the limits of the image field.

C.3.2 Rating a single inclusion

If, in the case of a single inclusion, for the same length, the width is only half that in the equivalent diagram of column 3 or 6, the area of the inclusion is also halved so that the rating number is therefore reduced by 1. This is represented by columns 2 and 5, each on the left of a basic column. Similar considerations apply for the evaluation of thicker inclusions with twice the area. In such cases, the rating number is to be increased by 1.

C.3.3 Rating of very small inclusions

If other non-metallic inclusions up to two rating numbers smaller are visible in the field under observation, the area of the inclusions within the circular sub-field again increases and the rating number is increased by 1 as in columns 4 and 7, on the right of basic columns.

C.4 Test procedure

C.4.1 Magnification

The polished surface of the specimens shall be observed using a microscope with a magnification of 100:1. See Figure C.1.

C.4.2 Selection of inclusions

For rating non-metallic inclusions in a field under observation it is necessary to determine the diagram in Figure C.1 corresponding to that observed. Only the inclusions with rating numbers equal or greater than 3 shall be considered.

C.4.3 Rating of inclusions extending the diameter of observation

For an evaluation on the basis of Figure C.1 (Diagram Plate No. 1), it is particularly important to note that for rating numbers 6, 7 and 8 of columns 2 to 6 there are some fields in which the length of the non-metallic inclusion to be considered extends beyond the diameter of the circular field to a certain extent. Non-metallic inclusions observed in such cases are to be rated on the basis of the inclusion length given below each diagram. Each larger inclusion (of the same or of greater thickness) than those shown has to be classified under rating number 9.

C.4.4 Rating of inclusions of different types and shapes

If inclusions of different types and shapes, as shown in the series of diagrams, can be clearly distinguished from each other within one field under observation, these shall be treated as though they had occurred separately in different fields.

C.4.5 Rating of continuous and isolated inclusions

Inclusions of types OS and, at a lower degree of fragmentation, OA, lying one behind another on one line shall be regarded as continuous if the distance between two inclusions is less than the length of the smaller of the two inclusions. Isolated point-shaped inclusions are not to be taken into account when determining the total length.

C.4.6 Area to be examined

The complete area (200 mm^2) of the polished surface of the specimens shall be examined.

C.5 Evaluation

C.5.1 General

C.5.1.1 Designation of inclusions

The non-metallic inclusions observed shall be designated (in the sequence indicated below and separated from each other by a point) in each case with the number of the diagram column concerned (type and shape of inclusion) and with the rating number as in Figure C.1, determined in accordance with the procedure described in C.3 and C.4, e.g. 5.3, 6.5.

It is not permitted to give fractions to indicate the inclusion rating (e.g. 2,5, 4 1/2).

C.5.1.2 Templates for documentation

Printed forms should preferably be used for recording the test results and their evaluation (e.g. as shown in Table C.2).

C.5.2 Method of evaluation

The polished section to be evaluated shall be 200 mm^2.

C.5.3 Calculation procedure for evaluation using method K

The calculation procedure for obtaining the total index is, for simplicity, based on the method of assigning the factor 1 to the most frequently determined rating number 4. The factors obtained on the basis of the 2^{n-4} geometric series for the other rating numbers are to be rounded so that, in the calculation, it is only necessary to double or halve the numbers. The resulting deviation in the calculation lies within the dispersion arising from the fact that non-metallic inclusions are not uniformly distributed in steel. With this procedure, the larger inclusions are more accurately evaluated.

Table C.1 gives the factors to be used in the calculations.

For calculation of the total indices the procedure is as follows (see also examples given in Table C.2): the number of non-metallic inclusions of each inclusion type (OA, OS, OG) and each rating number observed shall be multiplied by the appropriate factor (f_g, see Table C.1) and the products added. The “first subtotals“ obtained in this manner for each individual polished section are then to be added for the two specimens of the heat, thus producing a “second subtotal“ (in mm^2) for this heat. This result is then to be converted to a section area of 1 000 mm^2, using Formula (C.1):

$$K3 = SST * 1\,000 / TA \quad (C.1)$$

where

K3 is the total index of purity;

SST is the second subtotal (in mm^2);

TA is the total area of the polished sections of specimens (in mm^2).

The value obtained shall be rounded to integers.

This total index K3 represents the degree of purity of the heat examined.

Table C.2 gives an example of evaluation including a complete description of the evaluation conditions.

Table C.1 — Values of factor f_g to be used for the evaluation using method K

Rating number (n)	0	1	2	3	4	5	6	7	8	(9)[b]
Factor $F = 2^{n-4}$	1/16	1/8	1/4	1/2	1	2	4	8	16	32
Factor f_g[a] to be used for the evaluation	0,05	0,1	0,2	0,5	1	2	5	10	20	50

[a] $_g$ = rounded.

[b] See C.4.3.

Table C.2 — Example of evaluation using method K3, as described in C.5.3

Specimen No.	Area of polished section evaluated [mm^2]	Types of inclusion as in Diagram Plate No. 1 (Figure C.1)	Number of inclusions classified by rating number										Multiplication and first subtotal
			0	1	2	3	4	5	6	7	8	9	
			Factor $F = 2^{n-4}$										
			1/16	1/8	1/4	1/2	1	2	4	8	16	32	
			Factor f_g[a] to be used for the evaluation										
			0,05	0,1	0,2	0,5	1	2	5	10	20	50	
1	200	OA											
		OS				2							1
		OG											
2	200	OA											
		OS											
		OG				1	1						1,5
Total	400	Second subtotal:											2,5
		Total index K3 (rounded value = 6)[a]:											6

[a] TA = 400 mm^2 for the two samples per heat.

2,5 × 1 000/400 = 6,25

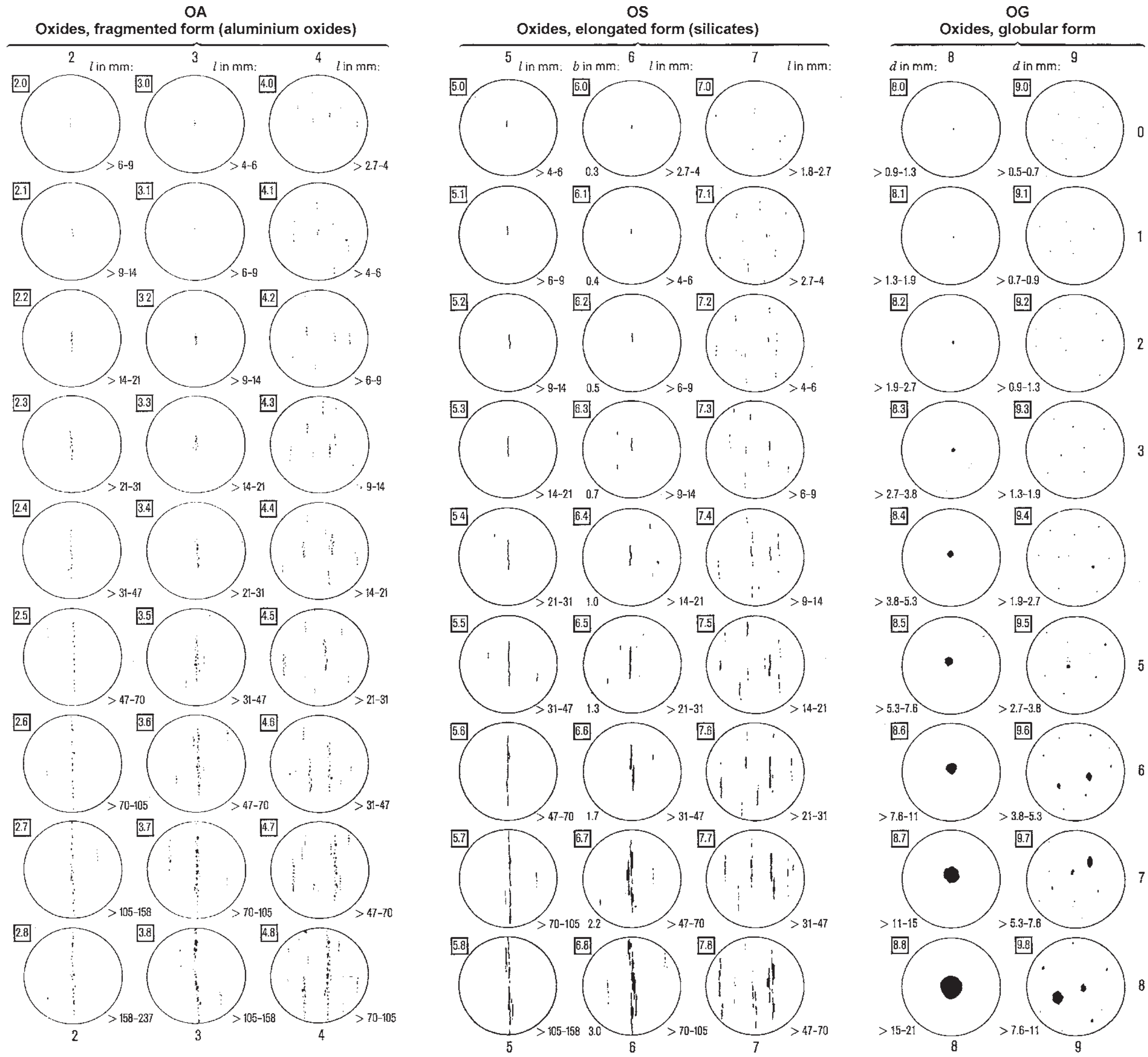


Figure C.1 — Diagram Plate No. 1: Diagrams for examining rail steels for non-metallic inclusions

Diagram Plate No. 1 (Figure C.1) shows the diagrams on a reduced scale of about one third of that of the original full-scale diagram plate. It can therefore only give an approximate indication of the original full-scale diagram plate.

For proper evaluation, the full-scale diagram plate should be used. This can be obtained from Beuth Verlag GmbH, D-10772 Berlin.

Annex D
(informative)

Rail profile

Rail profile 60E1 in the European Standard EN 13674-1:2011 is given for the purpose of positioning artificial defects of rail head, web and foot for ultrasonic testing.

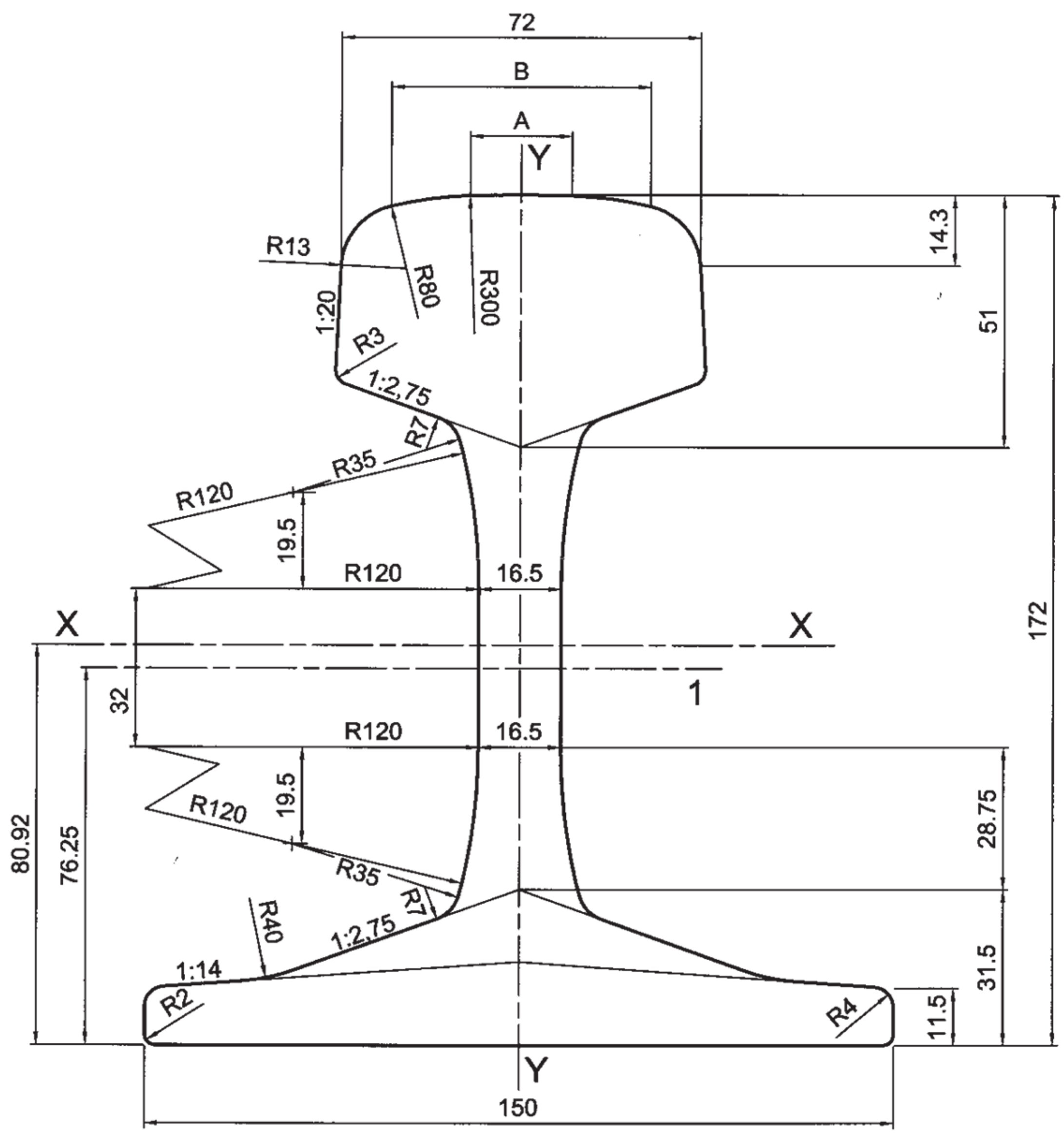


Figure D.1 — Rail profile 60E1

Annex E
(normative)

Method for the determination of rail foot surface longitudinal residual stresses

E.1 Procedure

Residual stresses shall be estimated by first attaching an electrical strain gauge on the rail foot surface. The surface to which the gauge is attached shall be progressively isolated from the rail and the relaxed strains shall then be used to estimate the stresses which have been relieved while the original residual stresses are taken to be those values but with a change of sign.

E.2 Strain gauges and their location

Electrical strain gauges of the encapsulated type shall be used, 3 mm in length with a gauge factor accuracy of better than ±1 %.

The strain gauge shall be attached to the surface of the rail foot in order to measure longitudinal strain at the positions as shown in Figure E.1. The surface of the rail foot shall be prepared and the strain gauge shall be attached, in accordance with the recommendations of the strain gauge manufacturer.

Any surface preparation shall not result in a change of the residual stresses in the rail foot.

The strain gauge should be located at the centre of the 1 m length of the sample rail set aside for this work.

Readings shall be taken from the strain gauges. While cooling the rail to maintain a constant temperature, two saw cuts shall be made to remove a 20 mm thick slice from the centre of the rail length (Figure E.2). A second set of readings from the strain gauges shall be taken after the second cut.

The residual stresses shall be calculated from the differences between the first set before and the second set of readings after relieving the strains by multiplying by $2{,}07 \times 10^5$ MPa.

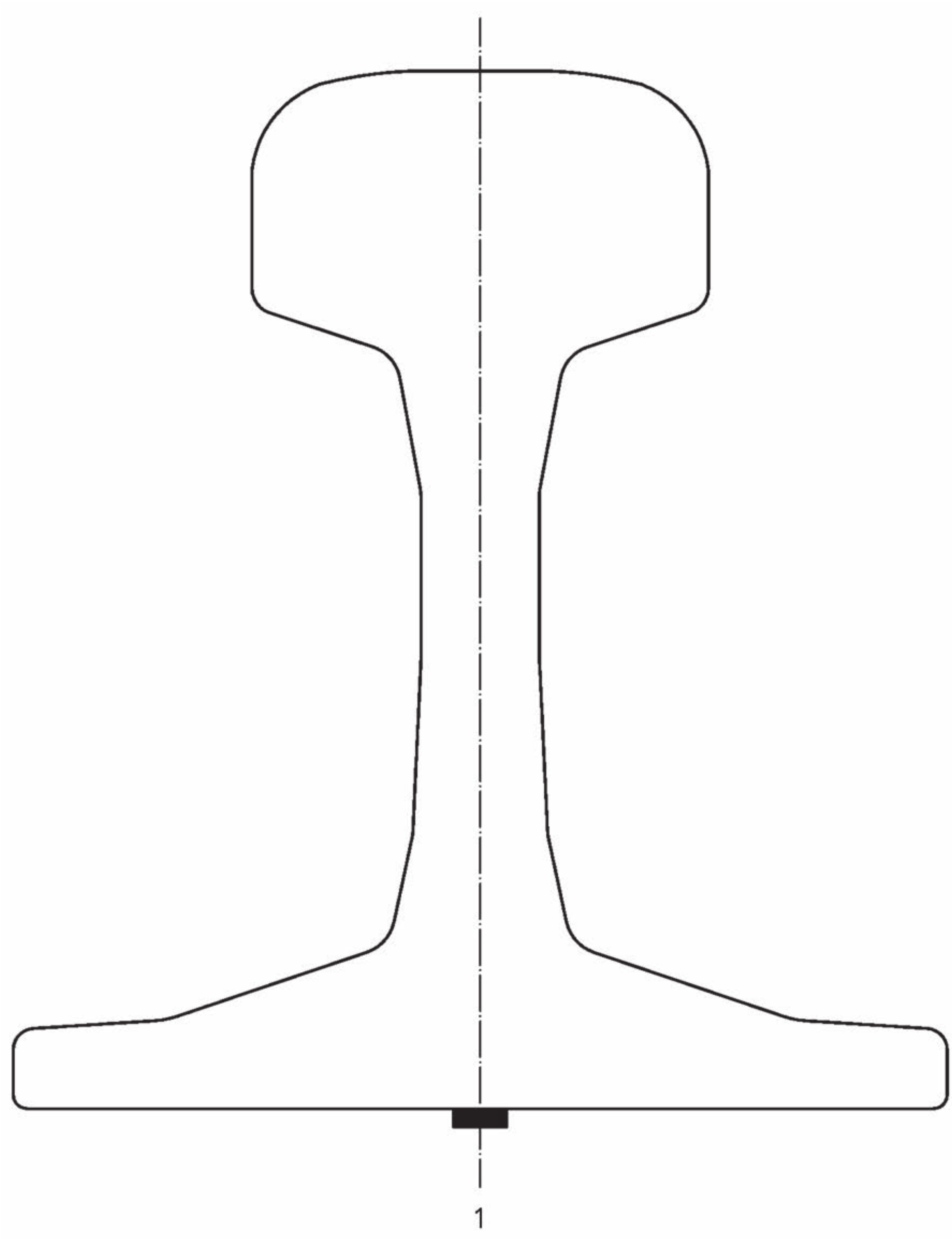


Figure E.1 — Location of strain gauge to measure rail foot surface longitudinal residual stresses

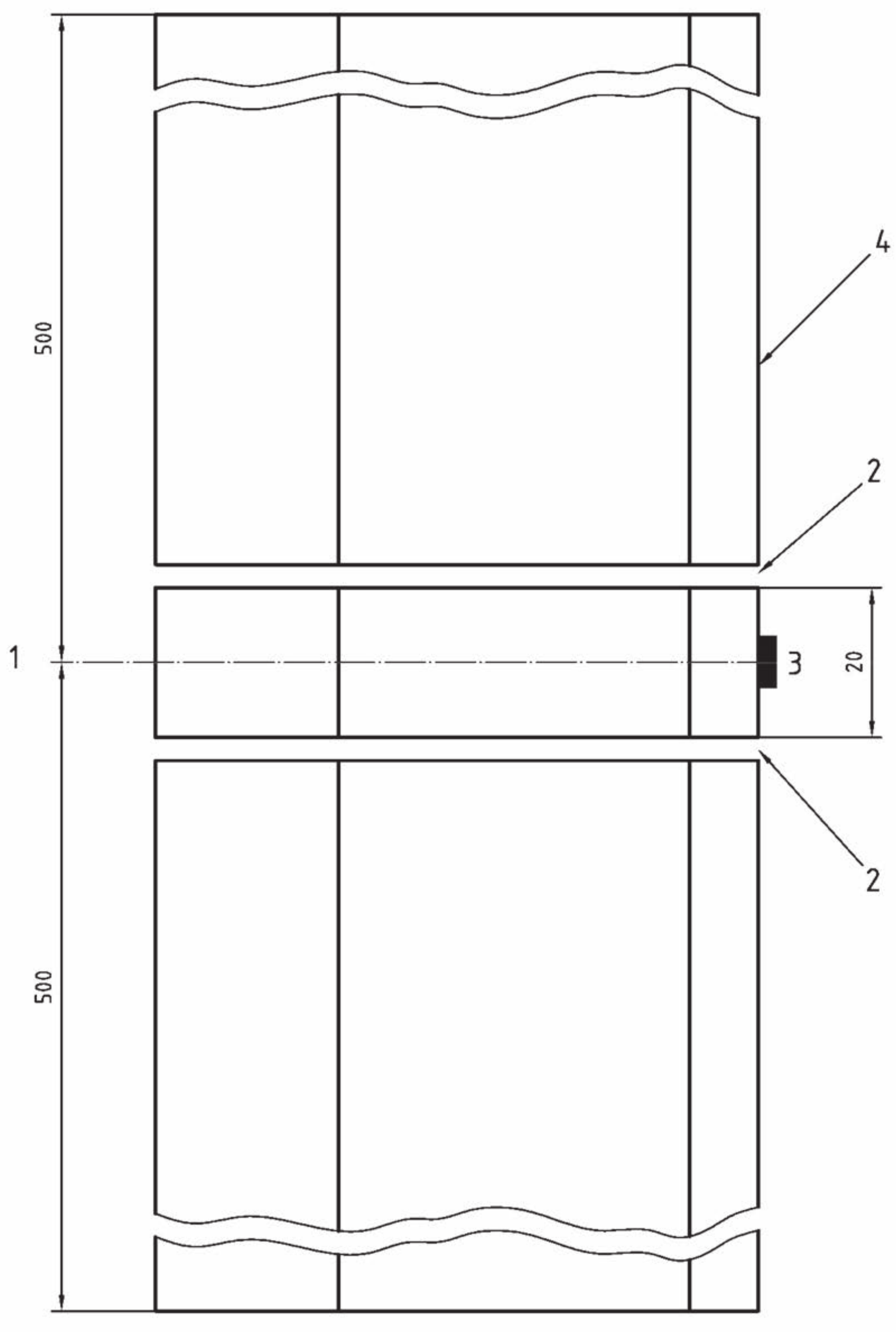


Figure E.2 — Slice removed from the rail

Annex F
(normative)

Standard test method for the determination of the plane strain fracture toughness (K_{Ic}) of rails

F.1 Test methods

This test shall be performed in accordance with the requirements of ASTM E399 except where superseded by the requirements specified in this International Standard. The requirements specified in this annex apply only to the determination of plane strain fracture toughness of railway rail steels covered by the definitions and requirements of this International Standard.

F.2 Test pieces

F.2.1 The location of the test piece in the rail's transverse section is shown in Figure F.1.

F.2.2 The thickness "B" of all test pieces shall be 25 mm. For any rail head transverse profile, the test piece width "*W*" shall be the maximum achievable of the following dimensions:

— 40 mm;

— 45 mm;

— 50 mm.

F.3 Test conditions

NOTE It is recommended that the chevron notch in ASTM E399 is used to avoid crack front curvature problems.

F.3.1 Fatigue pre-cracking shall be carried out in the temperature range between +15 °C to +25 °C, using a stress ratio in the range between 0 and +0,1. Fatigue pre-cracking shall be carried out at a cyclic frequency in the range between 15 Hz and 120 Hz. The final crack length to test piece width ratio shall be in the range between 0,45 to 0,55 and during the last 1,25 mm of crack growth K_{max}, shall be in the range between 18 MPa $m^{1/2}$ and 22 MPa $m^{1/2.}$

F.3.2 The single edge notched bend test piece shall be loaded under displacement control using three-point bending with a loading span (*S*) equal to four times the test piece width (*W*).

F.3.3 Tests shall be performed at a test temperature of −20 °C ±2 °C. Test piece temperature shall be measured using a beadless thermocouple, spot-welded to the test piece at the location shown in Figure F.2.

F.4 Analysis of test data

F.4.1 The calculation of K_Q shall be in accordance with ASTM E399. The checks made to establish whether this value is a valid K_{Ic} shall be in accordance with ASTM E399 except for the requirements of F.4.2 to F.4.6.

F.4.2 P_{max}/P_Q shall be less than 1,10 for force-crack mouth opening curves where pop-in does not occur before the intersection of the curve with the 95 % secant. There shall be no P_{max}/P_Q criterion for other types of curve.

F.4.3 The linearity of force-crack mouth opening curves Ia, Ib, IIa and III (see Figure F.3) shall be checked in the following manner:

— measure the distance (v_1) between the tangent OA and the force-crack mouth opening curve at a constant force of $0{,}8P_Q$;

— measure the distance (v) between the tangent OA and the force-crack mouth opening curve at a constant force of P_Q.

For a test result to be valid, $v_1 \leq 0{,}25v$.

F.4.4 The linearity of force-crack mouth opening curves IIb and IIc (see Figure F.3) shall be checked in the following manner:

— measure the distance between the tangent OA and the force-crack mouth opening curve at constant forces of $0{,}8P_Q$ and P_Q, recording these values as v_1* and v*, respectively;

— measure the crack mouth opening values arising from all “pop-ins” that occur up to P_Q. This is done by

  — measuring the horizontal distance travelled along the crack mouth opening axis between the start and finish of each “pop-in”, and

  — sum the values for “pop-ins” occurring below $0{,}8P_Q$ and for those occurring between $0{,}8P_Q$ and P_Q, recording them as Σv_{1pi} and Σv_{pi}, respectively.

For a test result to be valid, $[v_1^* - \Sigma v_{1pi}] \leq 0{,}25\ [v^* - (\Sigma v_{pi} + \Sigma v_{1pi})]$.

F.4.5 The linearity criterion cannot be applied to force-crack mouth opening curve IV.

F.4.6 For all force-crack mouth opening curves, the K_Q value shall be subjected to the validity check that the test piece thickness (B) and crack length (a) are equal to, or greater than, the value of $2{,}5\ (K_Q/R_{p0,2})^2$, where $R_{p0,2}$ is 0,2 % proof stress at the fracture test temperature of −20 °C.

F.5 Reporting of results

All measurements required to calculate the test result and to show that the test conditions were as specified in the test procedure shall be recorded.

All results shall be reported as either K_{Ic} values K^*_Q values or K_Q values; where K^*_Q values are those K_Q values which failed the validity criteria due only to one or more of the following:

a) $P_{max}/P_Q > 1{,}1$;

b) exceedance of the $2{,}5\ (K_Q\ /R_{p0,2})^2$ criterion;

c) crack mouth opening displacement-force relationship.

The mean and standard deviation of both K_{Ic} and K^*_Q results shall be recorded. For each grade of rail tested, these results shall be included in a table with the following information.

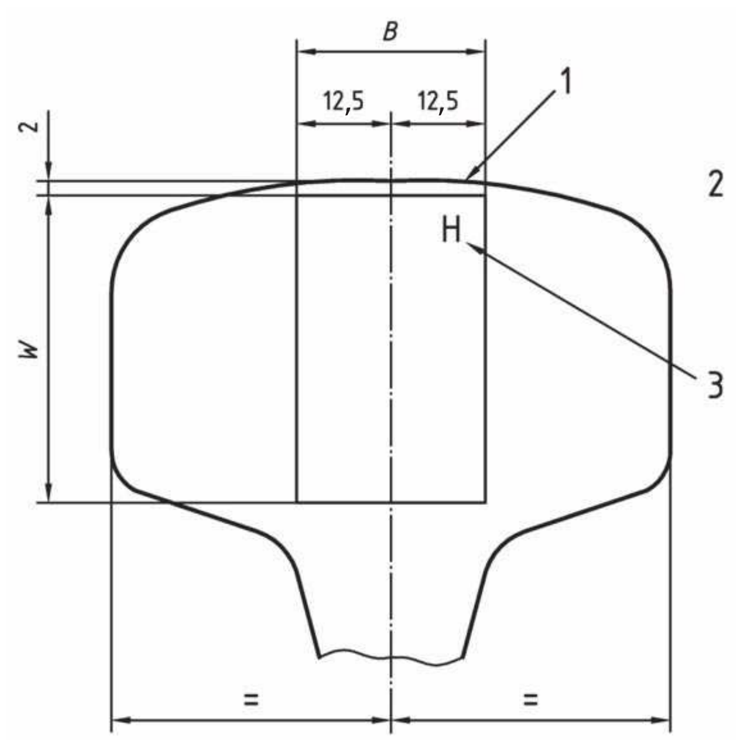
Steel Grade	0,2 % proof Strength at −20 °C (MPa)	Mean K_{Ic} (MPa m$^{1/2}$)	Number of K_{Ic} results	Sample standard deviation (MPa m$^{1/2}$)	Mean K_Q (MPa m$^{1/2}$)	Number of K_Q results	Sample standard deviation (MPa m$^{1/2}$)

The value to be used for the acceptance criteria is that of the mean K_{Ic} and shall be based on a minimum of five K_{Ic} values.

When five K_{Ic} values have not been obtained, any K^*_Q values shall be included with any K_{Ic} values in the mean value to be used for the acceptance criteria. In this event, the number of test results shall be at least 10.

All values of K_{Ic} and K^*_Q shall be above the minimum value specified in Table 14.

Dimensions in millimetres



Key

1 notch machined in this face

2 section through rail head

3 letter “H” to be stamped on end face of test piece as shown

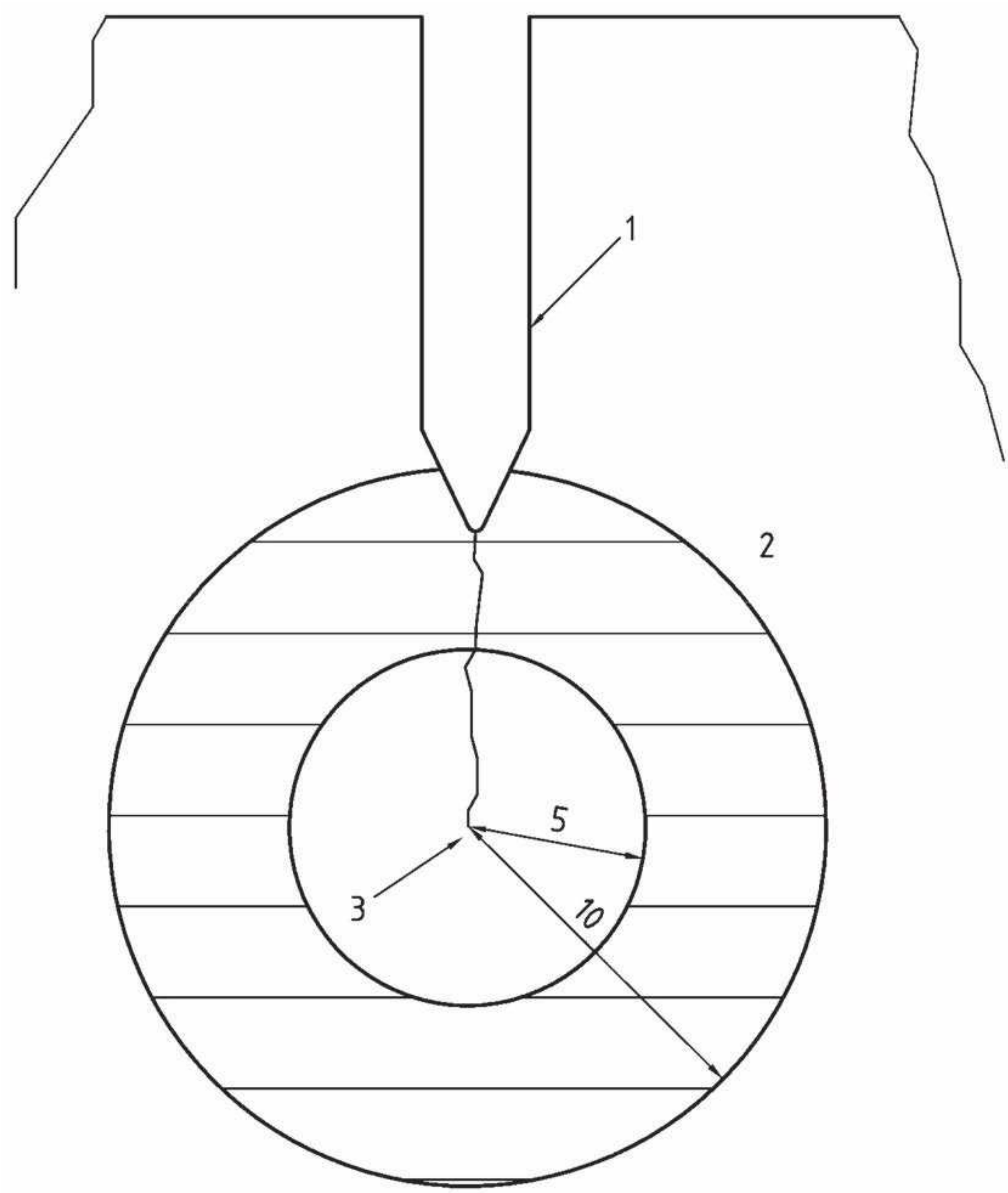
B = 25 mm

W See F.2.2.

NOTE For all other test piece proportions, see ASTM E399.

Figure F.1 — Location and section of fracture toughness test pieces

Dimensions in millimetres



Key

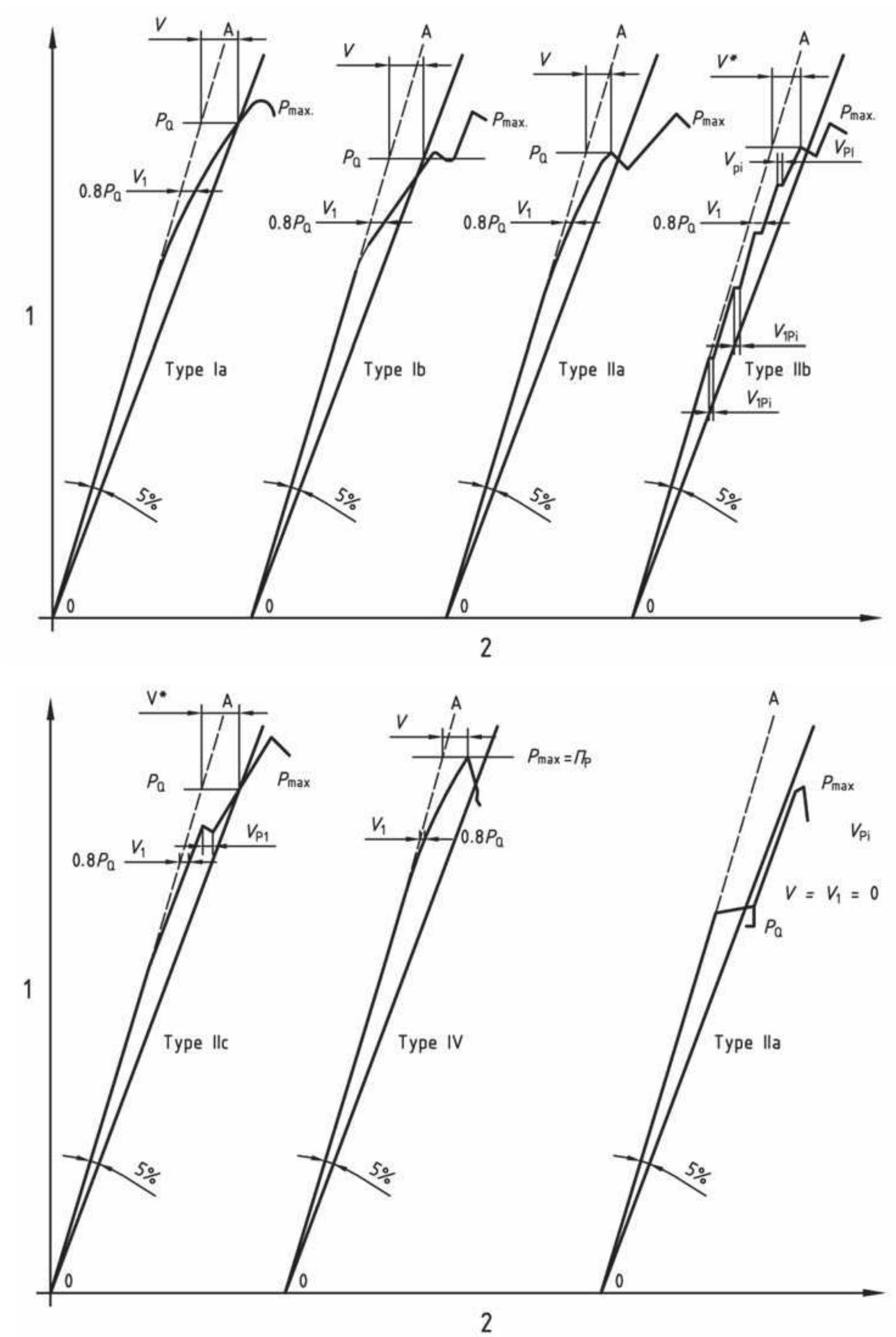
1 notch

2 thermocouple to be placed in the shaded zone

3 fatigue crack tip

Figure F.2 — Location of thermocouple on fracture toughness specimens

Dimensions in millimetres



Key

1 force, P

2 crack mouth opening displacement (v)

Figure F.3 — Force — Crack mouth opening curves

Annex G
(normative)

Profile and drilling gauges

The gauges for manufacture are shown in the figures which are summarized in Table G.1.

Table G.1 — Summary of figures

Figure G.1	Datum references for tolerances
Figure G.2	Datum references for decision
Figure G.3	Height of rail
Figure G.4	Width or rail head
Figure G.5	Crown profile
Figure G.6 and G.7	Asymmetry
Figure G.8	Fishing height HF
Figure G.9	Web thickness
Figure G.10	Width of rail foot
Figure G.11	Foot toe thickness
Figure G.12 and G.13	Drilling gauges

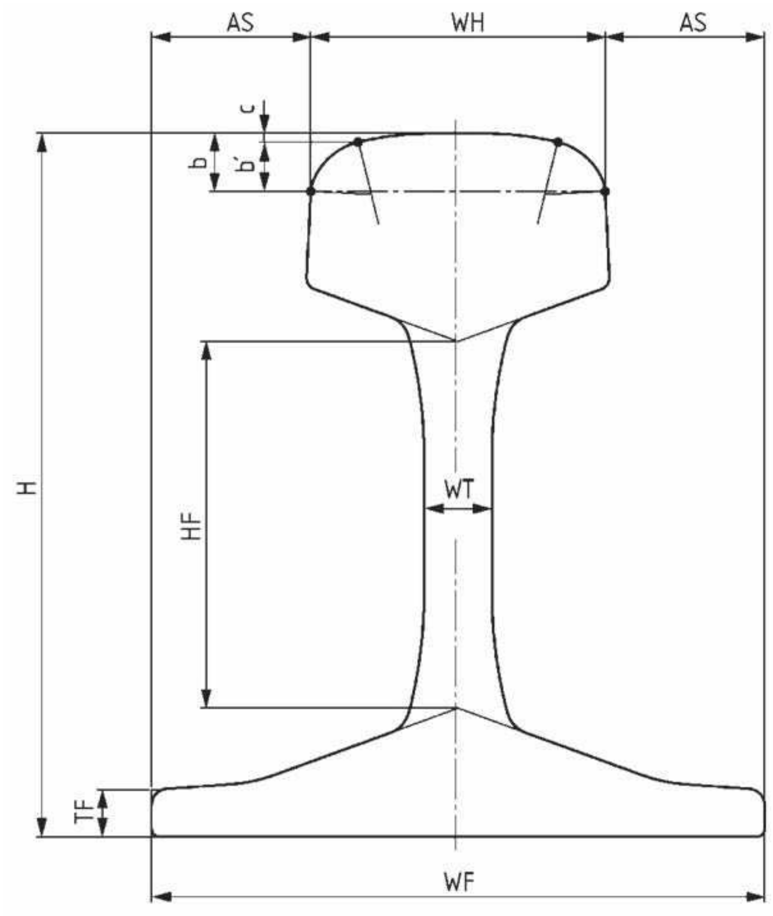
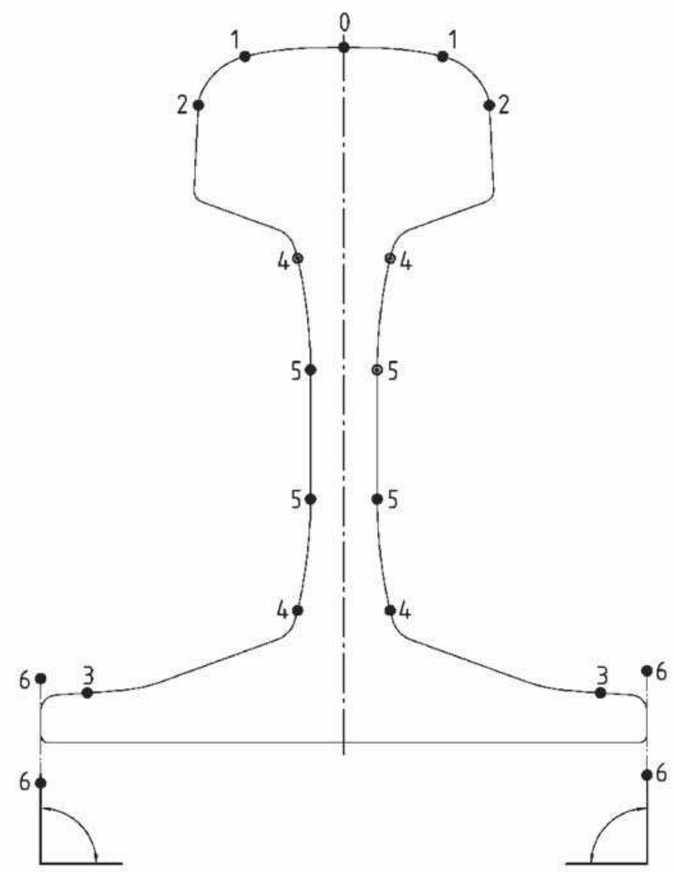


Figure G.1 — Datum references for tolerances (see Table 2)



Datum	Reference			Figure number
0	height:	– must not	+ must pass	Figure G.3
0	crown profile:	– must	+ must not pass the wedge	Figure G.5
1	width of rail head:	– must not	+ must touch	Figure G.4
2	rail asymmetry:	– must not	+ must touch	Figure G.6 Figure G.7
4, 5	height of fish plating:	– must	+ must not touch	Figure G.8
5	web thickness:	– must not	+ must pass	Figure G.9
3, 6	foot toe thickness must touch foot edge	must be into the ± range		Figure G.11
6	width of rail foot:	– must not	+ must pass	Figure G.10

Figure G.2 — Datum references for decision

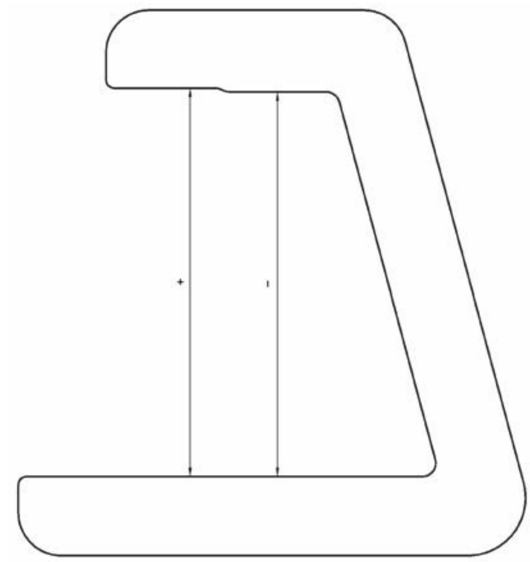


Figure G.3 — Height of rail

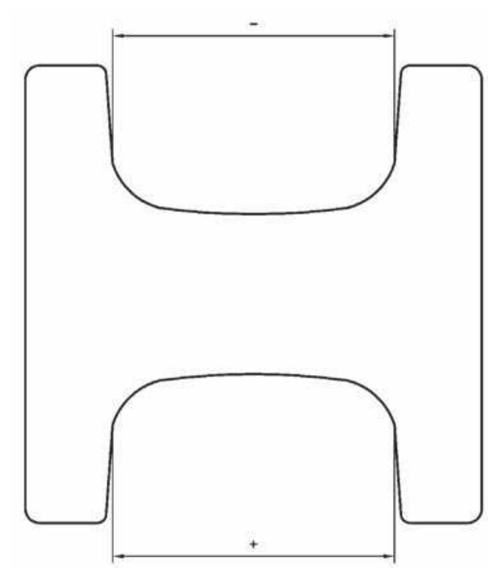
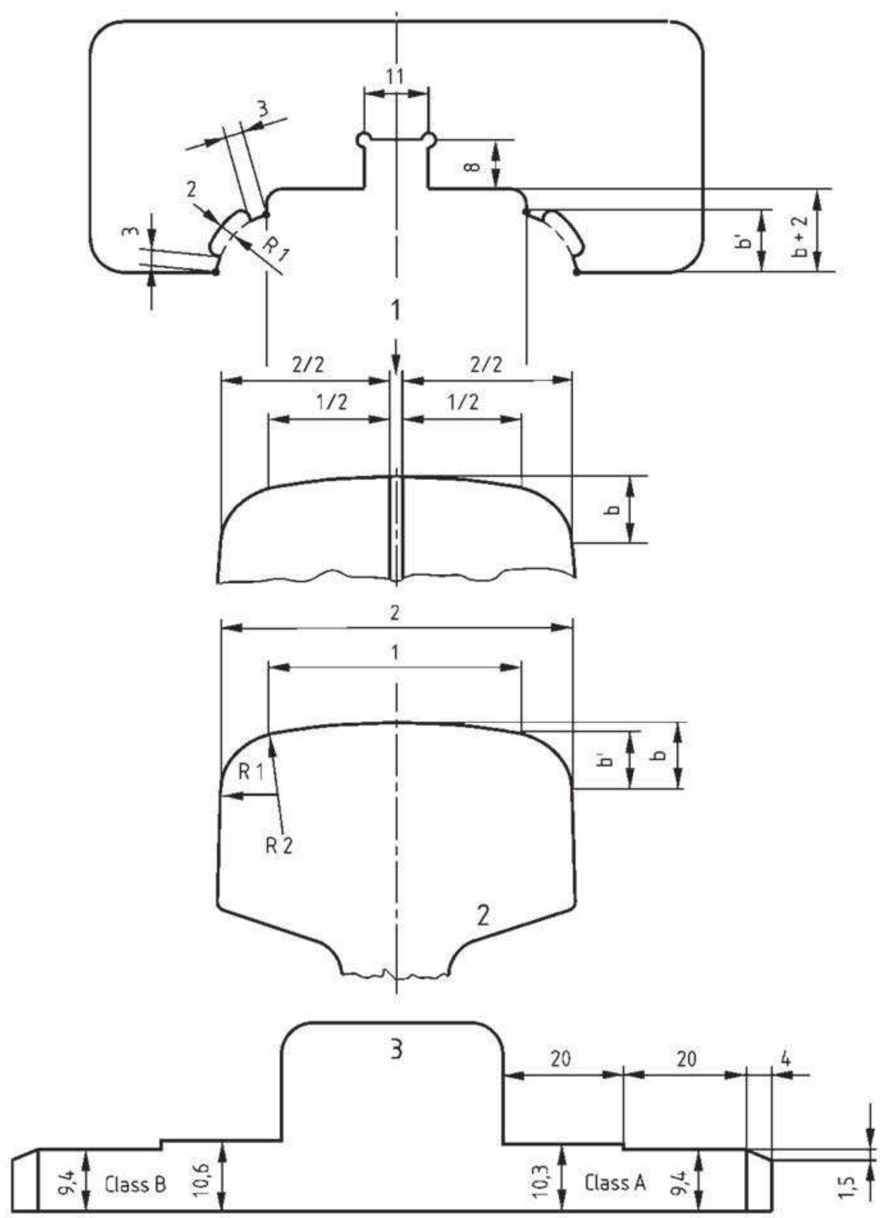


Figure G.4 — Width of rail head



Key

1 maximum width of rail head tolerance
2 theoretical profile
3 step gauge to check the table shape, 10 mm thickness

Figure G.5 — Crown profile

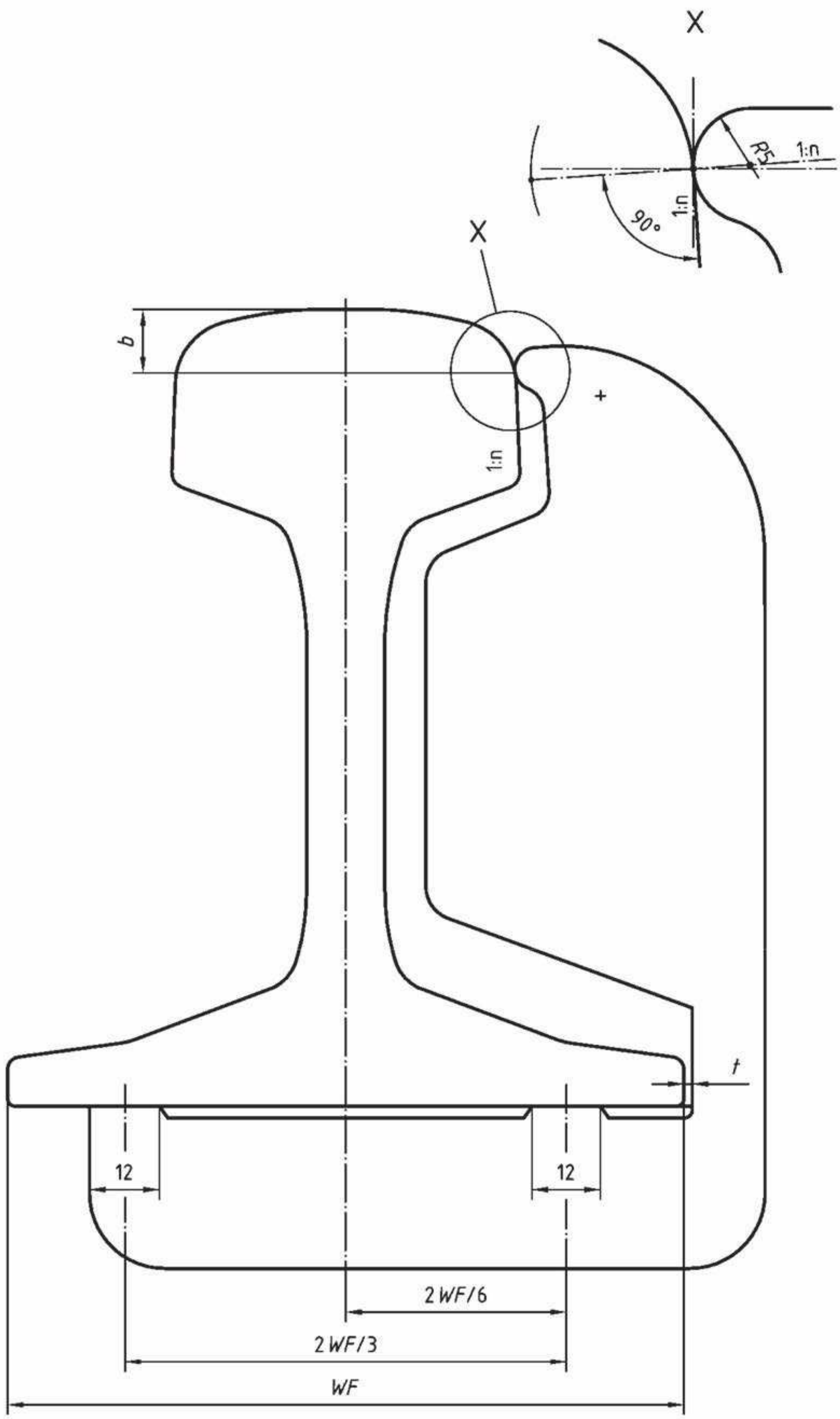


Figure G.6 — Rail asymmetry

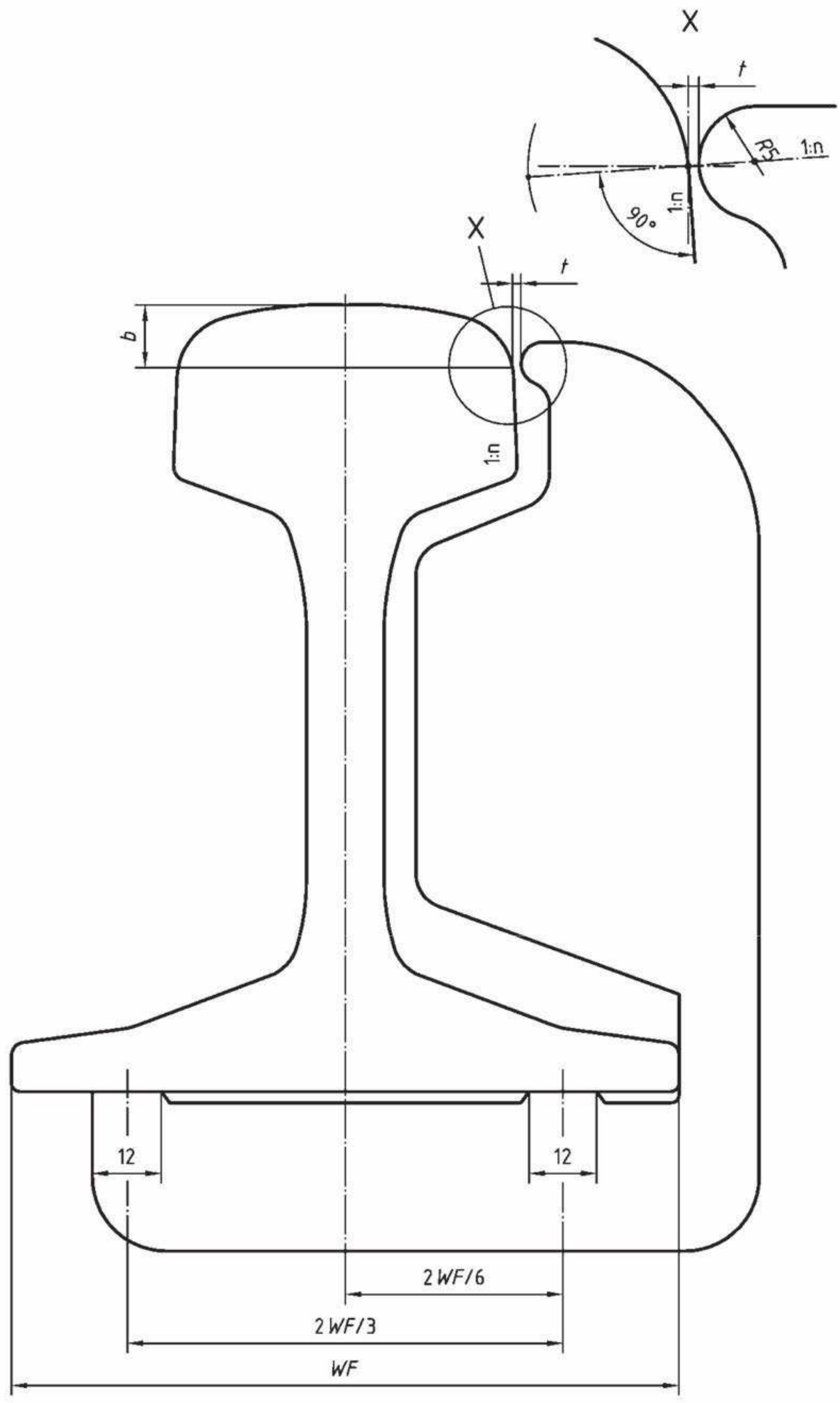
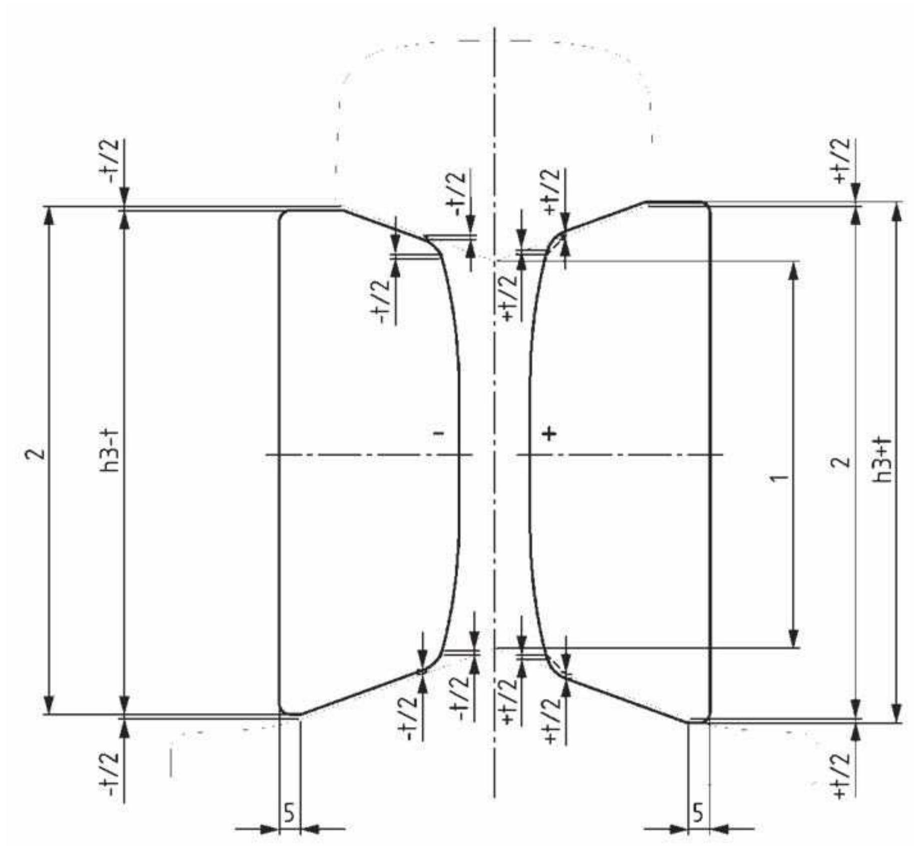


Figure G.7 — Rail asymmetry

Dimensions in millimetres



Key

1 and 2 marks engraved 14 mm apart to indicate measuring point

h3 = theoretical

Figure G.8 — Fishing height

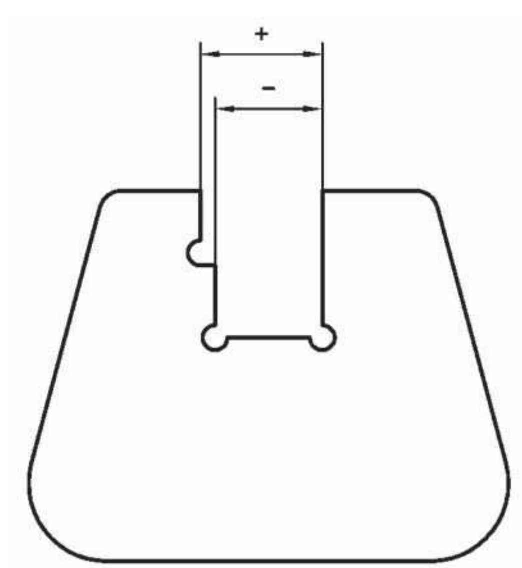


Figure G.9 — Web thickness

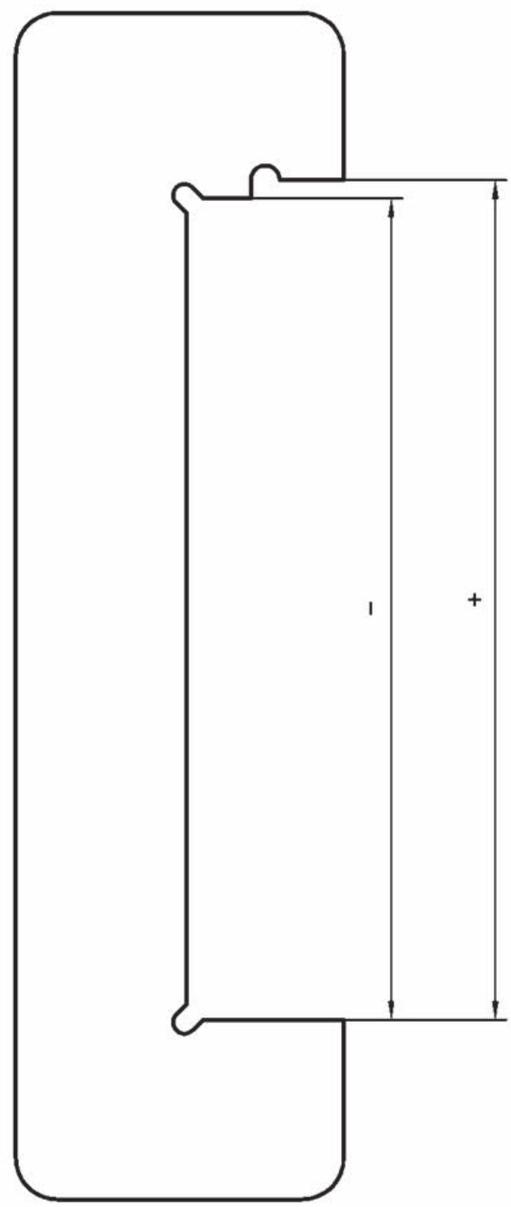
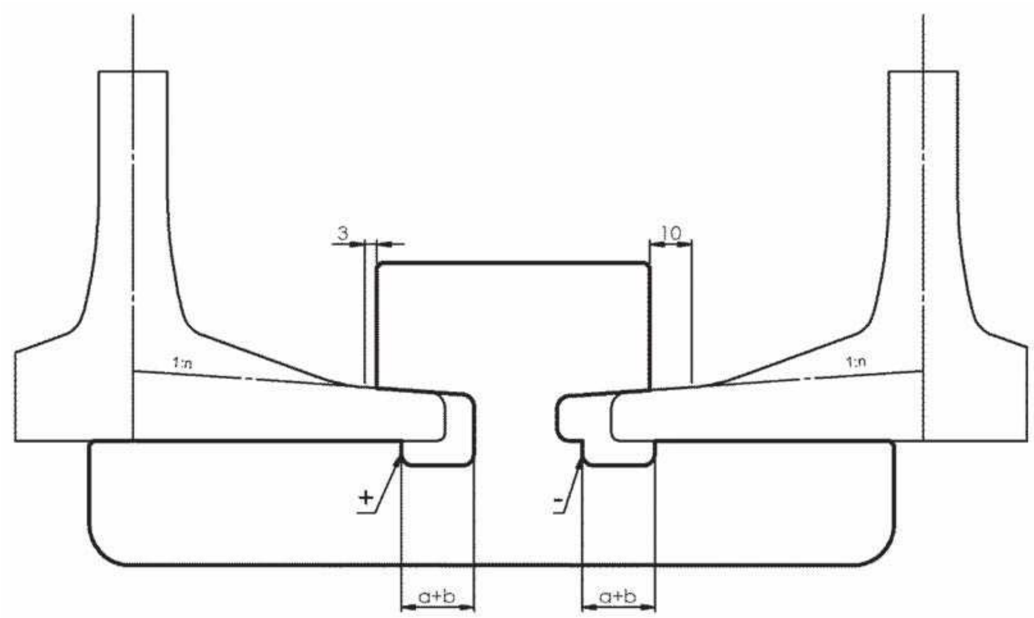


Figure G.10 — Width of rail foot

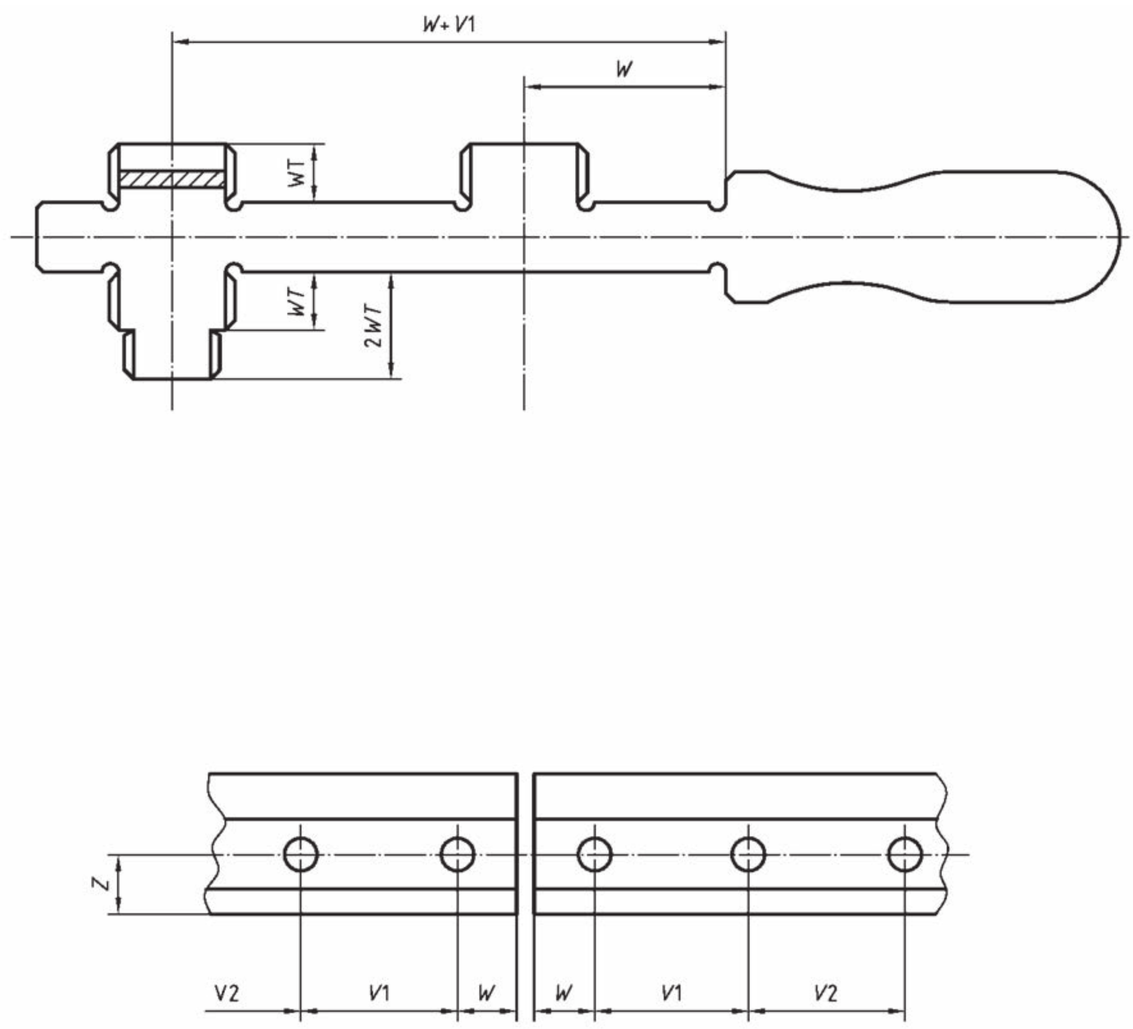


Key

a = + Tolerance*n

b = – Tolerance*n

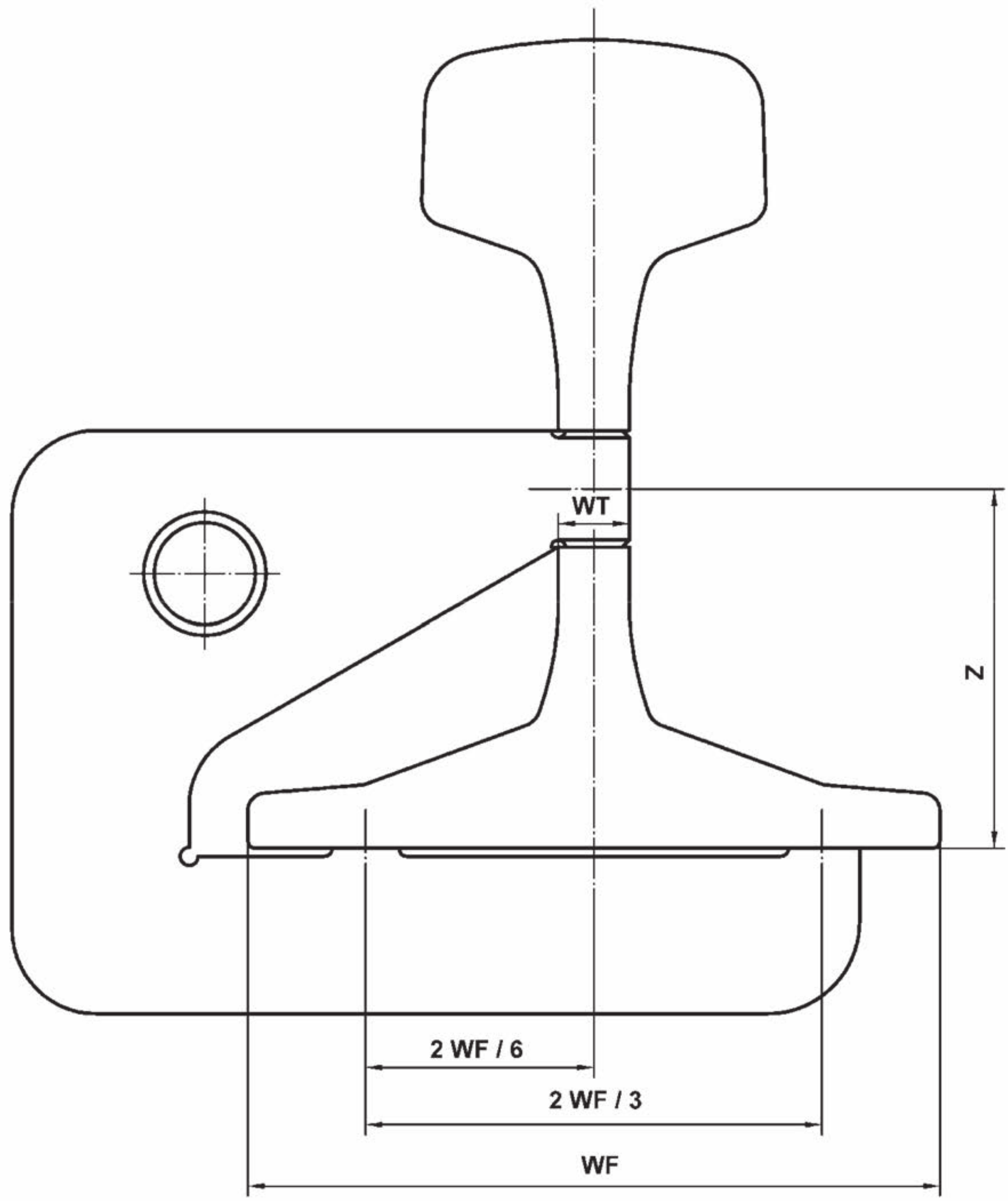
Figure G.11 — Foot toe thickness



Key

WT web thickness

Figure G.12 — Gauge for checking distance between holes and rail end and hole diameter



Key

WF width of foot

WT web thickness

Z distance between centre of the hole and base of the rail

Figure G.13 — Gauge for checking distance between holes and base of rail

Annex H
(normative)

Standard diagrams for the check of the macrostructure of rails in accordance with ISO 4969

According to Figure H.1, the areas of cross-section are defined as head, web, and base. Schematic descriptions of some rejectable conditions are depicted in Figure H.2 through Figure H.11. Rejectable conditions are presented in Table H.1.

Table H.1 — Rejectable conditions for the macrographs

Figure number	Rejectable condition
Figures H.2 and H.3	Hydrogen flakes
Figures H.4 and H.5	Pipe; any size
Figures H.6 and H.7	Central web streaking extending into the head or base
Figures H.8 and H.9	Streaking greater than 64mm in length
Figure H.10	Scattered central web streaking from the web into the head and base
Figure H.11	Scattered segregation extending more than 25 mm into the head or base
Figure H.12	Subsurface porosity
Figure H.13	Inverse or negative segregation having a width greater than 6 mm and extending more than 13 mm into the head or base
Figure H.14	Streaking greater than 3 mm in the head from radial streaks, radial cracks, halfway cracks, or hinged cracks
Figure H.15	Other defects that could cause premature failure (i.e. slag, refractory, etc.)

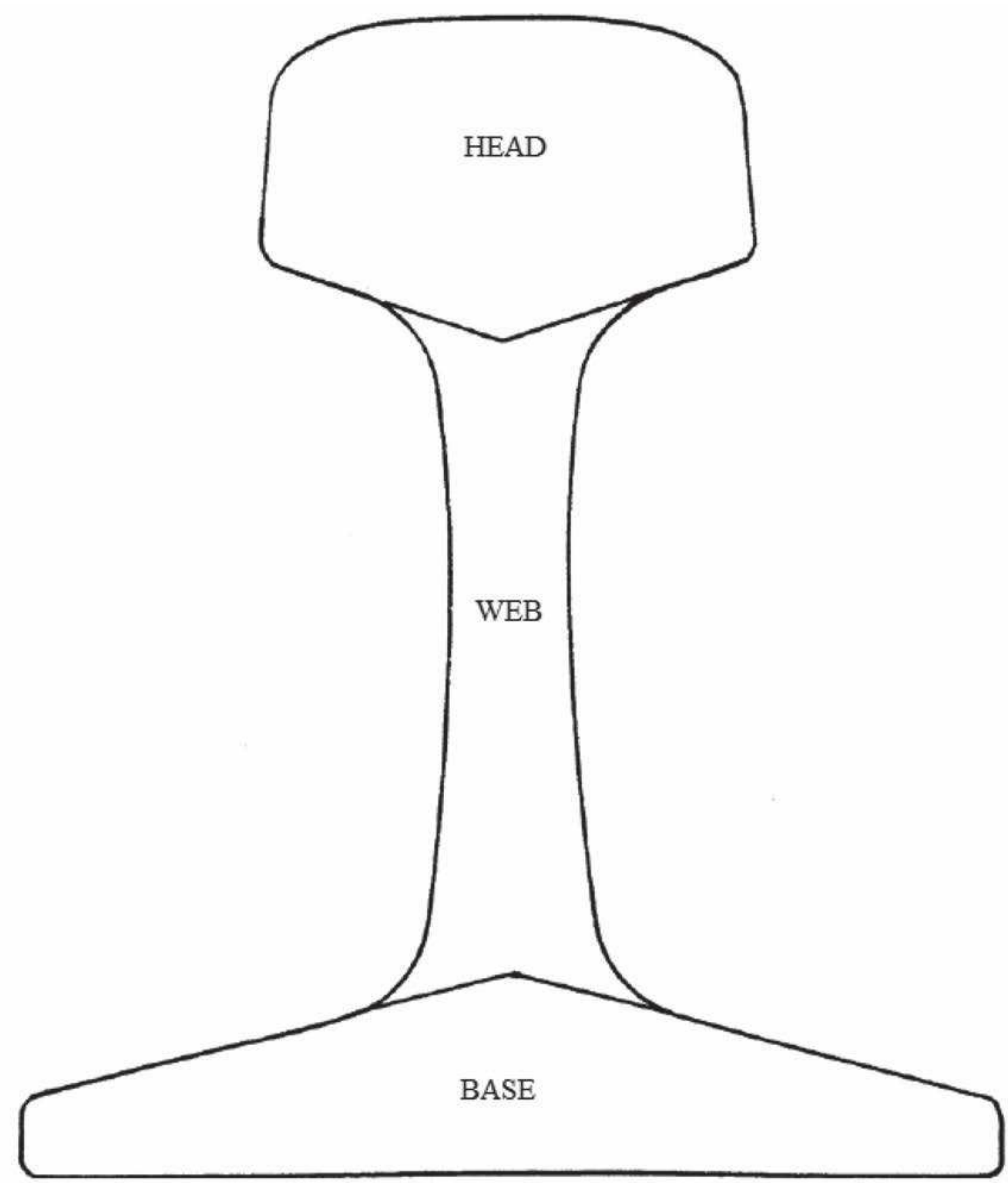


Figure H.1 — Definition of rail cross-sectional areas for macroetch evaluation

Figure H.2 — Hydrogen flakes

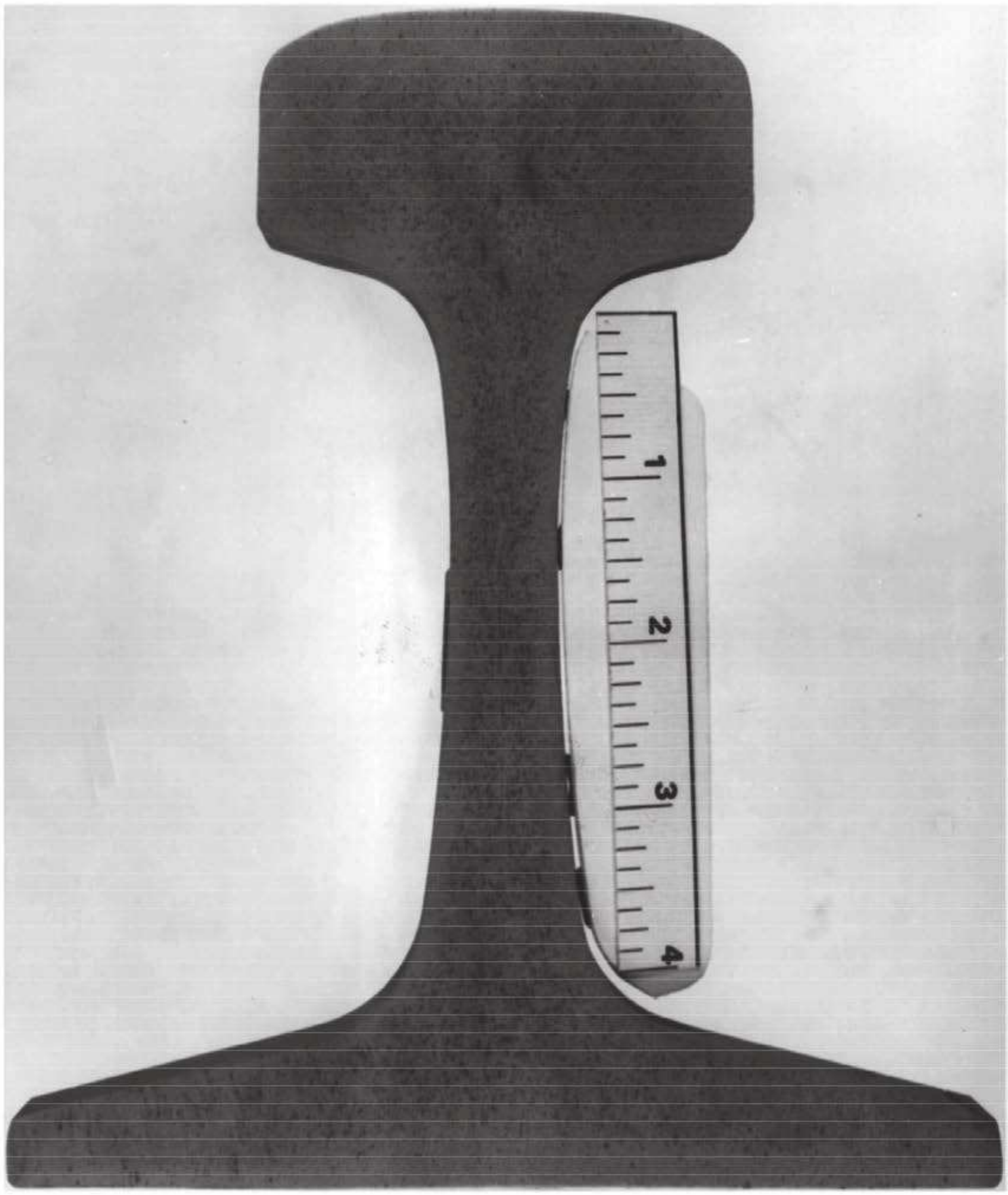


Figure H.3 — Hydrogen flakes

Figure H.4 — Pipe — Any size

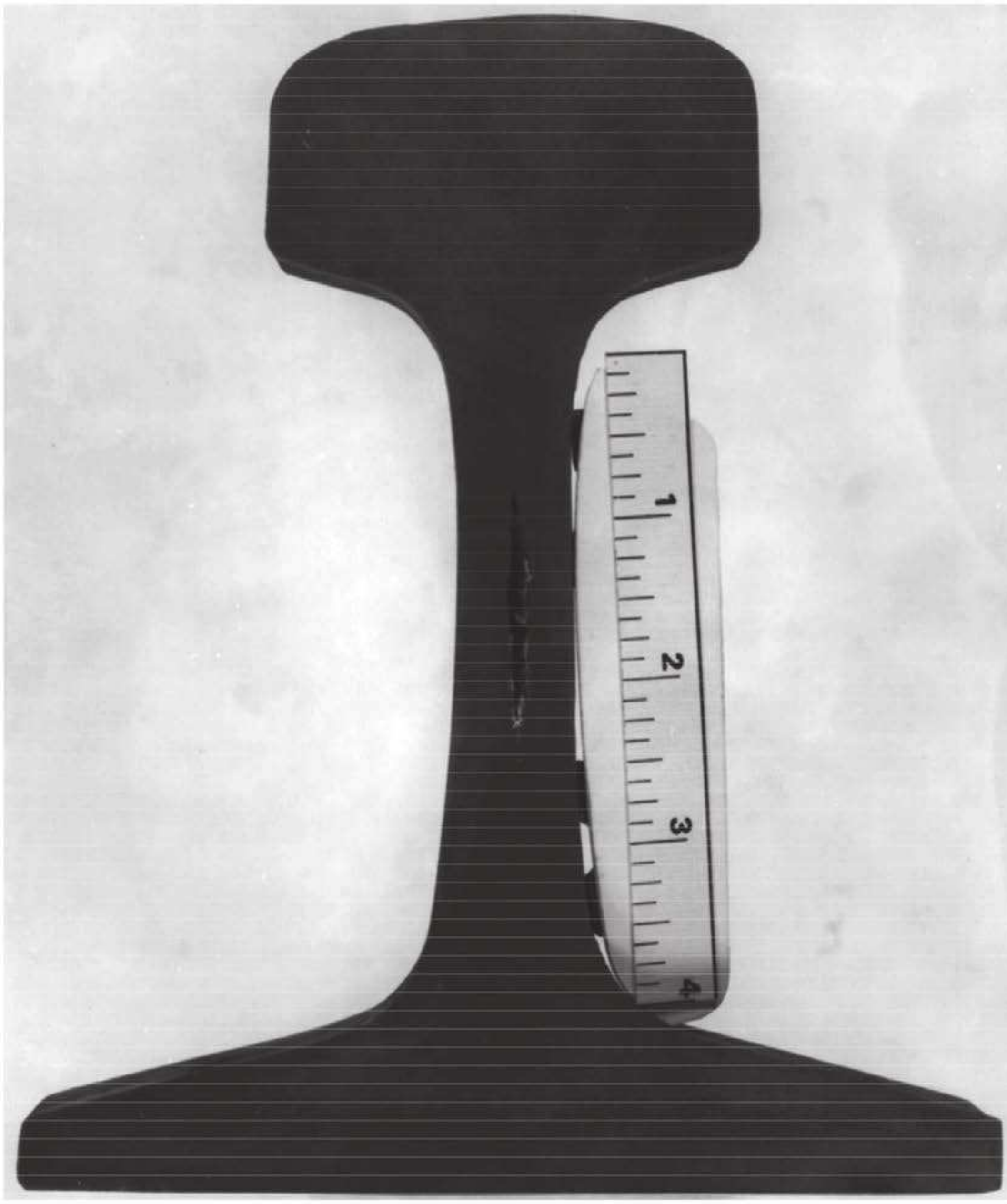


Figure H.5 — Pipe — Any size

Figure H.6 — Central web streaking extending into the head or base

Figure H.7 — Central web streaking extending into the head or base

Figure H.8 — Streaking, >63 mm in length

Figure H.9 — Streaking, >63 mm in length

Figure H.10 — Scattered central web streaking from the web into the head and base

Figure H.11 — Scattered segregation extending more than 25 mm into the head or base

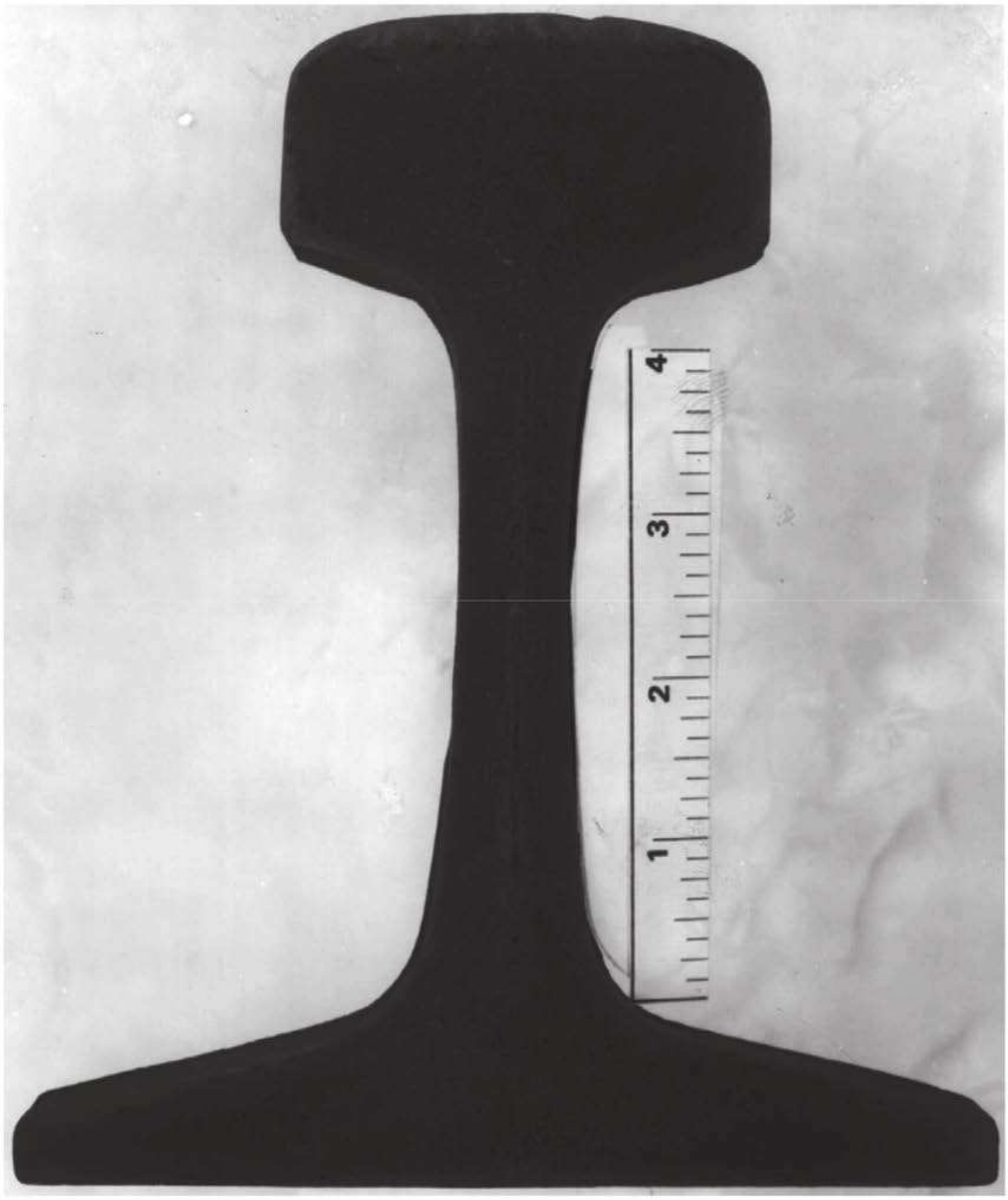


Figure H.12 — Subsurface porosity

Figure H.13 — Inverse or negative segregation >6 mm wide, extending more than 13 mm into the head or base

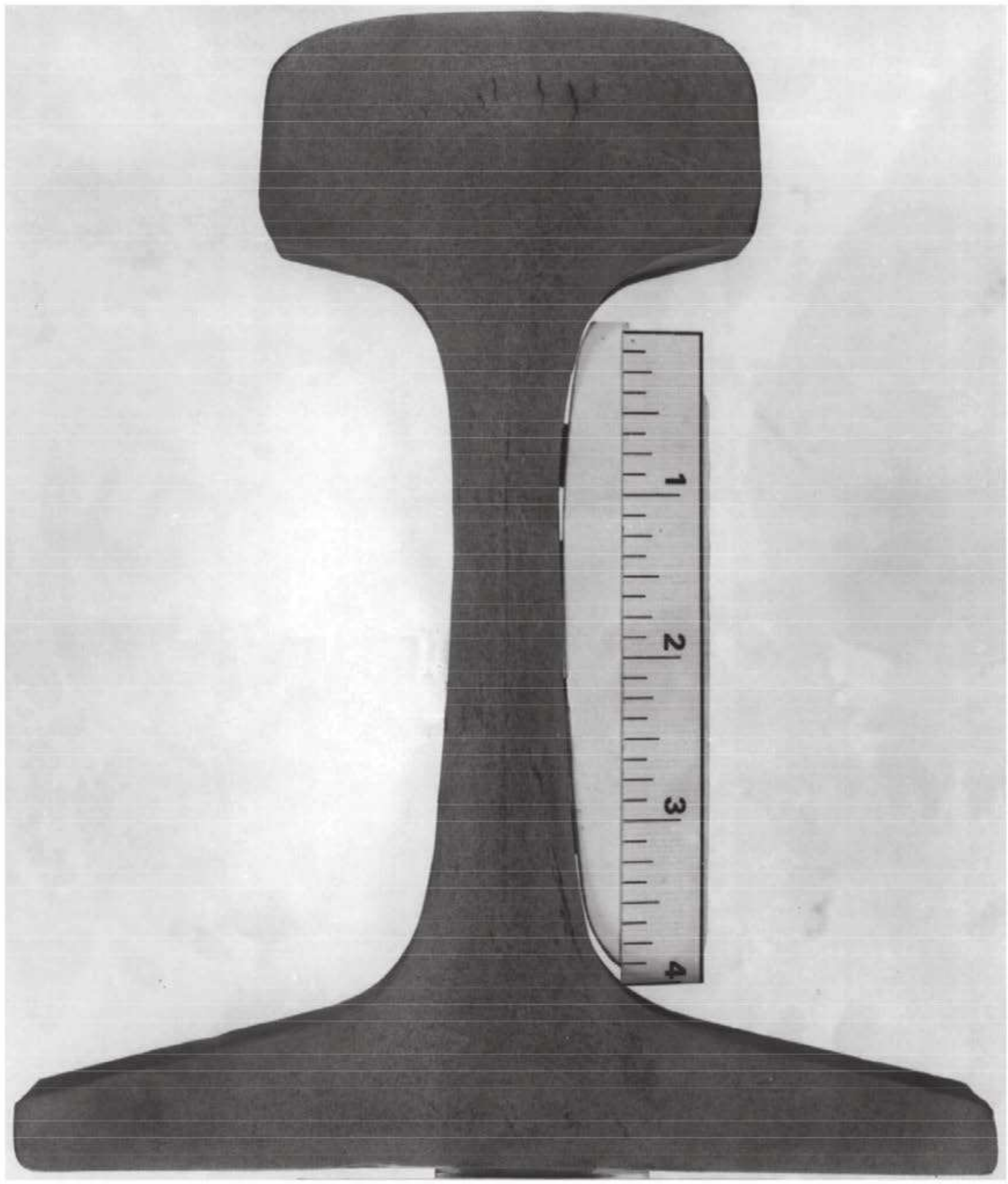


Figure H.14 — Streaking, >3 mm in the head from radial streaks and cracks, halfway or hinged cracks

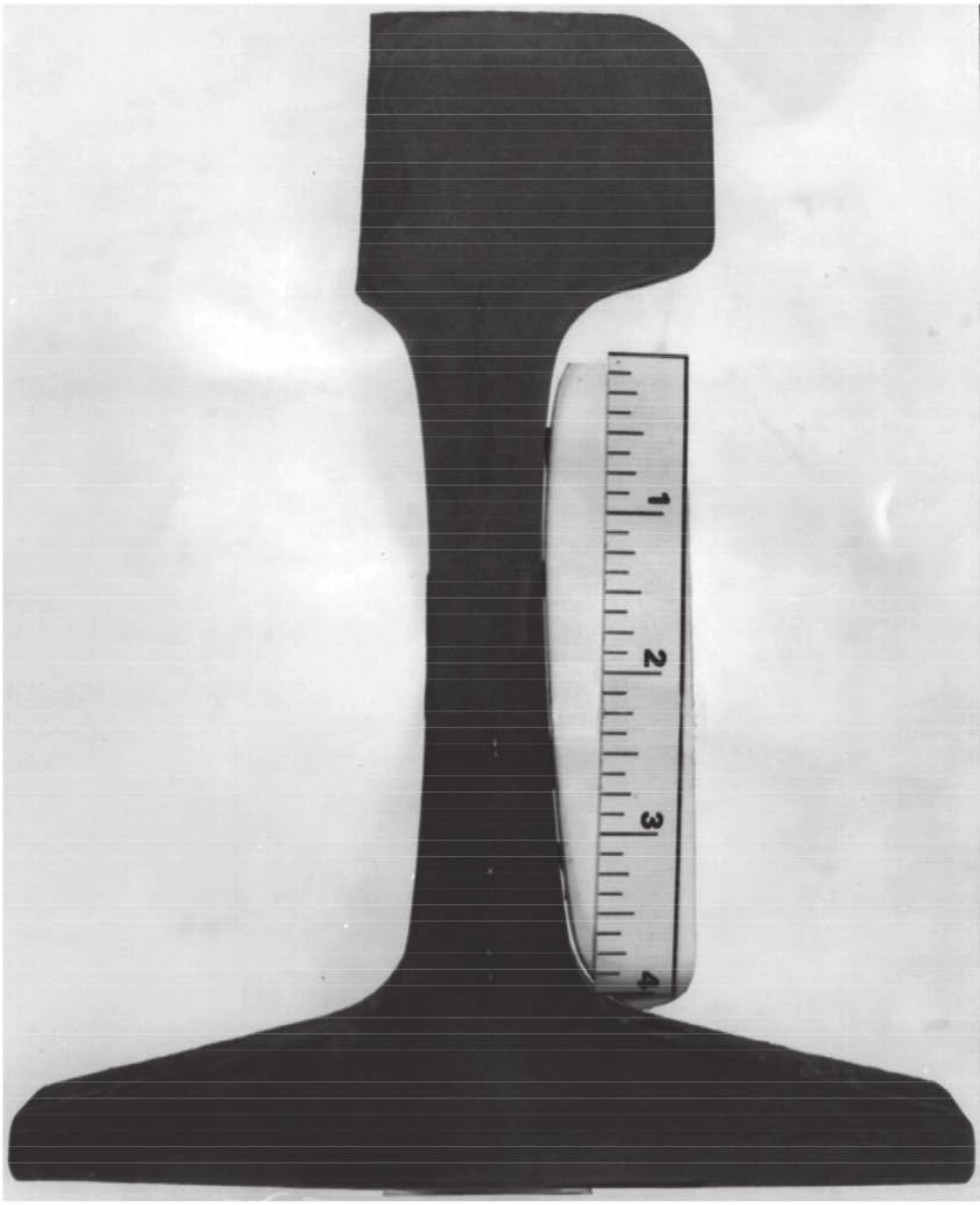


Figure H.15 — Other defects that could cause premature failure (i.e. slag, refractory, etc.)

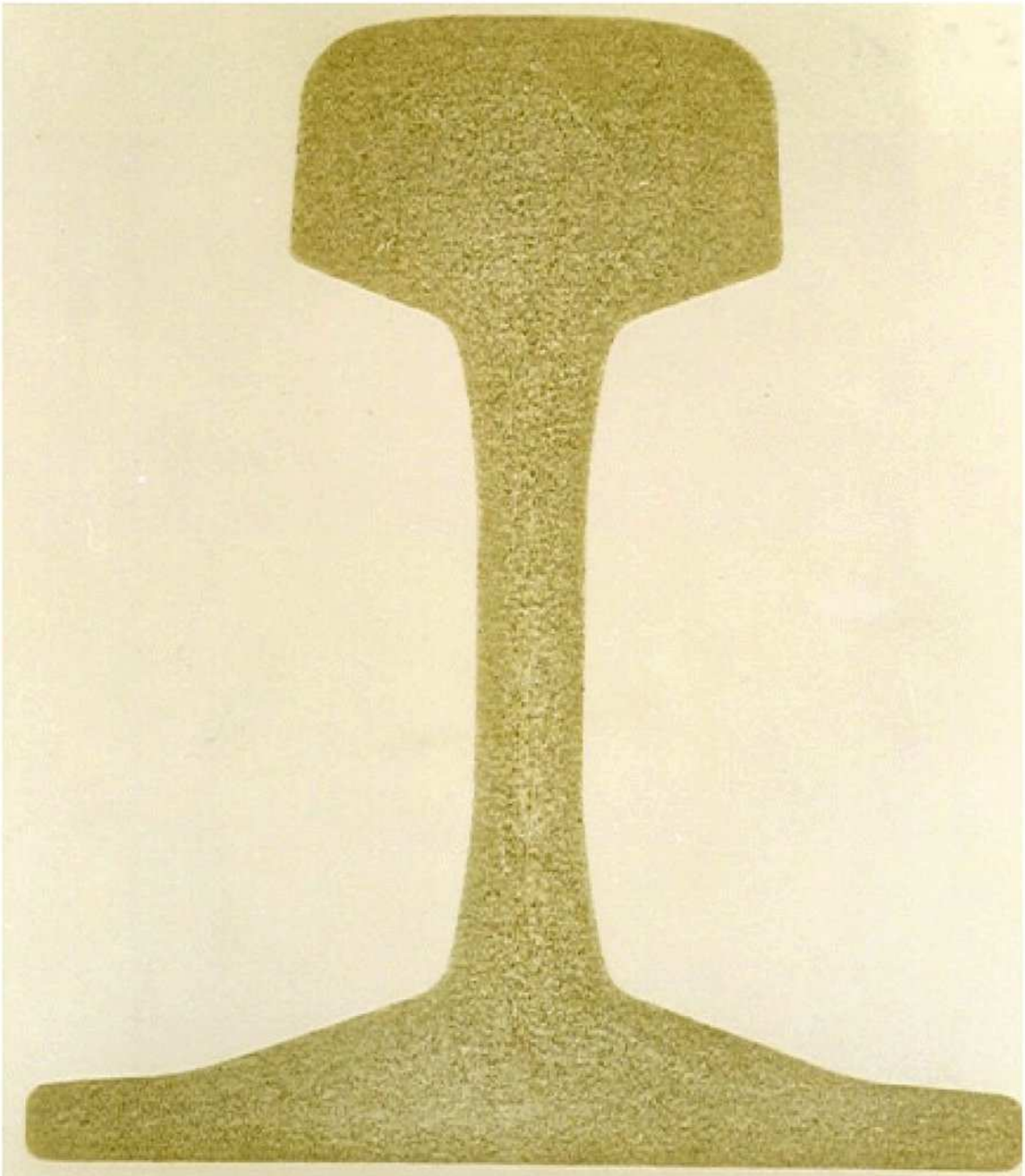
Annex I
(normative)

Limiting sulfur prints

The limiting sulfur prints presented in this annex are summarized in Table I.1. See Figures I.1 to I.13.

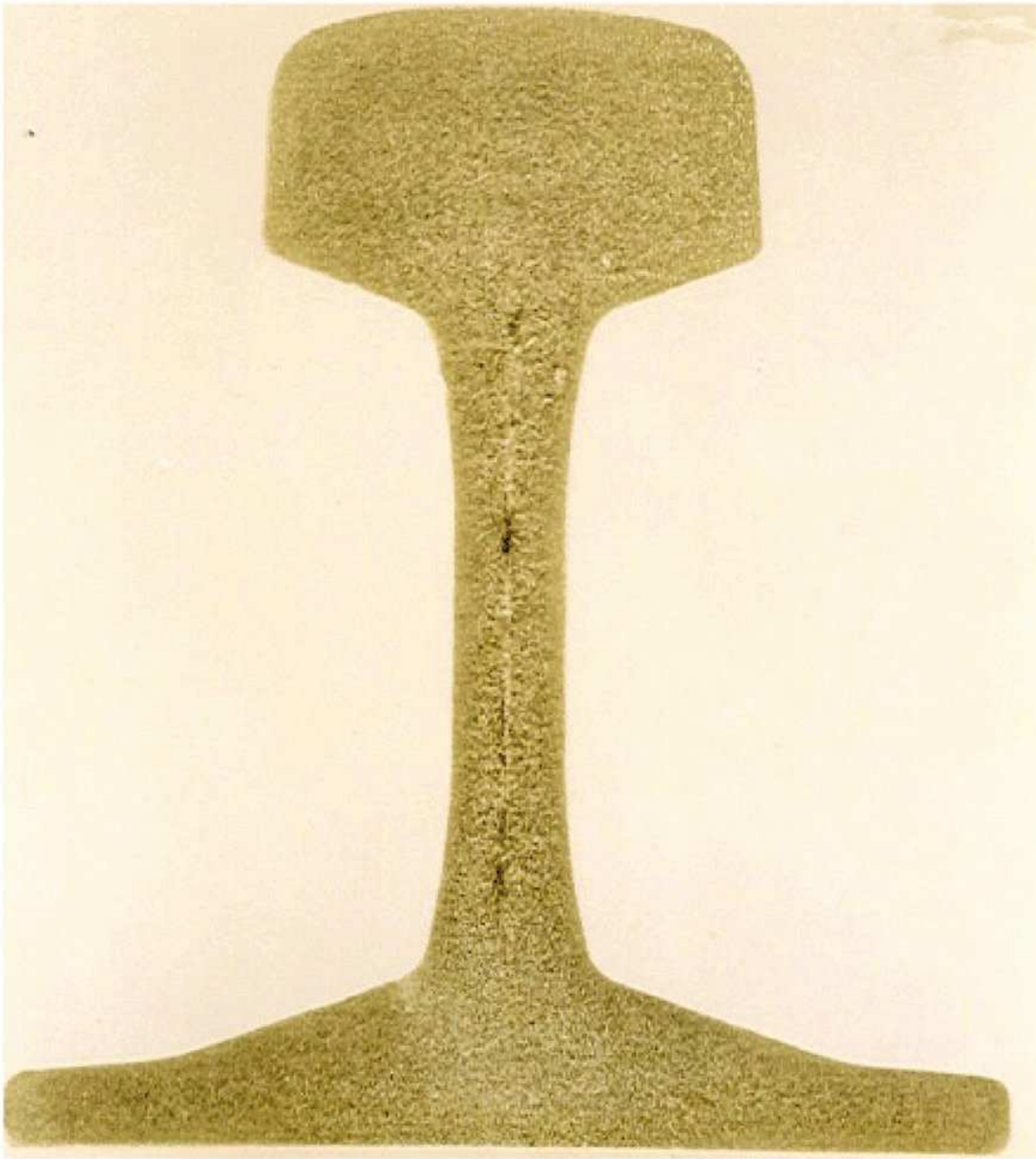
Table I.1 — Limiting sulfur prints

Figure number	Limiting sulfur print	Classification
Figure I.1	Perfect	Acceptable
Figure I.2	Small negative and positive segregation	
Figure I.3	Negative segregation in the web	
Figure I.4	Small positive segregation	
Figure I.5	Dendritic structure	
Figure I.6	Spotty segregation over the total cross-section	
Figure I.7	Negative segregation-zone arising from electromagnetic stirring	
Figure I.8	Negative rim	Not acceptable
Figure I.9	Positive segregation from internal hot cracks in the blooms	See Figure I.9
Figure I.10	Subsurface pin holes	Not acceptable
Figure I.11	Double positive segregation in the web	
Figure I.12	Central web segregation extending into head and/or base	
Figure I.13	Scheme of sulfur prints of rails rolled from continuously cast blooms	See Figure I.13



NOTE Classification: Acceptable.

Figure I.1 — Perfect sulfur print

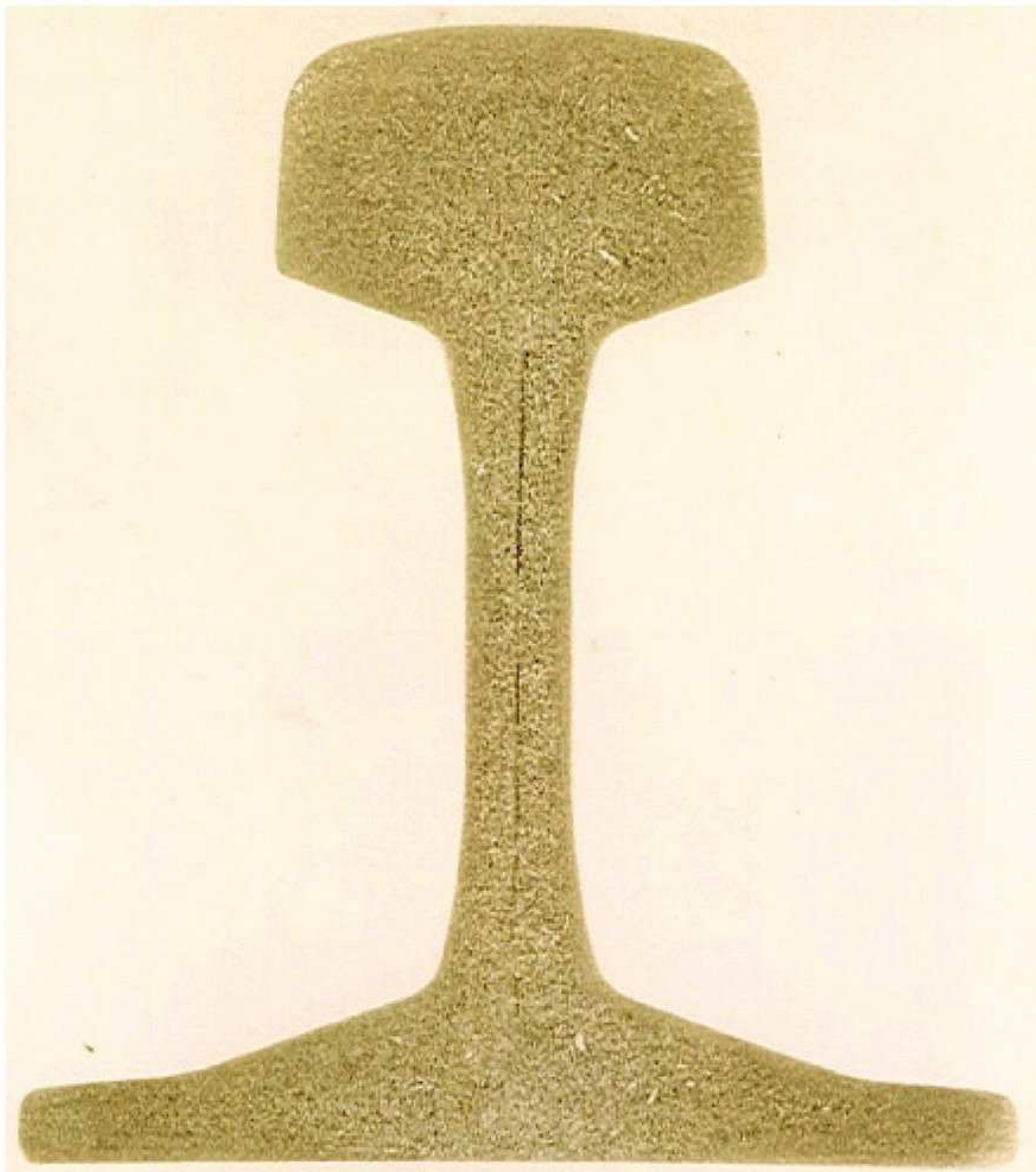


NOTE Classification: Acceptable.

Figure I.2 — Small negative and positive segregation

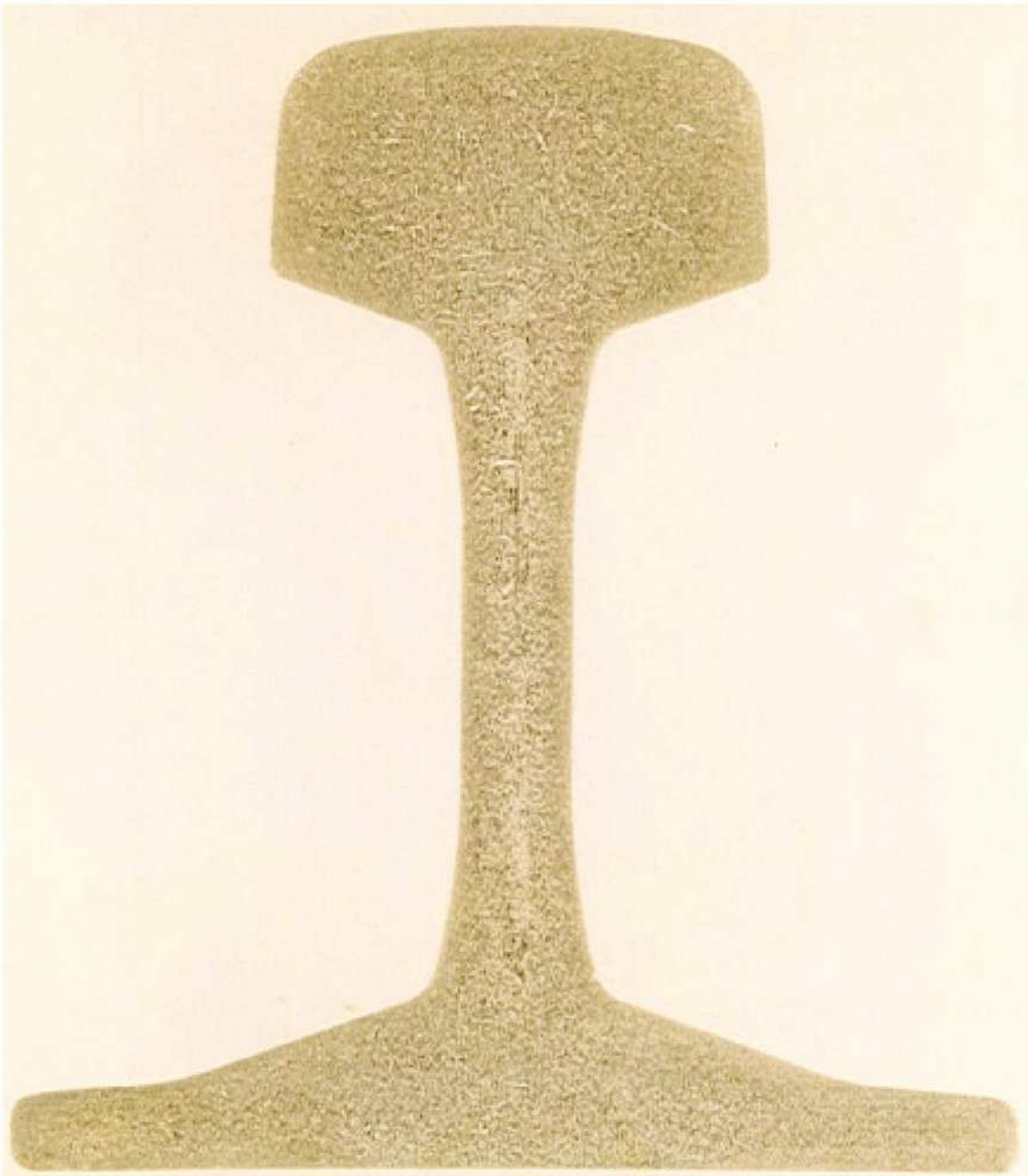
NOTE Classification: Acceptable.

Figure I.3 — Negative segregation in the web



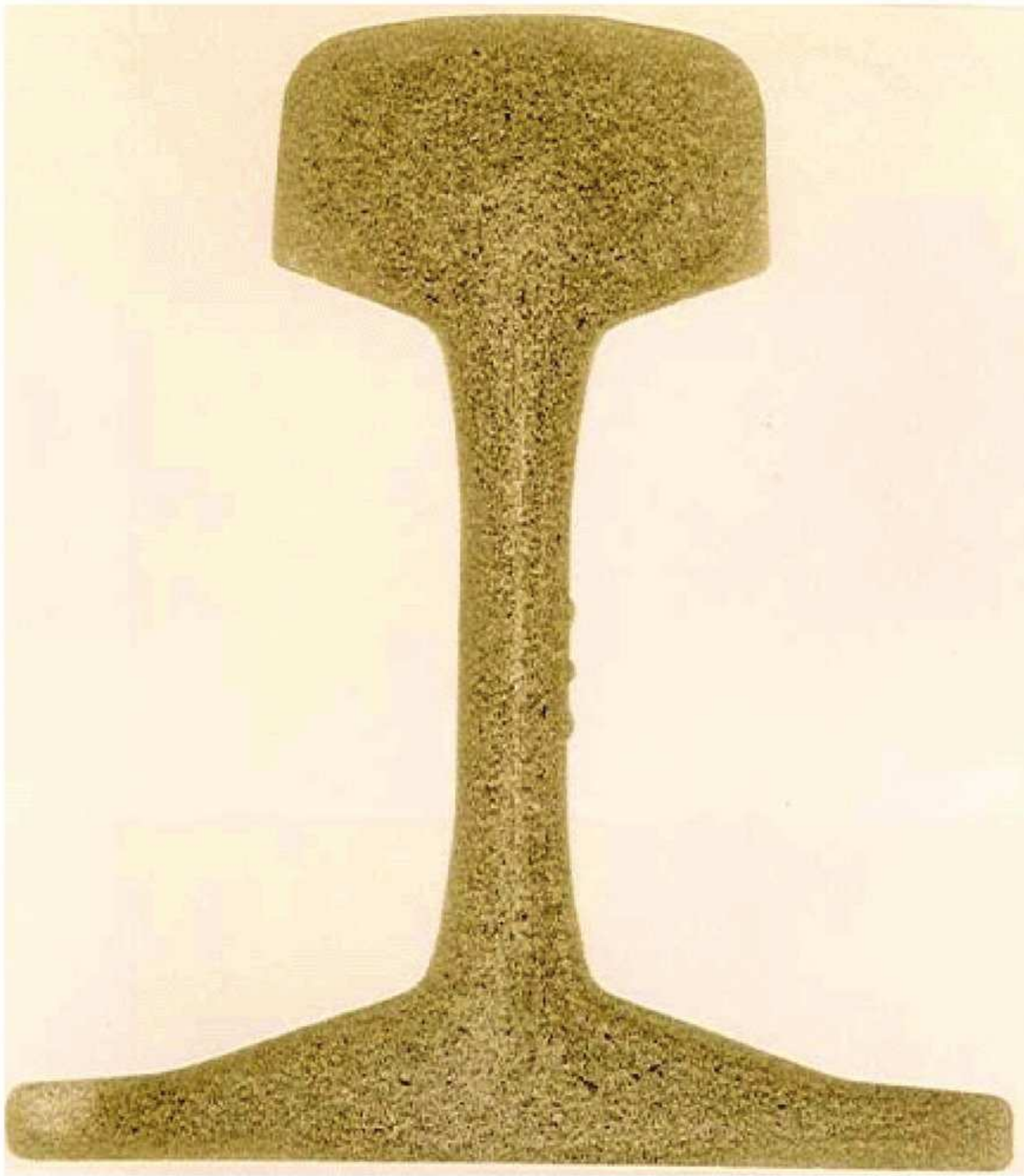
NOTE Classification: Acceptable.

Figure I.4 — Small positive segregation



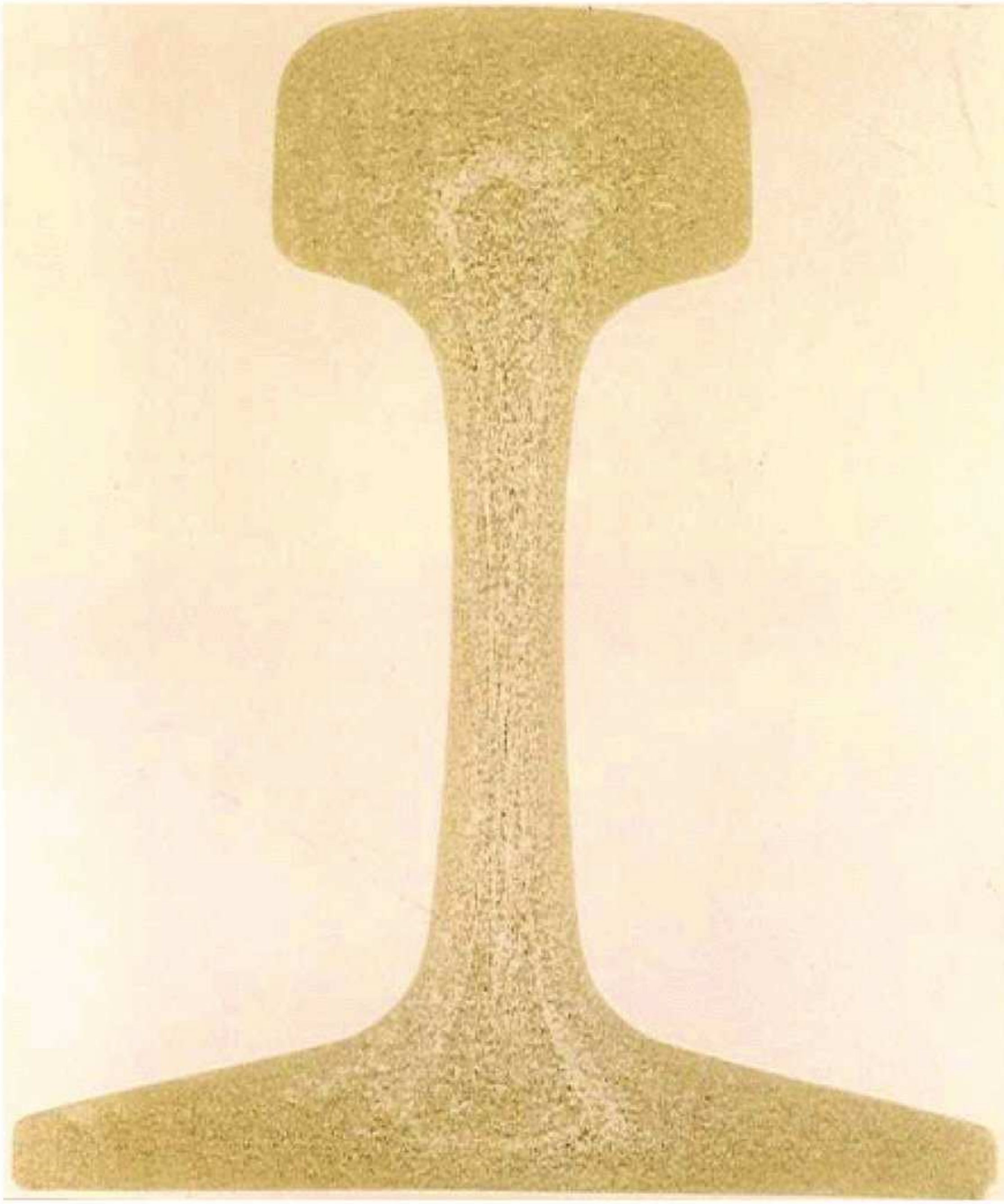
NOTE Classification: Acceptable.

Figure I.5 — Dendritic structure



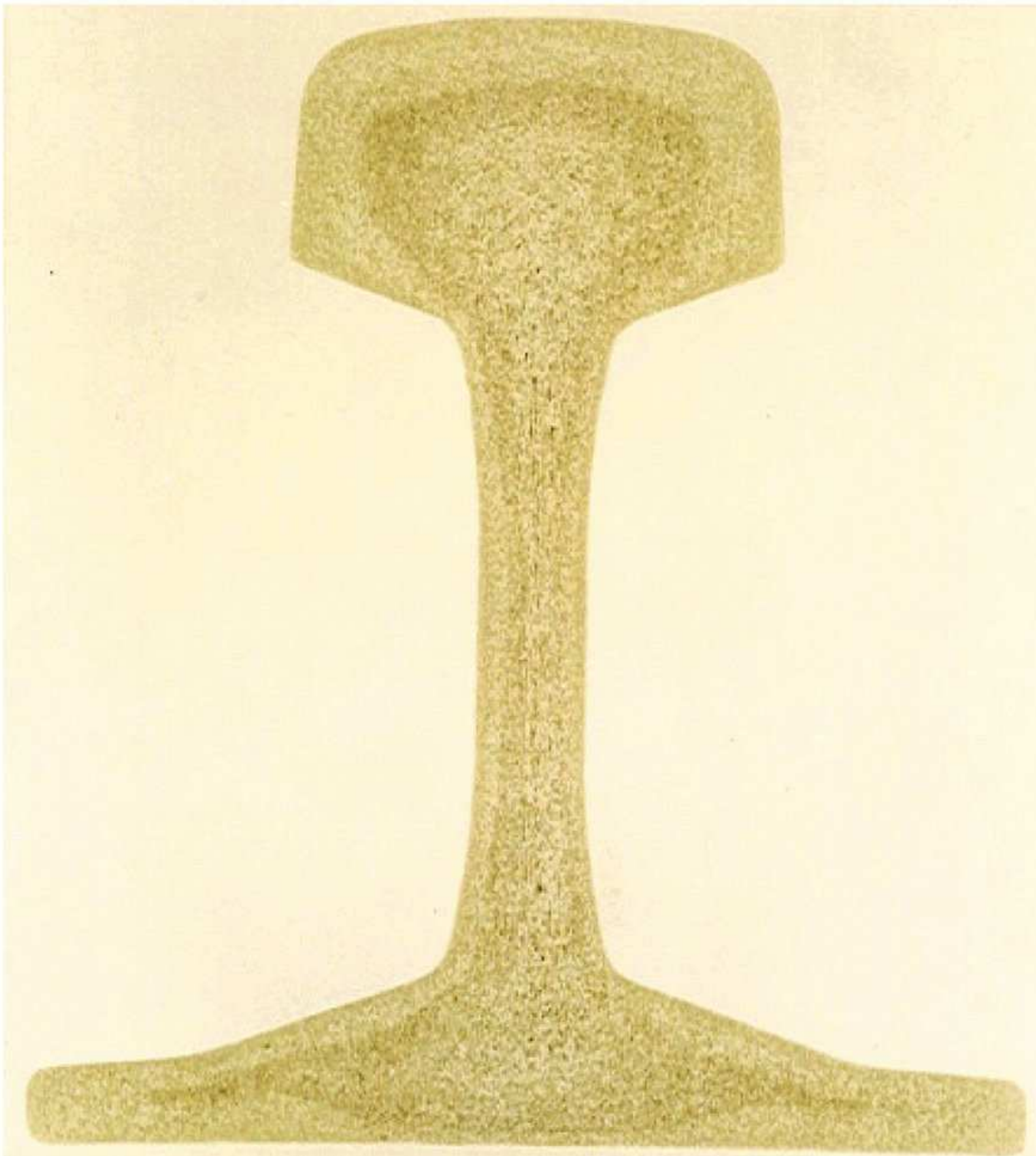
NOTE Classification: Acceptable.

Figure I.6 — Spotty segregation over the total cross-section



NOTE Classification: acceptable.

Figure I.7 — Negative segregation — Zone arising from electromagnetic stirring



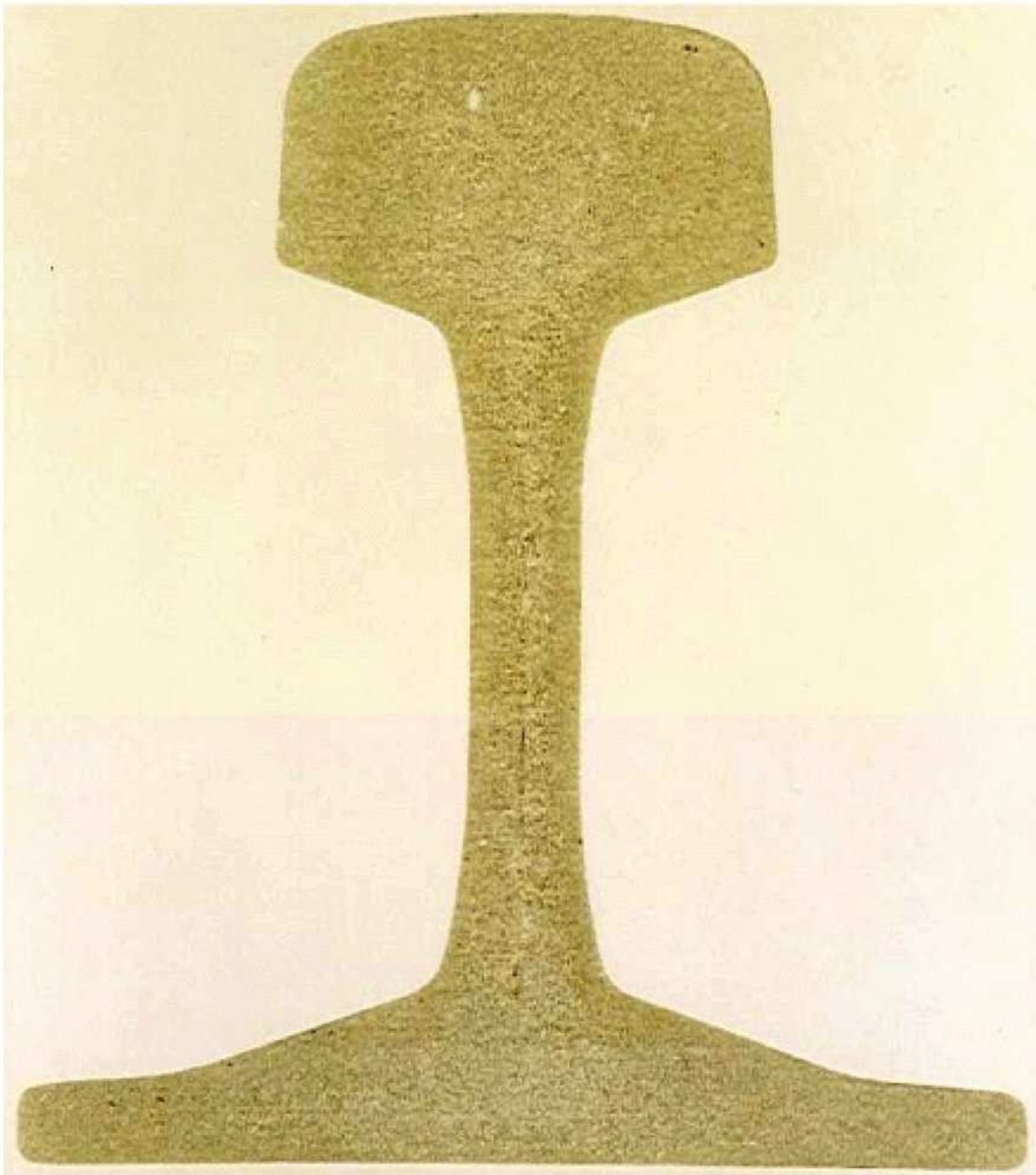
NOTE Classification: Not acceptable.

Figure I.8 — Negative rim

NOTE 1 Classification: Acceptable for crack length 5 mm for not heat-treated and 3 mm for heat-treated materials.

NOTE 2 Classification: Acceptable for added length of single cracks 10 mm.

Figure I.9 — Positive segregation from internal hot cracks in blooms

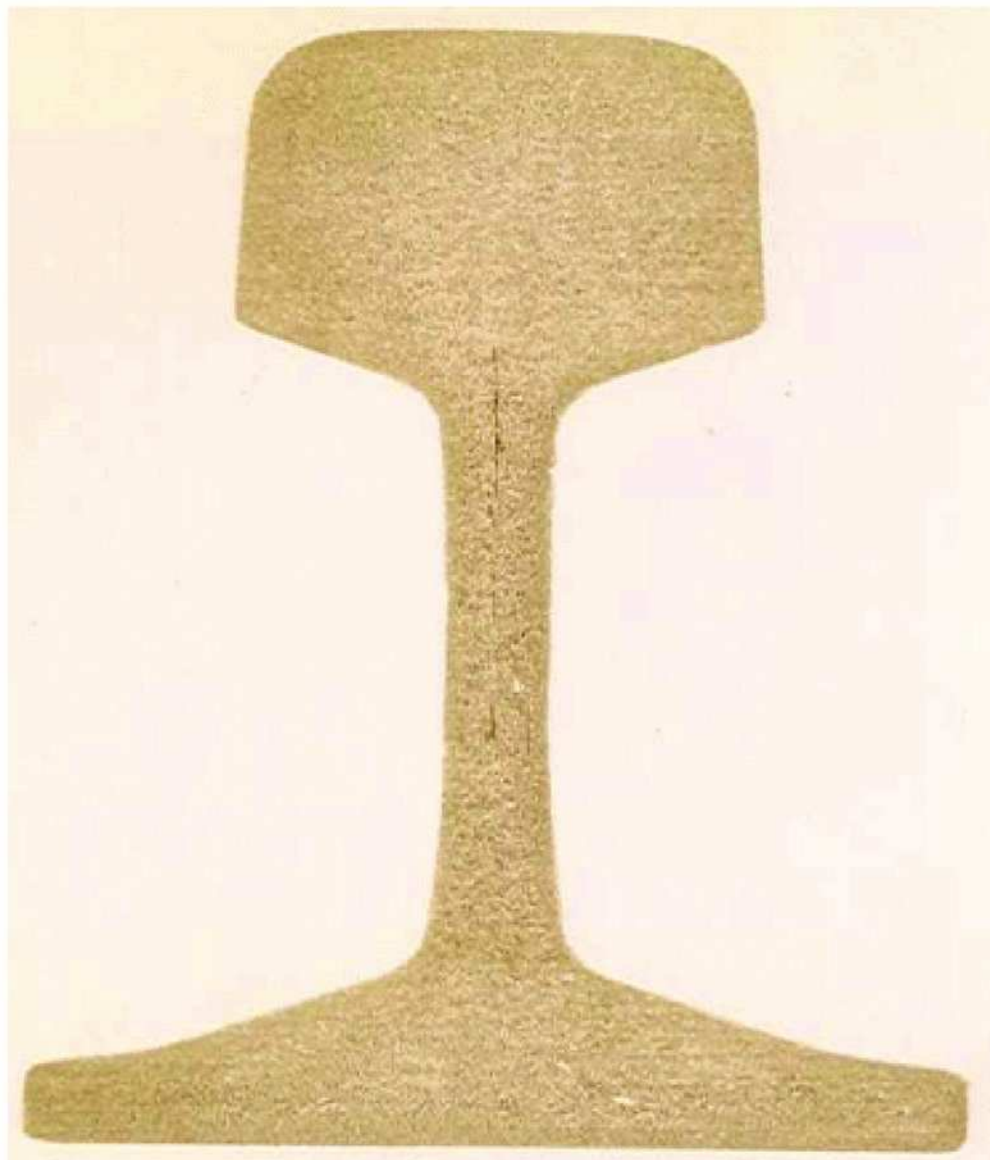


NOTE Classification: Not acceptable.

Figure I.10 — Subsurface pin holes

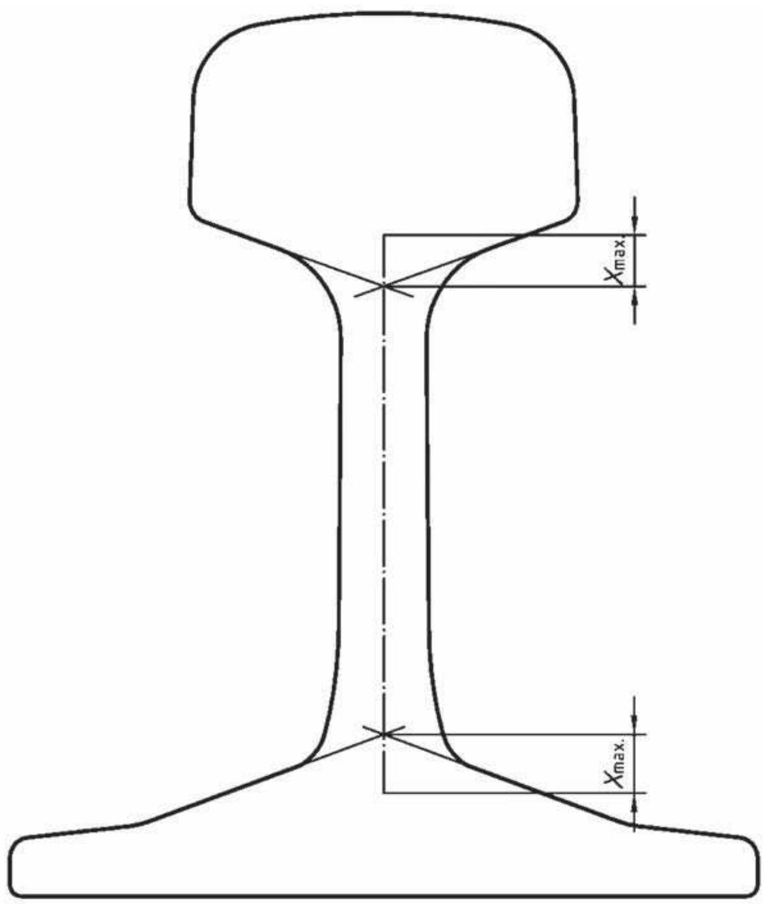
NOTE Classification: Not acceptable.

Figure I.11 — Double positive segregation in the web



NOTE Classification: Not acceptable.

Figure I.12 — Central web segregation extending into head and/or base



NOTE Classification: Central web segregation extending into head and/or base not acceptable exceeding a threshold value X_{max} of 15 mm.

Figure I.13 — Schematic diagram defining extent of allowable web segregation

Bibliography

[1] ISO 404, *Steel and steel products — General technical delivery requirements*

[2] ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition*

[3] AREMA-2010 Chapter 4: Rail-Part 2: Manufacture of rails

[4] EN 13674-1:2011, *Vignole railway rails 46 kg/m and above*

[5] GB 2585-2007, *As-rolled railway rails*

[6] JIS E1101-2001, *Flat bottom railway rails and special rails for switches and crossings of non-treated steel*

[7] JIS E 1120-2007, *Head hardened rails*

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