BS EN 13674-1:2011

BSI Standards Publication

Railway applications — Track — Rail

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

National foreword

This British Standard is the UK implementation of EN 13674-1:2011. It supersedes BS EN 13674-1:2003+A1:2007, which is withdrawn.

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

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

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

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This European Standard was approved by CEN on 10 December 2010.

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Foreword

This document (EN 13674-1:2011) 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of an identical text or by endorsement, at the latest by August 2011, and conflicting national standards shall be withdrawn at the latest by August 2011.

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

This document supersedes EN 13674-1:2003+A1:2007.

Annex F provides details of significant technical changes between this European Standard and the previous edition.

This document has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association, and supports essential requirements of EU Directive 2008/57/EC.

For relationship with EU Directive 2008/57/EC, see informative Annex ZA, which is an integral part of this document.

This part of EN 13674 is the first of the series EN 13674, *Railway applications – Track – Rail*, which consists of the following parts:

— *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 for rails and corresponding welding processes, already published or under preparation, are:

— EN 14587-1, *Railway applications – Track – Flash butt welding of rails – Part 1: New R220, R260, R260Mn and R350HT grade rails in a fixed plant*;

— EN 14587-2, *Railway applications – Track – Flash butt welding of rails – Part 2: New R220, R260, R260Mn and R350HT grade rails by mobile welding machines at sites other than at a fixed plant*;

— prEN 14587-3, *Railway applications – Track – Flash butt welding of rails – Part 3: Welding in association with crossing construction*;

— EN 14730-1, *Railway applications – Track – Aluminothermic welding of rails – Part 1: Approval of welding processes*;

— EN 14730-2, *Railway applications – Track – Aluminothermic welding of rails – Part 2: Qualification of aluminothermic welders, approval of contractors and acceptance of welds*;

— EN 14811, *Railway applications – Track – Special purpose rail – Grooved and associated construction*;

— EN 15594, *Railway applications – Track – Restoration of rails by electric arc welding*;

— prEN xxxxx, *Railway applications – Track – Forged rail transitions.*

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

Introduction

This Introduction provides an explanation of the concepts, and reasoning considered for this standard.

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 take into account performance requirements. They also include typical results from relevant acceptance tests.

The acceptance tests control those characteristics of the rail steel and rail that are of relevance to the production of high quality rails including heat treated rails and the demands of the railway.

To ensure the supply of high quality rails, some restrictions on production processes are considered.

The performance based standard applies to all procurements falling inside the requirements of the European Procurement Directive (93/38/EEC of 14th June 1993), 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 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.

The standard includes a 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.

1 Scope

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

Nine pearlitic steel grades are specified covering a hardness range of 200 HBW to 440 HBW and include non heat treated non alloy steels, non heat treated alloy steels, and heat treated non alloy steels and heat treated alloy steels .

There are 23 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 10163-1, *Delivery requirements for surface condition of hot-rolled steel plates, wide flats and sections — Part 1: General requirements*

EN 10247, *Micrographic examination of the non-metallic inclusion content of steels using standard pictures*

CEN/TR 10261, *Iron and steel — Review of available methods of chemical analysis*

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)*

EN ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature (ISO 6892-1:2009)*

EN ISO 14284, *Steel and iron — Sampling and preparation of samples for the determination of chemical composition (ISO 14284:1996)*

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

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

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

ASTM E399, *Standard test method for linear-elastic plane-strain fracture toughness K_{Ic} 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. 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 may 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
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 test
special test 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 test
test carried out as part of the process and product control system, normally on a heat, sequence or tonnage basis

3.10
rail running surface
curved surface of the rail head. 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 tender or order:

a) rail profile (see Annex A);

b) steel grade (see Clause 5);

c) profiles class, ‘X’ or ‘Y’ (see 9.2.1);

d) straightness class ‘A’ or ‘B’ of rail as specified in 9.2.2;

e) length(s) of rail (see Table 9);

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 treatment to be applied to bolt holes and corresponding special tolerances for bolt holes (see 9.2.3);

h) cold stamping on the cut face (see 7.4.3);

i) paint code requirements (see 7.4.4).

5 Steel grades

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

For the steel grades in Table 1, the steel names and steel numbers were allocated in accordance with EN 10027-1 and EN 10027-2, respectively.

Table 1 — Steel grades

Steel grade [a]		Hardness range (HBW)	Description	Branding lines
Steel name	Steel number			
R200	1.0521	200 to 240	Non-alloy (C-Mn) Non heat treated	No branding lines
R220	1.0524	220 to 260	Non-alloy (C-Mn) Non heat treated	
R260	1.0623	260 to 300	Non-alloy (C-Mn) Non heat treated	
R260Mn	1.0624	260 to 300	Non-alloy (C-Mn) Non heat treated	
R320Cr	1.0915	320 to 360	Alloy (1 %Cr) Non heat treated	
R350HT	1.0631	350 to 390 [b]	Non-alloy (C-Mn) Heat treated	
R350LHT	1.0632	350 to 390 [b]	Non-alloy (C-Mn) Heat treated	
R370CrHT	1.0992	370 to 410	Alloy (C-Mn) Heat treated	
R400HT	1.1254	400 to 440	Non-alloy (C-Mn) Heat treated	

[a] See Table 5 a) and Table 5 b) for chemical composition/mechanical properties.
[b] See Table 6 for hardness requirements.

6 Profile drawings/properties/mass

Rail profiles, dimensions, properties and linear masses shall be in accordance with Annex A. The tolerances of certain dimensions shall be as given in Table 7. All other quantities are informative only.

NOTE Linear masses have been calculated based on the density of steel of 7,85 kg/dm^3.

7 Manufacture

7.1 Product integrity

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.

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

7.2 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) identification of the mill;

b) steel grade as shown in Table 1;

c) last two figures of the year of manufacture;

d) rail profile identification as shown in Annex A.

EXAMPLES

ROLLING MILL ‾‾ ____ 07 60 E1

(60 E1 profile rail rolled 2007, non-alloy rail steel grade R260).

ROLLING MILL _______ _______ 07 60 E1

(60 E1 profile rail rolled 2007, non-alloy heat treated rail steel grade R350HT).

NOTE The sequence of the branding marks is at the discretion of the manufacturer.

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 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 1.

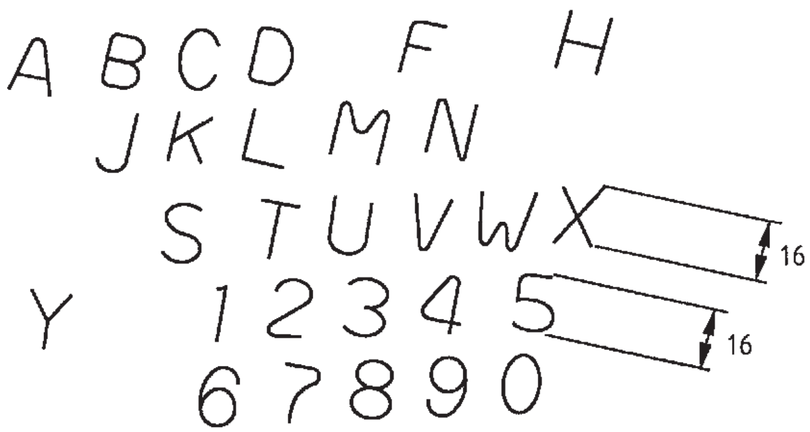


Figure 1 — Design of letters and numbers on a 10° angle for rail stamps

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

c) 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

The purchaser shall specify their requirements for any colour coding or special marking instructions and their position on the rail at the time of enquiry or order.

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 9.1.3.2.

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.

The manufacturer shall only carry out testing on the 60E1 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 9.1.9.2).

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 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 value K_{Ic} (MPa m$^{1/2}$)
R200 and R220	30	35
R260 and R260Mn	26	29
R320Cr	24	26
R350HT	30	32
R350LHT, R370CrHT, R400HT	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 ISO 12108.

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	ΔK = 10 MPa m^{½}	ΔK = 13,5 MPa m^{½}
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;
- strain cycle shall be symmetrical about the initial, zero load.

8.4.4 Qualifying criteria

For a total strain amplitude of 0,001 35, the 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.

8.5 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 9.1.9.

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).

8.7.3 The results of the predictive equations shall be compared with experimentally determined tensile strength and elongation results as described in 9.1.9. 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 a minimum of the last 100 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) manufacturer shall carry out an investigation;

b) problem will be resolved by the manufacturer taking appropriate corrective action;

c) 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 8.7.1. 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 9.1.3 to 9.1.9 inclusive. All rails supplied shall meet the requirements of Clause 9.

9.1.2 Sampling and preparation of samples and test pieces

Sampling and sample preparation for chemical analysis shall be carried out in accordance with EN ISO 14284, unless otherwise specified in 9.1.3.

For sampling and test piece preparation for all other tests, see 9.1.4 to 9.1.9.

9.1.3 Chemical composition

9.1.3.1 General

The chemical composition of the liquid steel 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) and Table 5 b).

The choice of the suitable physical or chemical analytical method for the product analysis shall be at the discretion of the manufacturer. In cases of dispute, the analysis method shall be agreed taking into account the relevant existing European Standards. The available European Standards are given in CEN/TR 10261.

9.1.3.2 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 5 a).

Table 4 — Testing frequency

Test (on)	Relevant sub-clause	Steel grades	
		R200, R220, R260, R260Mn, R320Cr	R350HT, R350LHT, R370CrHT, R400HT
Chemical composition	9.1.3	One per heat	One per heat
Hydrogen	9.1.3.2	One per heat (2 tests from first heat in sequence)	One per heat (2 tests from first heat in sequence)
Total oxygen	9.1.3.3	One per sequence [a]	One per sequence [a]
Microstructure	9.1.4	Not required for grades R200, R220 and R260 One per 1 000 tonnes or part thereof for grades R260Mn and R320Cr	One per 100 tonnes of heat treated rail [a,c]
Decarburisation	9.1.5	One per 1 000 tonnes or part thereof [a,b]	One per 500 tonnes of re-heated and mill heat treated [a,c]
Oxide cleanness	9.1.6	One per sequence [b]	One per sequence [b or c]
Sulfur print	9.1.7	One per 500 tonnes or part thereof [a,b]	One per 500 tonnes or part thereof [a,b or c]
Hardness	9.1.8	One per heat [a,b]	One per 100 tonnes of heat treated rail [a,c]
Tensile	8.7 and 9.1.9	One calculation per heat/one test per 2 000 tonnes[a,b]	One test 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 and mechanical properties

Steel grade		% by mass									10^{-4} % (ppm) by mass max.		Tensile strength R_m min.	Elongation A min.	Hardness of the rail running surface, centre line[c]
Steel name	Sample	C	Si	Mn	P max.	S max.	Cr	Al max	V max	N max	O[a]	H[b]	MPa	%	HBW
R200	Liquid	0,40 to 0,60	0,15 to 0,58	0,70 to 1,20	0,035	0,035	≤ 0,15	0,004	0,030	0,009	20	3,0			
	Solid	0,38 to 0,62	0,13 to 0,60	0,65 to 1,25	0,040	0,040	≤ 0,15	0,004	0,030	0,010	20	3,0	680	14	200 to 240
R220	Liquid	0,50 to 0,60	0,20 to 0,60	1,00 to 1,25	0,025	0,025	≤ 0,15	0,004	0,030	0,009	20	3,0			
	Solid	0,48 to 0,62	0,18 to 0,62	0,95 to 1,30	0,030	0,030	≤ 0,15	0,004	0,030	0,010	20	3,0	770	12	220 to 2**60**
R260	Liquid	0,62 to 0,80	0,15 to 0,58	0,70 to 1,20	0,025	0,025	≤ 0,15	0,004	0,030	0,009	20	2,5			
	Solid	0,60 to 0,82	0,13 to 0,60	0,65 to 1,25	0,030	0,030	≤ 0,15	0,004	0,030	0,010	20	2,5	880	10	260 to 300
R260Mn	Liquid	0,55 to 0,75	0,15 to 0,60	1,30 to 1,70	0,025	0,025	≤ 0,15	0,004	0,030	0,009	20	2,5			
	Solid	0,53 to 0,77	0,13 to 0,62	1,25 to 1,75	0,030	0,030	≤ 0,15	0,004	0,030	0,010	20	2,5	880	10	260 to 300
R320Cr	Liquid	0,60 to 0,80	0,50 to 1,10	0,80 to 1,20	0,020	0,025	0,80 to 1,20	0,004	0,18	0,009	20	2,5			
	Solid	0,58 to 0,82	0,48 to 1,12	0,75 to 1,25	0,025	0,030	0,75 to 1,25	0,004	0,20	0,010	20	2,5	1 080	9	320 to 360
R350HT	Liquid	0,72 to 0,80	0,15 to 0,58	0,70 to 1,20	0,020	0,025	≤ 0,15	0,004	0,030	0,009	20	2,5			
	Solid	0,70 to 0,82	0,13 to 0,60	0,65 to 1,25	0,025	0,030	≤ 0,15	0,004	0,030	0,010	20	2,5	1 175	9	350 to 390
R350LHT	Liquid	0,72 to 0,80	0,15 to 0,58	0,70 to 1,20	0,020	0,025	≤ 0,30	0,004	0,030	0,009	20	2,5			
	Solid	0,70 to 0,82	0,13 to 0,60	0,65 to 1,25	0,025	0,030	≤ 0,30	0,004	0,030	0,010	20	2,5	1 175	9	350 to 390
R370CrHT	Liquid	0,70 to 0,82	0,40 to 1,00	0,70 to 1,10	0,020	0,020	0,40 to 0,60	0,004	0,030	0,009	20	1,5			
	Solid	0,68 to 0,84	0,38 to 1,02	0,65 to 1,15	0,025	0,025	0,35 to 0,65	0,004	0,030	0,010	20	1,5	1.280	9	370 to 410
R400HT	Liquid	0,90 to 1,05	0,20 to 0,60	1,00 to 1,30	0,020	0,020	≤ 0,30	0,004	0,030	0,009	20	1,5			
	Solid	0,88 to 1,07	0,18 to 0,62	0,95 to 1,35	0,025	0,025	≤ 0,30	0,004	0,030	0,010	20	1,5	1.280	9	400 to 440

[a] See 9.1.3.3.

[b] See 9.1.3.2.

[c] See Figure 8.

Table 5 b) — Maximum residual elements, % 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, R370CrHT, R400HT	0,02	0,10	0,15	0,030	0,020	0,025	0,04	0,35	0,20 (Mo + Ni + Cu + V)

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); in these cases, all heats shall be tested in the rail form, or the manufacturer shall calculate the hydrogen content with a documented model of hydrogen diffusion taking into account the time – temperature evolution of the blooms during the isothermal treatment process. In case of dispute, the hydrogen content shall be tested in the rail form.

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 after corrective treatment fails to meet the requirements stated in Table 5 a) the heat shall be rejected.

9.1.3.3 Determination of total oxygen content

9.1.3.3.1 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.

9.1.3.3.2 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.

9.1.3.3.3 Measurement

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

9.1.4 Microstructure

9.1.4.1 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.

9.1.4.2 Grade R260Mn, R320Cr R350HT, R350LHT, R370CrHT and R400HT

The microstructure shall be fully pearlitic with no martensite, bainite or grain boundary cementite. In the case of the grade R260Mn, grain boundary ferrite may occur.

9.1.5 Decarburisation

The decarburisation depth shall 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 9.1.8 shall be performed at three points. None of the results of hardness obtained shall be lower than the minimum value specified for the grade, reduced by 7 HBW (example: 253 HBW for grade R260).

Alternatively to the hardness test, or if there are any doubts regarding the conformity with the requirements on decarburization, metallographic investigations shall be carried out according to the manufacturer's decision or upon request of the purchaser.

Photomicrographs showing the depth of decarburisation allowed are shown in Figure 6.

Figure 7 defines the rail head surface for decarburisation checks.

No closed ferrite network shall be observed below 0,5 mm depth measured anywhere on the rail head surface.

9.1.6 Oxide cleanness

Samples shall be prepared and assessed in accordance with EN 10247. 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. For orders less than 5 000 tonnes, only one sample with a K3 greater than 10 and less than 20 is allowed.

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 8.

9.1.7 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.

9.1.8 Hardness

Brinell hardness tests (HBW 2,5 / 187,5) shall be carried out in accordance with EN ISO 6506-1 at the frequency shown in Table 4.

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 6 for the relevant grade. The testing positions are shown in Figure 9.

For the steel grades R200, R220, R260, R260Mn and R320Cr the hardness shall only be tested for position RS.

In the case of the heat treated rails, the following shall apply:

$HBW_2 > HBW_3 + 0,4 (HBW_1 – HBW_3)$,

where HBW_1, HBW_2 and HBW_3 are the mean hardness values at position 1, 2 or 3 respectively. Also the difference between any of the three positions shall be no more than 30 HBW.

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

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

Table 6 — Hardness testing positions and requirements

Position	Rail Steel Grade						
	R200	R220	R260, R260Mn	R320Cr	R350HT, R350LHT	R370CrHT	R400HT
	Hardness (HBW 2.5)						
RS[a]	200 to 240	220 to 260	260 to 300	320 to 360	350 to 390[b]	370 to 410[c]	400 to 440[d]
1	[e]	[e]	[e]	[e]	≥ 340 min	≥ 360	≥ 390
2					≥ 331 min	≥ 350	≥ 380
3					≥ 321 min	≥ 340	≥ 370
4					≥ 340 min	≥ 360	≥ 390

[a] RS = Point on the centre line rail running surface.

[b] 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.

[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.

[e] Not relevant.

9.1.9 Tensile tests

9.1.9.1 General

The tensile test shall be carried out with the test frequency specified in Table 4. Test samples from the rail shall be taken as given in Figure 5. Results obtained shall comply with the values given in Table 5 a).

9.1.9.2 Method of test

The manufacturer shall determine the tensile properties in accordance with EN ISO 6892-1 using a proportional circular test piece of 10 mm diameter.

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

9.1.10 Retest procedures

If any test fails to meet the requirements of 9.1.3 to 9.1.9 (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 9.1.3.2 and 9.1.3.3 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 a) 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 7.

Table 7 — Profile tolerances

* Reference points (see Figure E.1)			Profile class (tolerances in mm)		Gauge, figure number (see Annex E)
Location/property		Symbol	X	Y	
Height of rail[a]	< 165 mm	*H	± 0,5	+ 0,5 – 1,0	E.3
	≥ 165 mm		± 0,6	+ 0,6 – 1,1	
Crown profile	– Class A straightness	*C	+ 0,6 – 0,3	+ 0,6 – 0,3	E.4
	– Class B straightness		± 0,6	± 0,6	
Width of rail head		*WH	± 0,5	+ 0,6 – 0,5	E.5
Rail asymmetry		*As	± 1,2	± 1,2	E.6, E.7
Height of fishing	< 165 mm	*HF	± 0,5	± 0,5	E.8
	≥ 165 mm		± 0,6	± 0,6	
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.

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 8. Unless otherwise agreed, rails < 54 kg/m are delivered with class B tolerances.

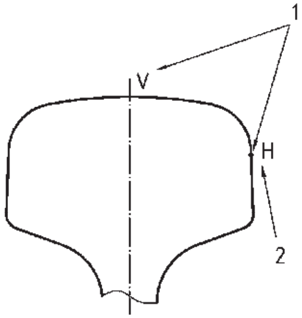
If the rail shows evidence of twist, this shall be checked in accordance with Figure 10 by inserting feeler gauges between the base of the rail and the rail skid nearest the rail end with the rail being laid head up on an inspection bed. If the gap exceeds 2,5 mm the rail shall be rejected.

Rotational twist in the end metre of the rail as measured by the gauge illustrated in Figure 11, shall not exceed 0,2°.

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

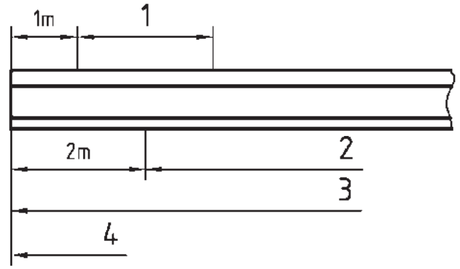
In cases of dispute on the results of the automatic technique, rail flatness shall be verified using a straight edge as shown in Table 8.

Table 8— Straightness, surface flatness and twist tolerances



Key

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



Key

1 overlap
2 body
3 whole rail
4 end "E"

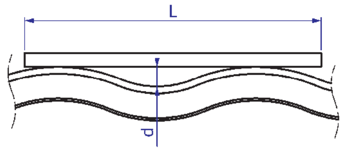
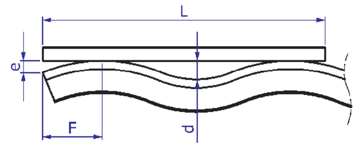
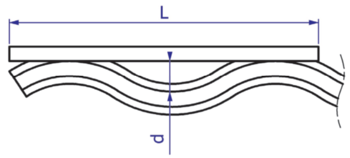
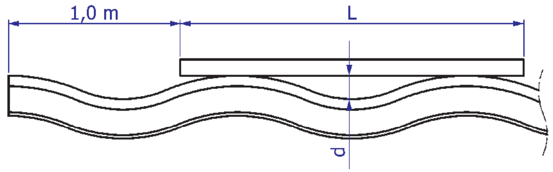
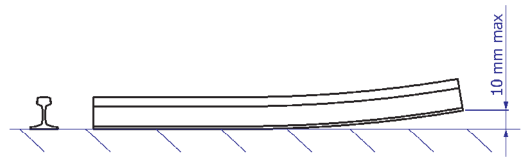
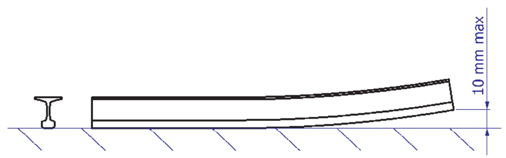
Location/Dimensional properties		Class B		Class A		
		d	*L*	*d*	*L*	
BODY [a]	Vertical flatness V	≤ 0,4 mm and ≤ 0,3 mm	3 m [c] and 1 m [c]	≤ 0,3 mm and ≤ 0,2 mm	3 m [c] and 1 m [c]	[b] 
	Horizontal flatness *H*	≤ 0,6 mm	1,5 m [c]	≤ 0,45 mm	1,5 m [c]	
ENDS [a]	End "E"	1,5 m		2 m		[b]  If $e > 0$ $F \geq 0,6$ m
	Vertical straightness	≤ 0,5 mm and $e \leq 0,2$ mm	1,5 m	≤ 0,4 mm and ≤ 0,3 mm and $e \leq 0,2$ mm	2 m and 1 m [d]	
	Horizontal straightness	≤ 0,7 mm	1,5 m	≤ 0,6 mm and ≤ 0,4 mm	2 m and 1 m [d]	[b] 

Table 8 (*continued*)

Location/Dimensional properties		Class B		Class A		
		d	*L*	*d*	*L*	
OVERLAP[a]	Length of overlap	1,5 m		2 m		[b] 
	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]	
SWEEP (whole rail)	Upsweep and downsweep	10 mm[e]		10 mm[e]		 
TWIST	Whole rail	max. gap of 2,5 mm				(see also 9.2.2 and Figure 9)
	End (1 m)	Max. rotational twist of 0,2° and max. relative twist of 0,003 5 x c				(see also 9.2.2 and Figure 10)

[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 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 9.

Drilled holes and rail ends shall be deburred. For holes that are to be subject to special treatment, this treatment and the corresponding tolerances shall be specified (see 4 g)).

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 for internal quality and surface quality

9.4.1 Internal quality

9.4.1.1 All rails shall be ultrasonically tested by an automated process ensuring that the entire rail length and a specified cross-sectional area are inspected, leaving only a very small area untested. Untested ends shall be tested by an appropriate procedure or cropped off.

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

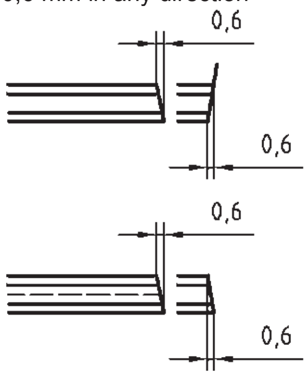
— at least 70 % of the head;

— at least 60 % of the web;

— the area of the foot specified in Figure 15.

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

Table 9 — Drilling and cutting tolerances

Number	Dimensional requirement	Tolerance
1	Drilling Diameter	
	≤ 30 mm	± 0,5 mm
	> 30 mm	± 0,7 mm
	Centring and positioning of the holes vertically and horizontally	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	± 3 mm
	> 24 m ≤ 40 m	± 4 mm
	> 40 m to 60 m	+/-10 mm
	> 60m:	+/-20 mm
	– other (undrilled or one end drilled)	± 1 mm/per metre of rail For special purpose undrilled rails the length tolerance is ± 6 mm up to 24 m and ± 10 mm for > 24 m rail.

[a] 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 automated equipment used shall be a minimum of 4 dB greater than the level required to detect the reference reflectors described in 9.4.1.4. After calibration with the reference reflectors, the signal-to-noise ratio of the automated equipment shall be at least 10 dB. 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.

Rails giving signals exceeding 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 signals and, if present, backwall echo signals.

9.4.1.4 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 in Figures 12, 13 and 14 respectively. Calibration rails for other profiles with calibration defects similar to those in accordance with Figures 12, 13 and 14 for 60E1 shall be available.

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

9.4.2 Surface quality

9.4.2.1 Requirements

a) Hot marks, protrusions and seams

Protrusions on the rail running surface or the underside of the foot and any protrusions affecting the fit of the fishplate at less than 1 m from the extremity of the delivered rail are not permitted.

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

— 0,35 mm for the rail 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 may be removed by dressing except those marks on the rail crown where a maximum of 3 per 40 m is allowed.

b) 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.

c) 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.

9.4.2.2 Inspection and dressing of surface imperfections

a) General inspection

All rails shall be visually or automatically inspected on all faces for surface imperfections. All rails shall comply with the acceptance criteria specified at 9.4.2.1. Dressing of imperfections shall be in accordance with 9.4.2.3.

b) Automated inspection

The rail shall be automatically inspected on the underside of the foot and on the head of the rail (running surface and sides) along its entire length.

The equipment used shall be able to detect artificial imperfections on the underside of the foot with sizes as shown in Table 10. For artificial imperfections, a tolerance of ± 0,1 mm shall apply.

Table 10 — Dimensions of test imperfections, in mm

Depth	Length	Width
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.

9.4.2.3 Dressing of surface imperfections

Imperfections exceeding the limits specified in 9.4.2.1 a) and 9.4.2.1 b) shall be dressed out. Any protrusions affecting the fit of the fishplate (see 9.4.2.1 a)) shall be dressed to shape.

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;

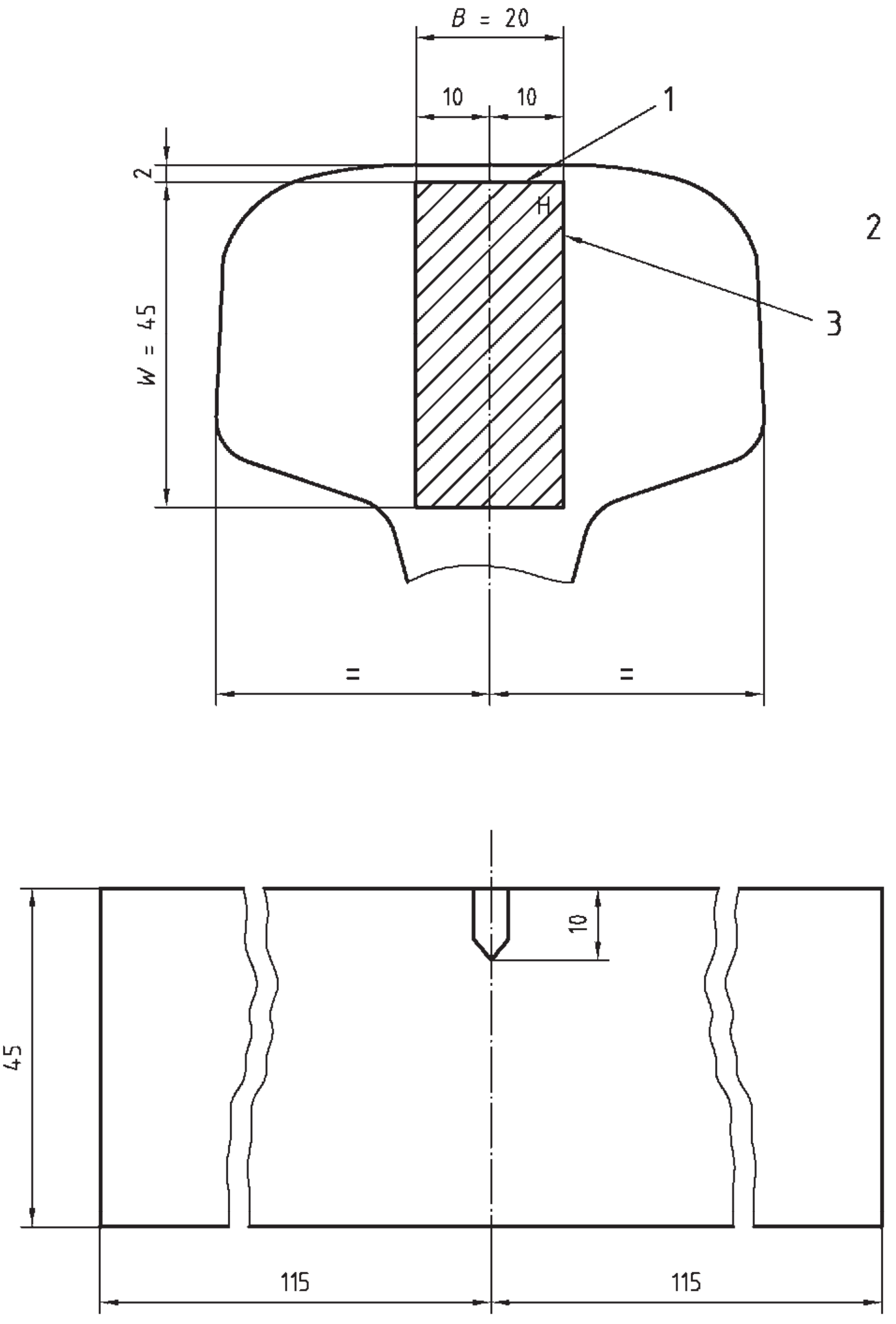
— 0,5 mm for the rest of rail.

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 7 and flatness tolerances shall be in accordance with Table 8.

9.4.3 Checking of automated testing equipment

A 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.

Dimensions in millimetres



Key

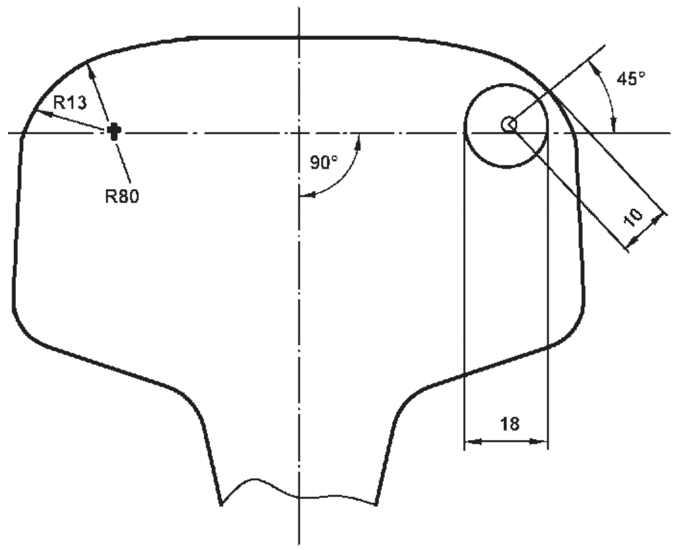
1 notch machined into this face

2 section through rail head

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

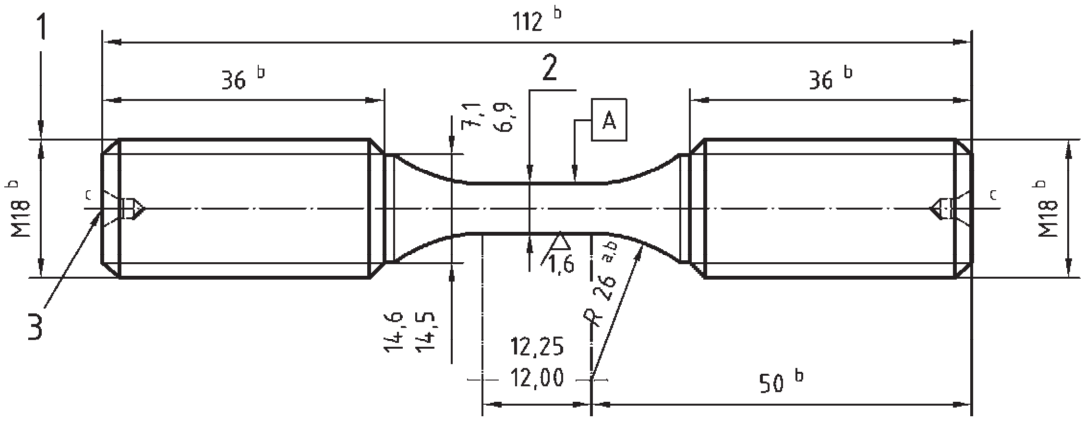
Figure 2 — Location and dimensions of fatigue crack growth test pieces

All dimensions in millimetres



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

○ location of the centre of the test piece



Key

1 screw threads (both ends) to be concentric with Ø *A* within 0,005 mm. Different forms (without threaded heads of test pieces) may also be used.

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

Figure 3 — Specimen for determining fatigue initiation life

Dimensions in millimetres

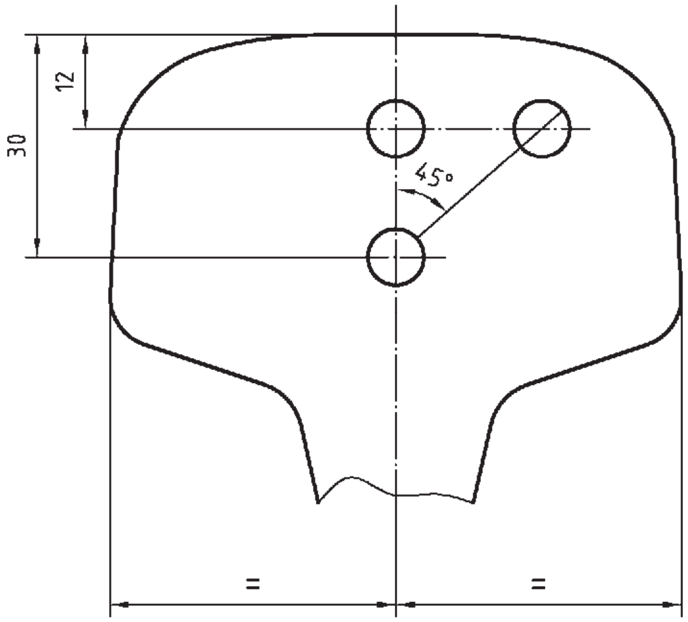
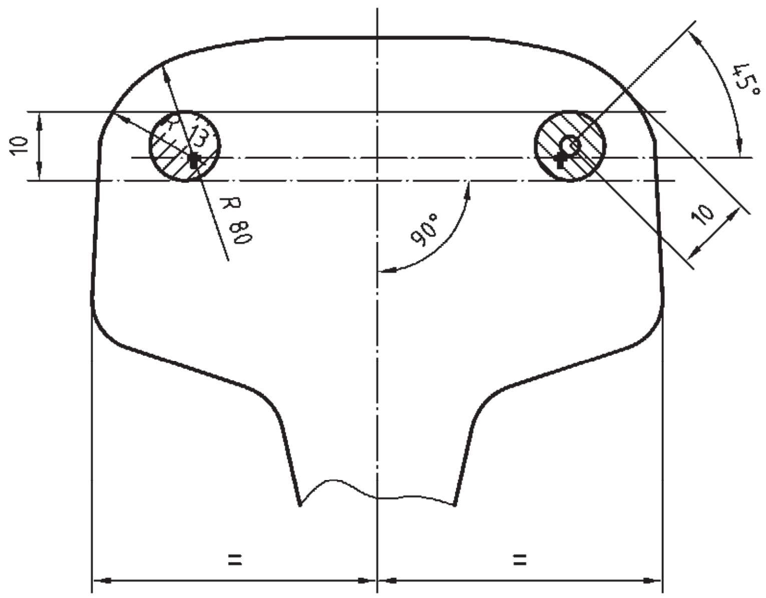


Figure 4 — Sampling positions in rail for total oxygen determination

Dimensions in millimetres



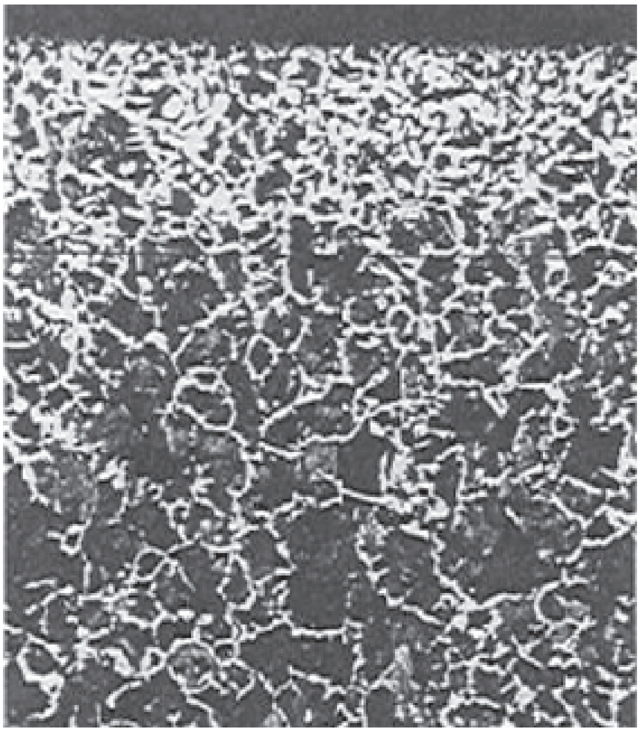
Key

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

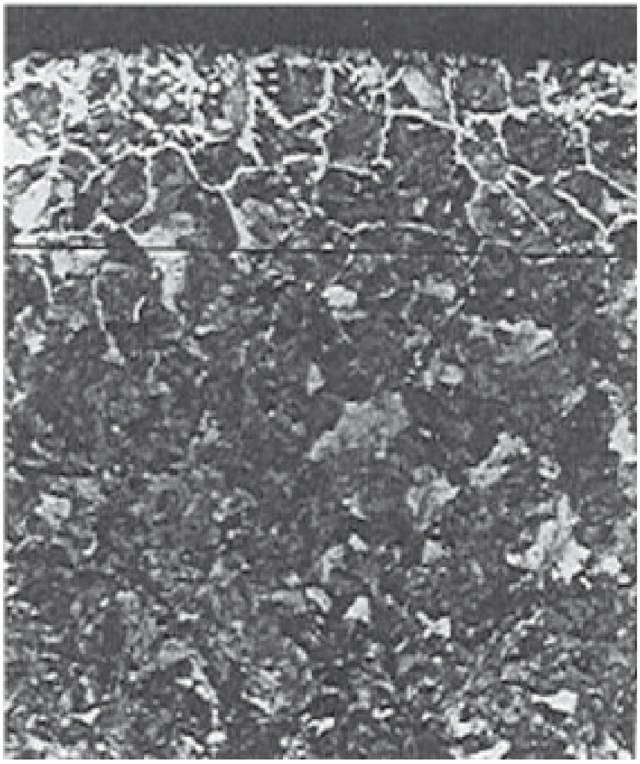
○ location at the centre of the tensile test piece

 area to be checked for microstructure

Figure 5 — Location of tensile test piece and microstructure checks

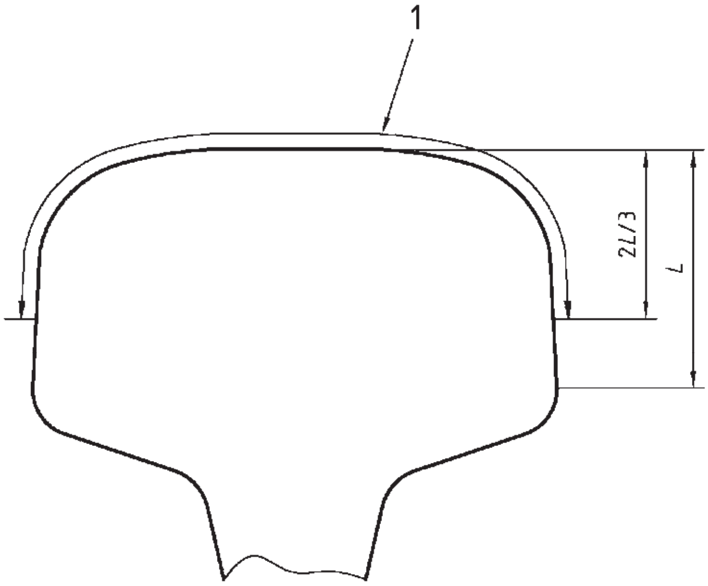


Grades R200 and R220



All grades other than R200 and R220

Figure 6 — Photomicrographs (x 100) showing depth of decarburisation allowed on the rail wear surface

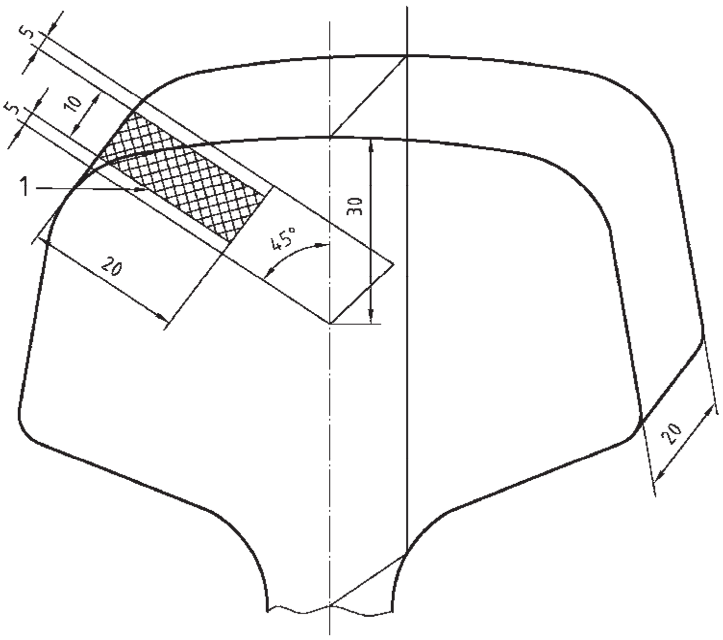


Key

1 decarburisation limits apply to this part of rail head

Figure 7 — Range of extent of rail head surface for decarburisation checks

Dimensions in millimetres

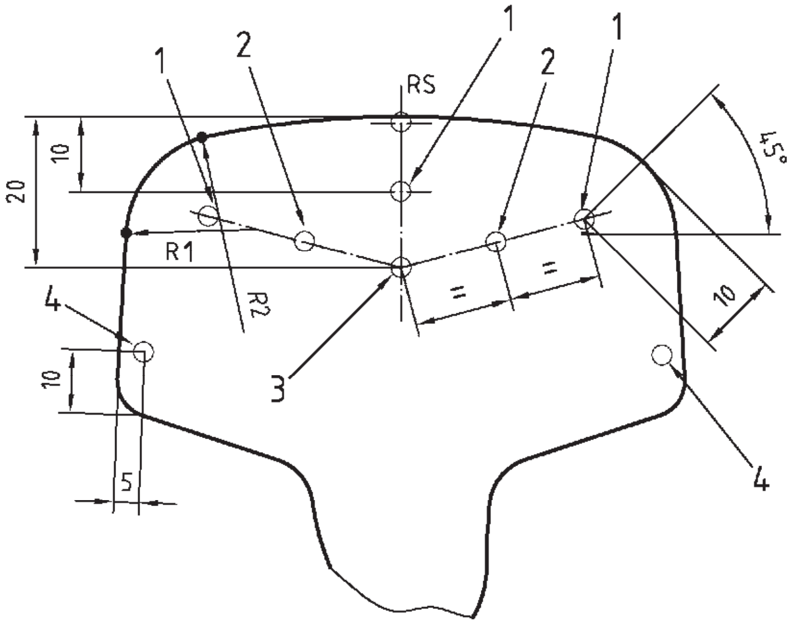


Key

1 face to be examined

Figure 8 — Oxide cleanness sampling position in rail head

Dimensions in millimetres



Key

1,2,3 and 4 location of hardness testing (see Table 6)

● exact intersecting points of the radii

Figure 9 — Hardness testing positions

Dimension in millimetres

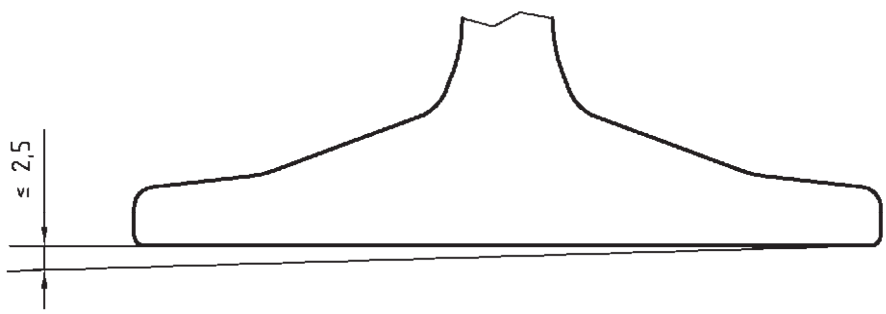
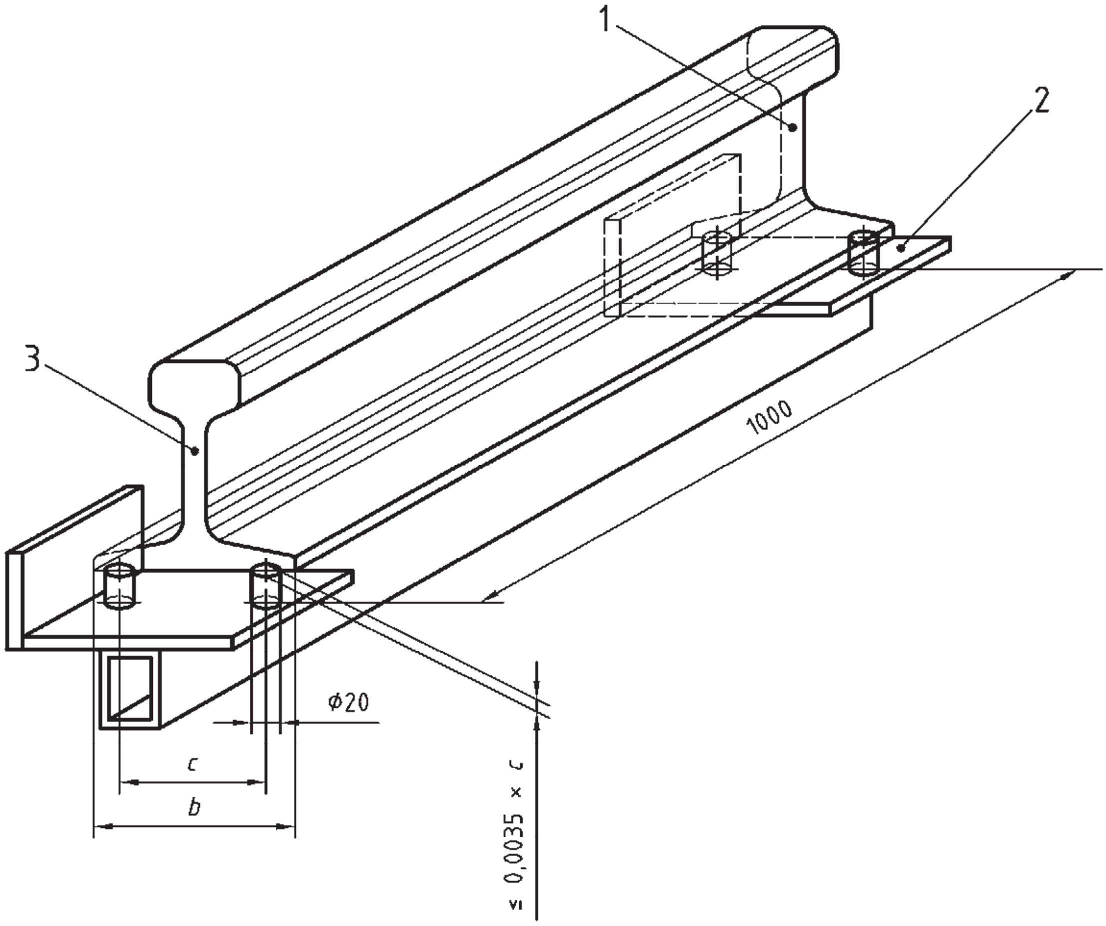


Figure 10 — Whole rail twist



Key

1 cross section 1 m away from the rail end

2 gauge

3 cross section at the rail end

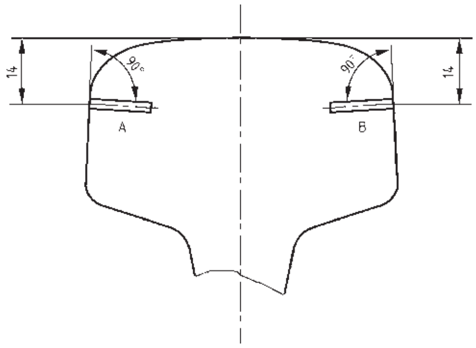
NOTE The relative twist between the cross-sections at the rail ends and the cross-sections 1 m away from each end should be measured with a specific gauge (1 m long) on each rail end using points on the under surface of the foot as measuring references, as explained above.

Dimensions in mm

Foot width b	Distance between contacts[a] c
$b < 130$	90
$130 \le b < 150$	110
$b \ge 150$	130
[a] diameter of contact surfaces: 20 mm.	

Figure 11 — Rail end twist

Dimensions in millimetres

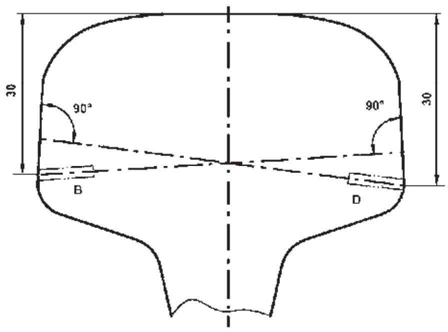


Key

A, C flat bottom holes

NOTE Both flat bottomed holes are 2 mm diameter and 15 mm deep.

Figure 12 a)



Key

B, D flat bottom holes

NOTE Both flat bottomed holes are 2 mm diameter and 15 mm deep.

Figure 12 b)

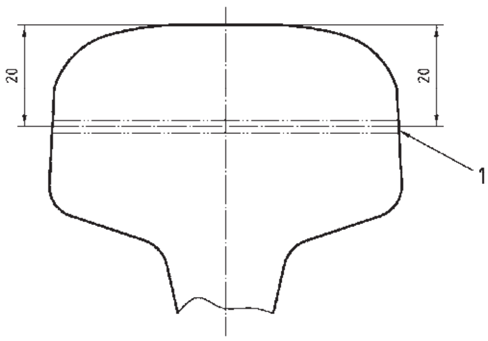


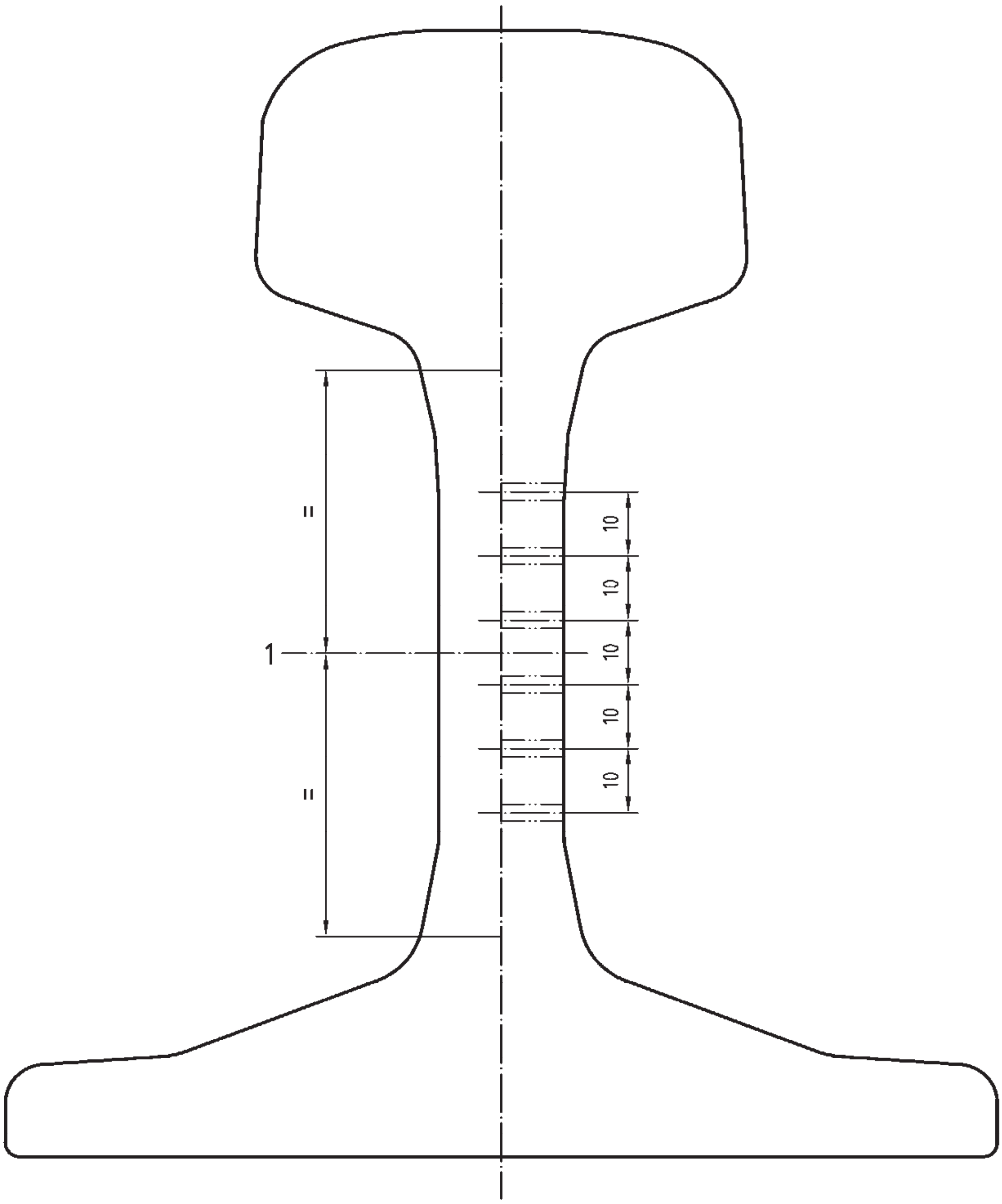
Figure 12 c)

Key

1 2 mm diameter through hole

Figure 12 — Location of artificial defects in rail head of 60E1 profile

All dimensions in millimetres measured from the centre line



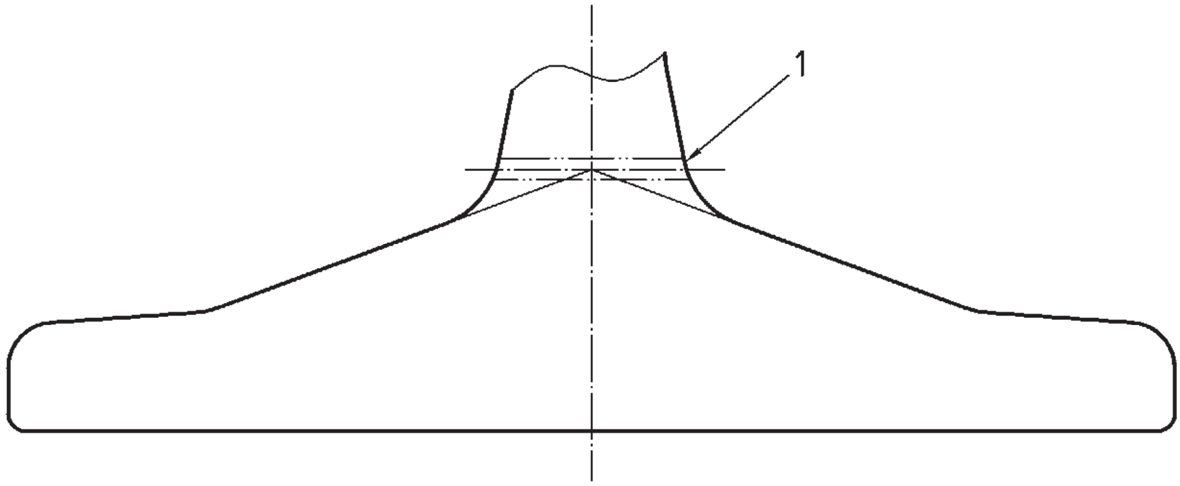
Key

1 centreline of web

NOTE 1 Flat bottomed holes are 2 mm diameter drilled to centre line of web.

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

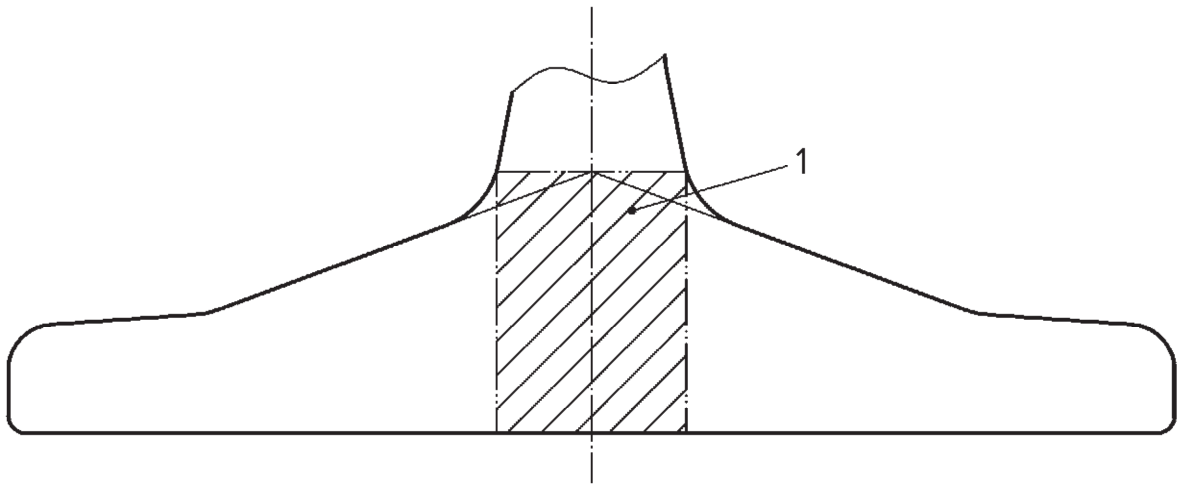
Figure 13 — Location of artificial defects in rail web of 60E1 profile



Key

1 2 mm diameter through hole

Figure 14 — Location of artificial defect in rail foot of 60E1 profile



Key

1 area to be tested

Figure 15 — Area to be tested in rail foot of 60E1 profile

Annex A
(normative)

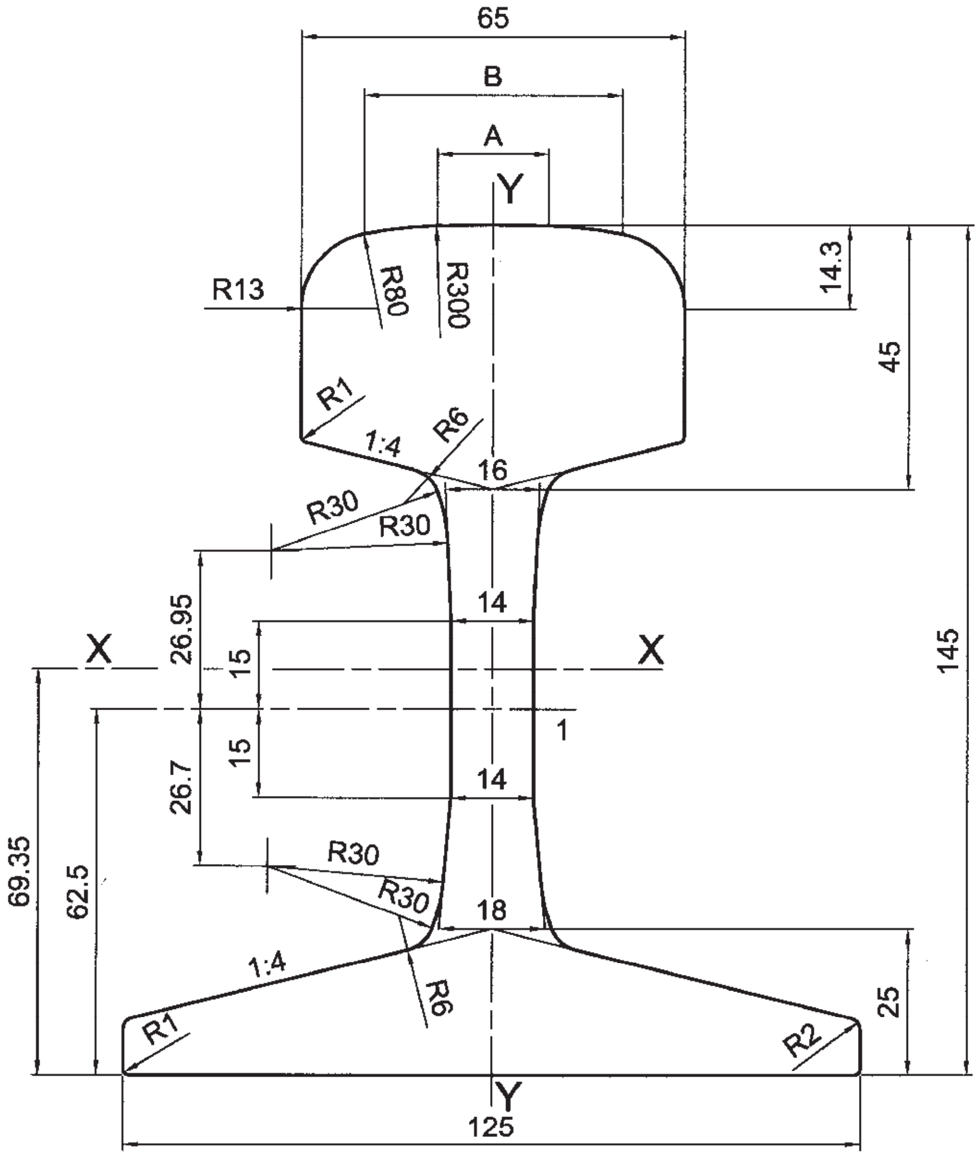
Rail profiles

The rail profiles listed in Table A.1 are designated and accurately dimensioned profiles developed from the previous less accurately dimensioned profiles listed. Table A.2 and Figure A.24 define the transition references.

Table A.1 — List of profiles and previous rail profiles

Figure No	Profile	Previous profile
A.1	46E1	SBB I
A.2	46E2	U33
A.3	46E3	NP 46
A.4	46E4	46 UNI
A.5	49E1	DIN S49
A.6	49E2	S49 T
A.7	49E5	-
A.8	50E1	U50E
A.9	50E2	50EB-T
A.10	50E3	BV 50
A.11	50E4	UIC 50
A.12	50E5	50 UNI
A.13	50E6	U 50
A.14	52E1	52 RATP
A.15	54E1	UIC 54
A.16	54E2	UIC 54 E
A.17	54E3	DIN S54
A.18	54E4	
A.19	54E5	54E1AHC
A.20	55E1	U55
A.21	56E1	BS 113lb BR Variant
A.22	60E1	UIC 60
A.23	60E2	-

Dimensions in millimetres



Key

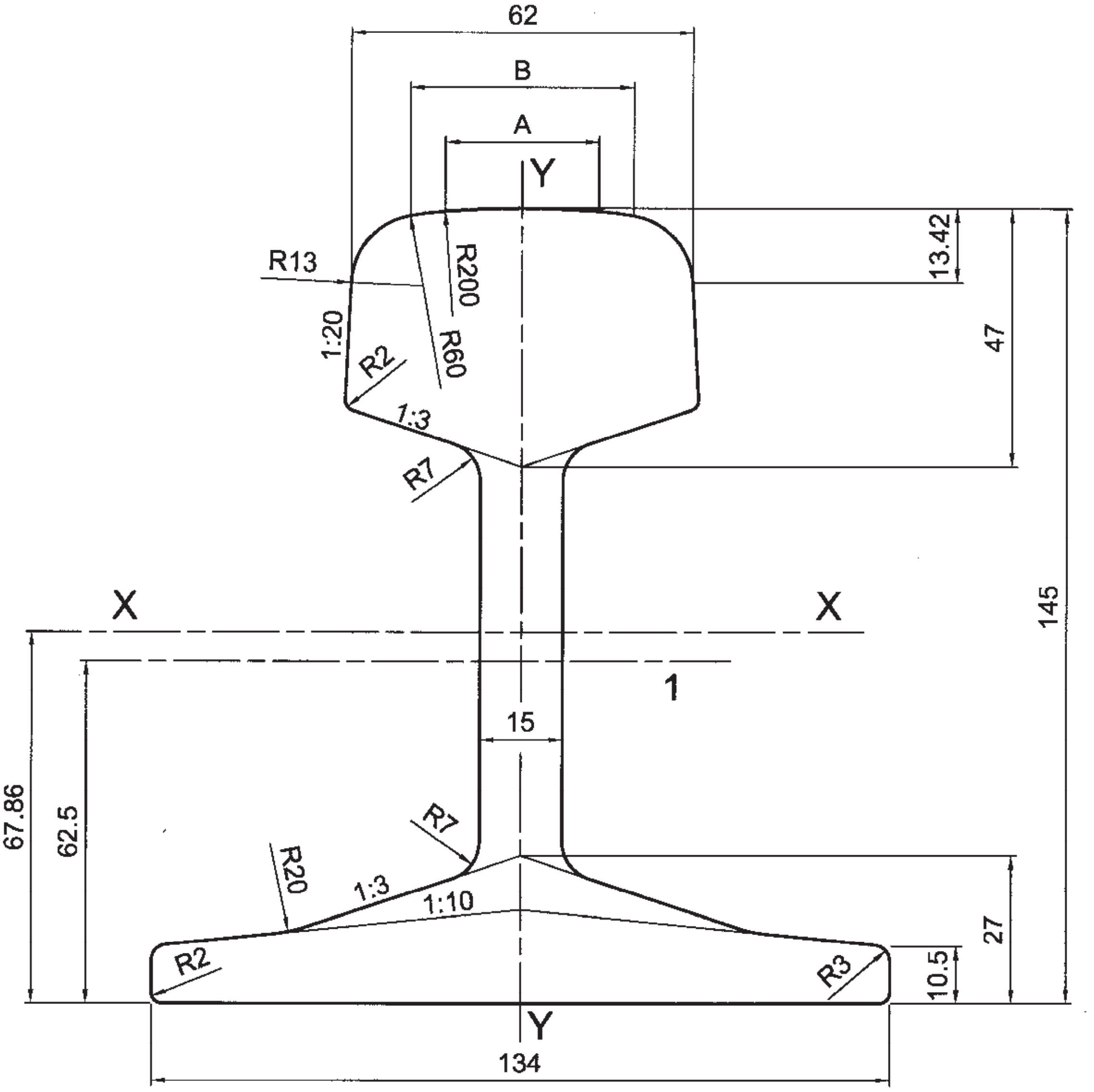
1 centre line of branding

Cross-sectional area	:	58,82	cm^2
Mass per metre	:	46,17	kg/m
Moment of inertia x-x axis	:	1 641,1	cm^4
Section modulus - Head	:	217	cm^3
Section modulus - Base	:	236,6	cm^3
Moment of inertia y-y axis	:	298,2	cm^4
Section modulus y-y axis	:	47,7	cm^3

Indicative dimensions : A = 18,881 mm
B = 43,881 mm

Figure A.1 — Rail profile 46E1

Dimensions in millimetres



Key

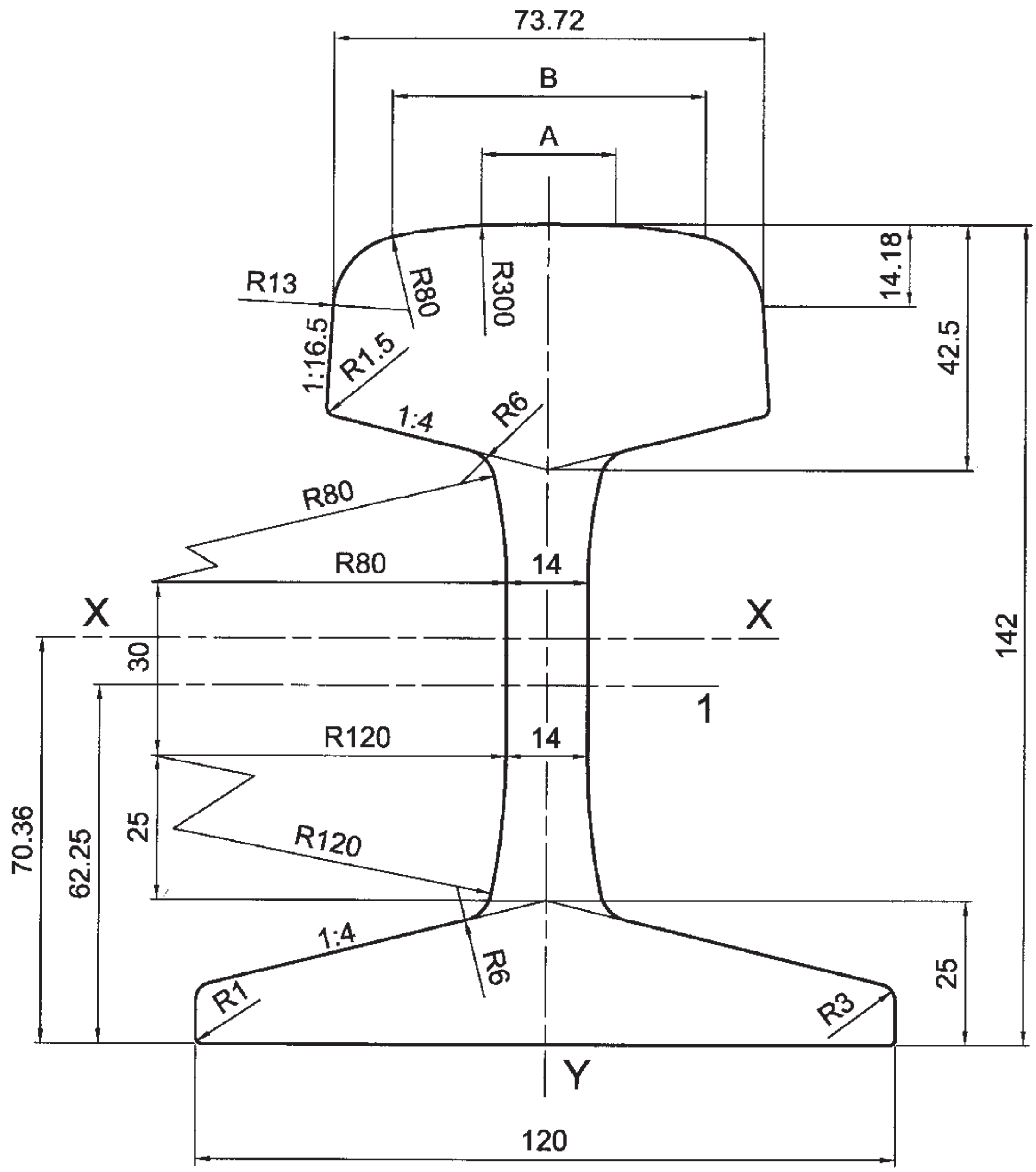
1 centre line of branding

cross-sectional area	:	58,94	cm^2
mass per metre	:	46,27	kg/m
moment of inertia x-x axis	:	1 642,7	cm^4
section modulus - Head	:	213	cm^3
section modulus - Base	:	242,1	cm^3
moment of inertia y-y axis	:	329,3	cm^4
section modulus y-y axis	:	49,1	cm^3

indicative dimensions : A = 27,946 mm
B = 40,588 mm

Figure A.2 — Rail profile 46E2

Dimensions in millimetres



Key

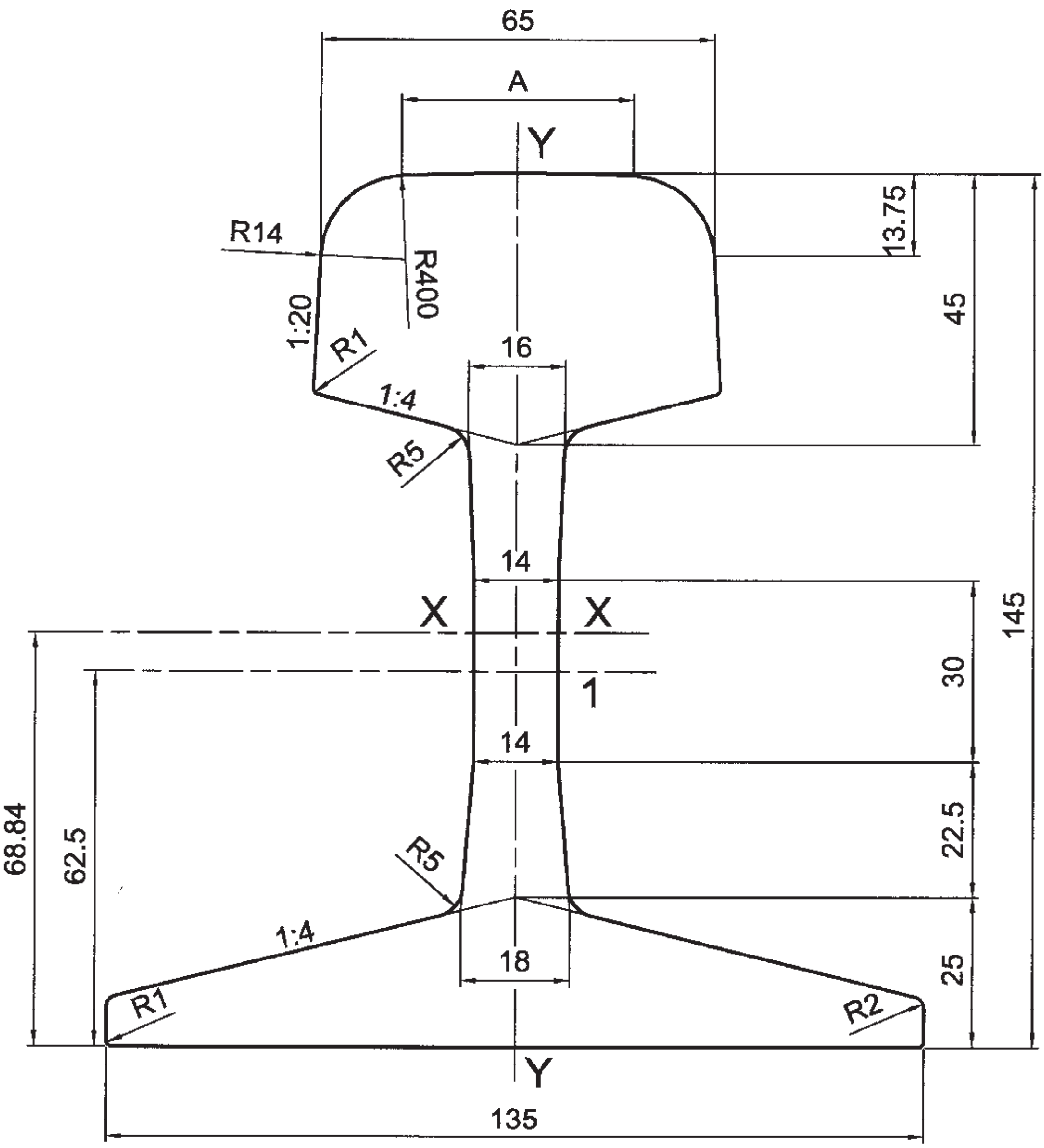
1 centre line of branding

cross-sectional area	:	59,44	cm^2
mass per metre	:	46,66	kg/m
moment of inertia x-x axis	:	1 605,9	cm^4
section modulus - Head	:	224,2	cm^3
section modulus - Base	:	228,2	cm^3
moment of inertia y-y axis	:	307,5	cm^4
section modulus y-y axis	:	51,3	cm^3

indicative dimensions : A = 23,015 mm
B = 53,761 mm

Figure A.3 — Rail profile 46E3

Dimensions in millimetres



Key

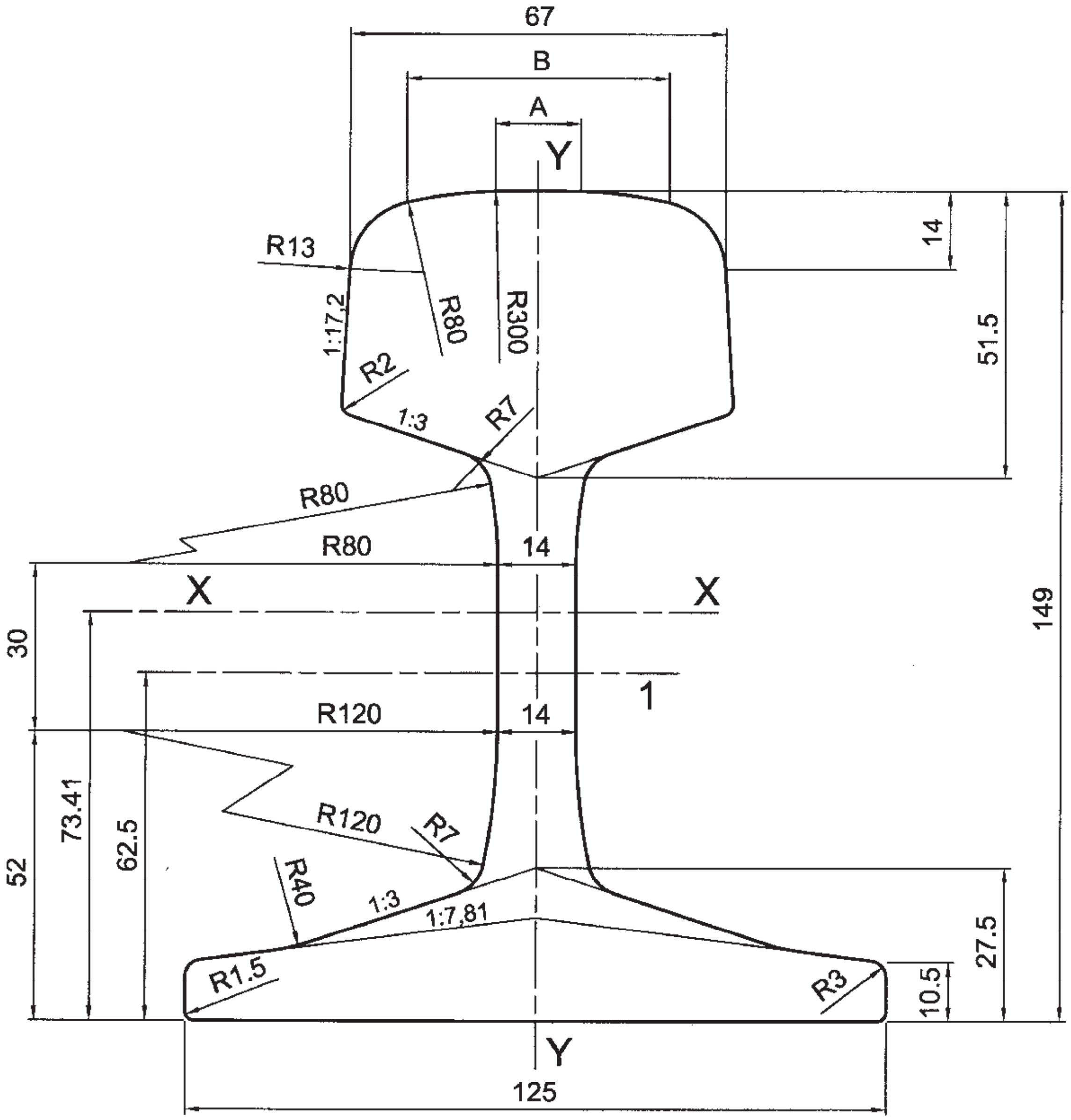
1 centre line of branding

cross-sectional area	:	59,78	cm^2
mass per metre	:	46,9	kg/m
moment of inertia x-x axis	:	1 688	cm^4
section modulus - Head	:	221,6	cm^3
section modulus - Base	:	245,2	cm^3
moment of inertia y-y axis	:	338,6	cm^4
section modulus y-y axis	:	50,2	cm^3

indicative dimensions : A = 38,378 mm

Figure A.4 — Rail profile 46E4

Dimensions in millimetres



Key

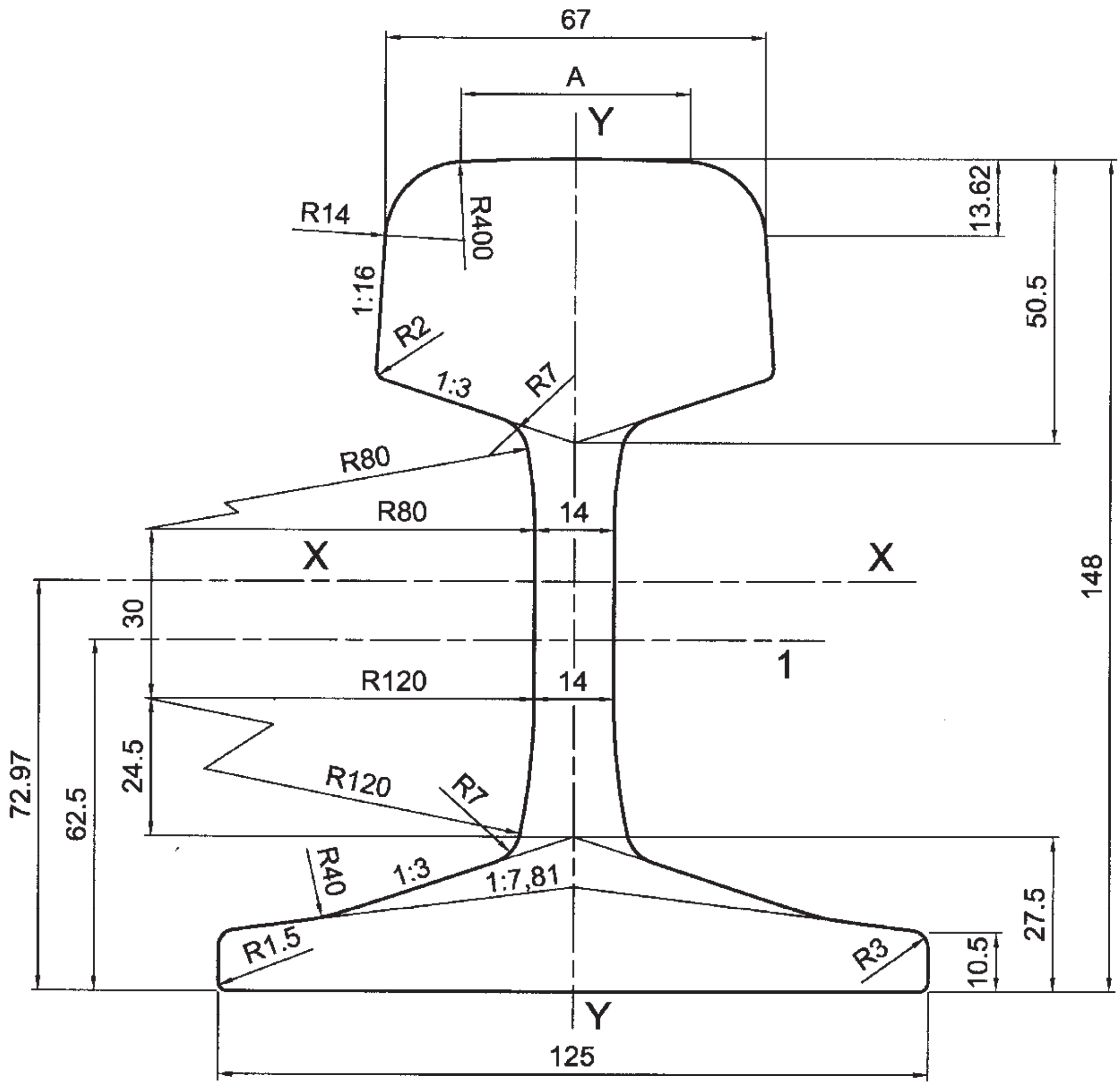
1 centre line of branding

cross-sectional area	:	62,92	cm^2
mass per metre	:	49,39	kg/m
moment of inertia x-x axis	:	1 816	cm^4
section modulus - Head	:	240,3	cm^3
section modulus - Base	:	247,5	cm^3
moment of inertia y-y axis	:	319,1	cm^4
section modulus y-y axis	:	51,0	cm^3

indicative dimensions: A = 15,267 mm
B = 46,835 mm

Figure A.5 — Rail profile 49E1

Dimensions in millimetres



Key

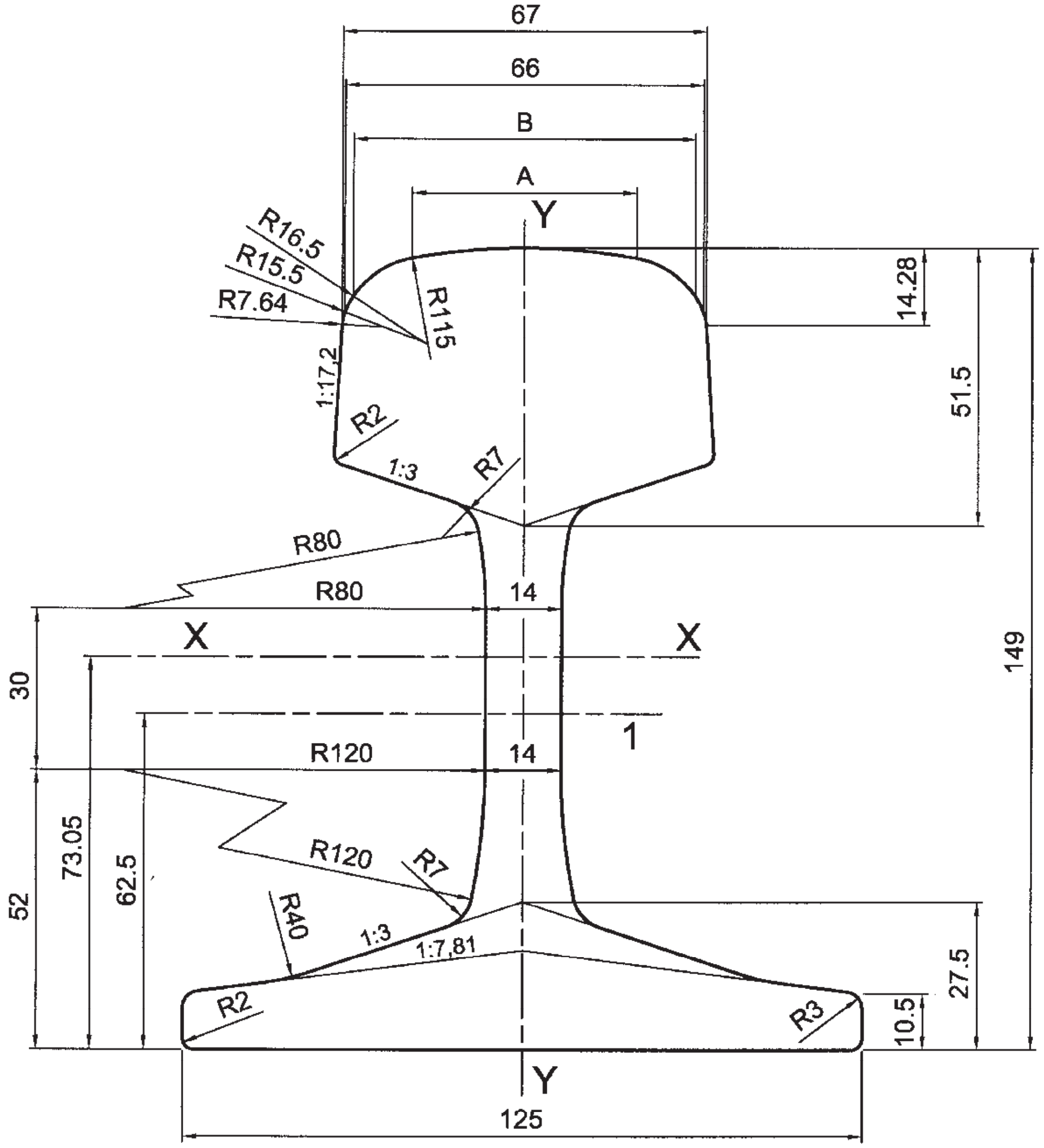
1 centre line of branding

cross-sectional area	:	62,55	cm^2
mass per metre	:	49,10	kg/m
moment of inertia x-x axis	:	1 796,3	cm^4
section modulus - Head	:	239,4	cm^3
section modulus - Base	:	246,2	cm^3
moment of inertia y-y axis	:	318,4	cm^4
section modulus y-y axis	:	50,9	cm^3

indicative dimensions: A = 40,471 mm

Figure A.6 — Rail profile 49E2

Dimensions in millimetres



Key

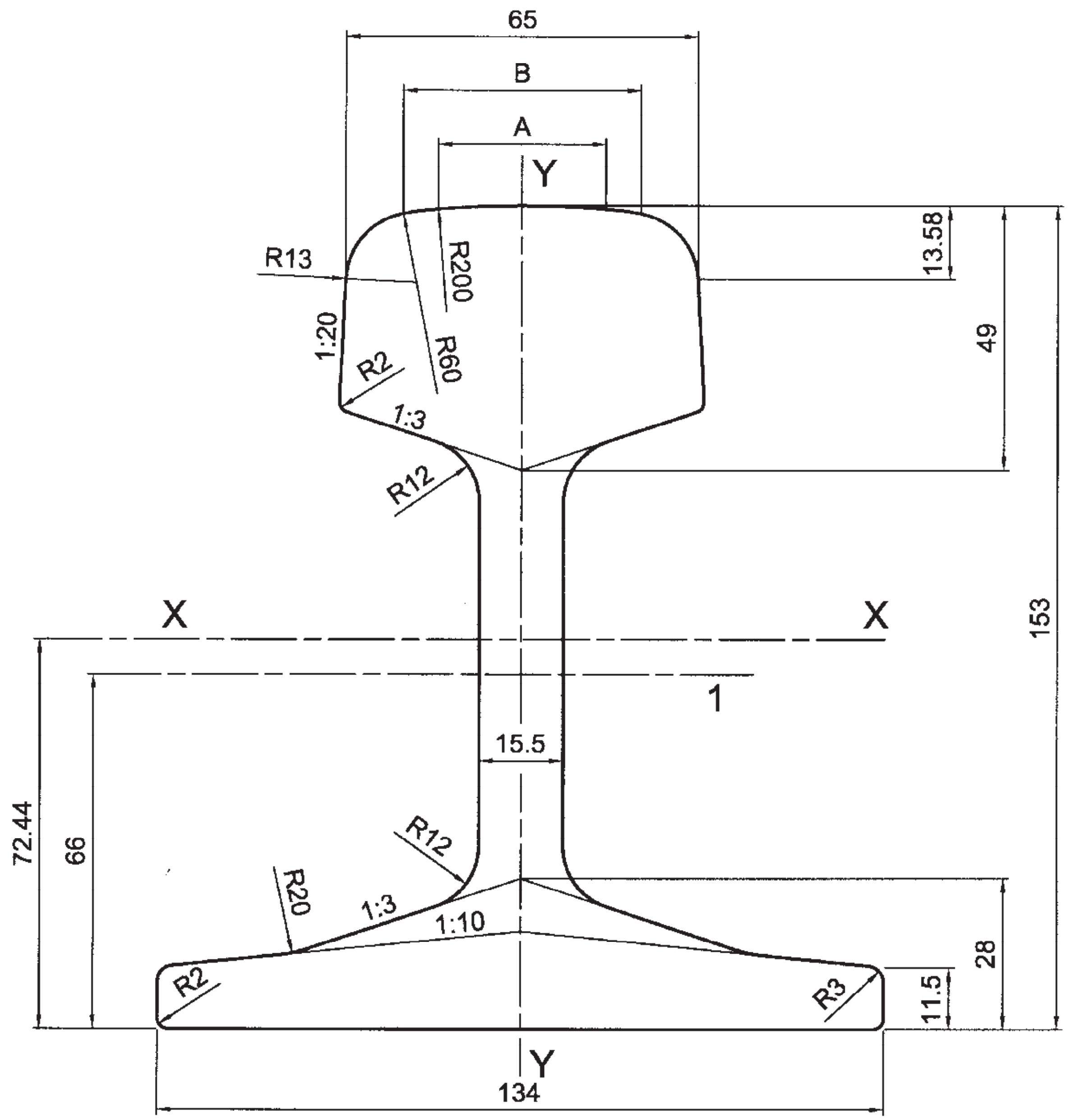
1 centre line of branding

cross-sectional area	:	62,59	cm^2
mass per metre	:	49,13	kg/m
moment of inertia x-x axis	:	1 799,7	cm^4
section modulus - Head	:	237,0	cm^3
section modulus - Base	:	246,4	cm^3
moment of inertia y-y axis	:	316,7	cm^4
section modulus y-y axis	:	50,7	cm^3

indicative dimensions: A = 41,342 mm
B = 62,980 mm

Figure A.7 — Rail profile 49E5

Dimensions in millimetres



Key

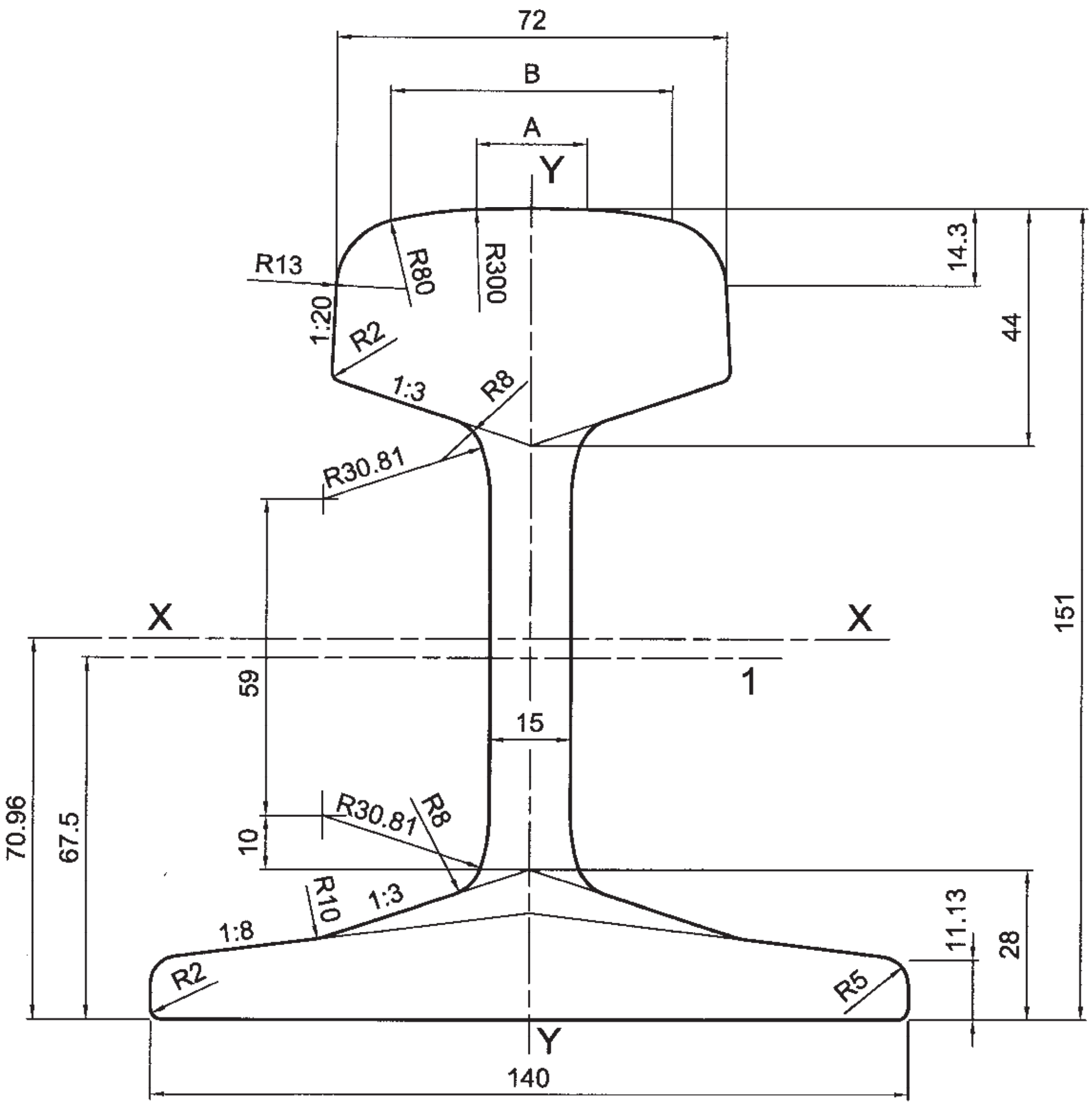
1 centre line of branding

cross-sectional area	:	64,16	cm^2
mass per metre	:	50,37	kg/m
moment of inertia x-x axis	:	1 987,8	cm^4
section modulus - Head	:	246,7	cm^3
section modulus - Base	:	274,4	cm^3
moment of inertia y-y axis	:	365	cm^4
section modulus y-y axis	:	54,5	cm^3

indicative dimensions: A = 30,942 mm
B = 43,838 mm

Figure A.8 — Rail profile 50E1

Dimensions in millimetres



Key

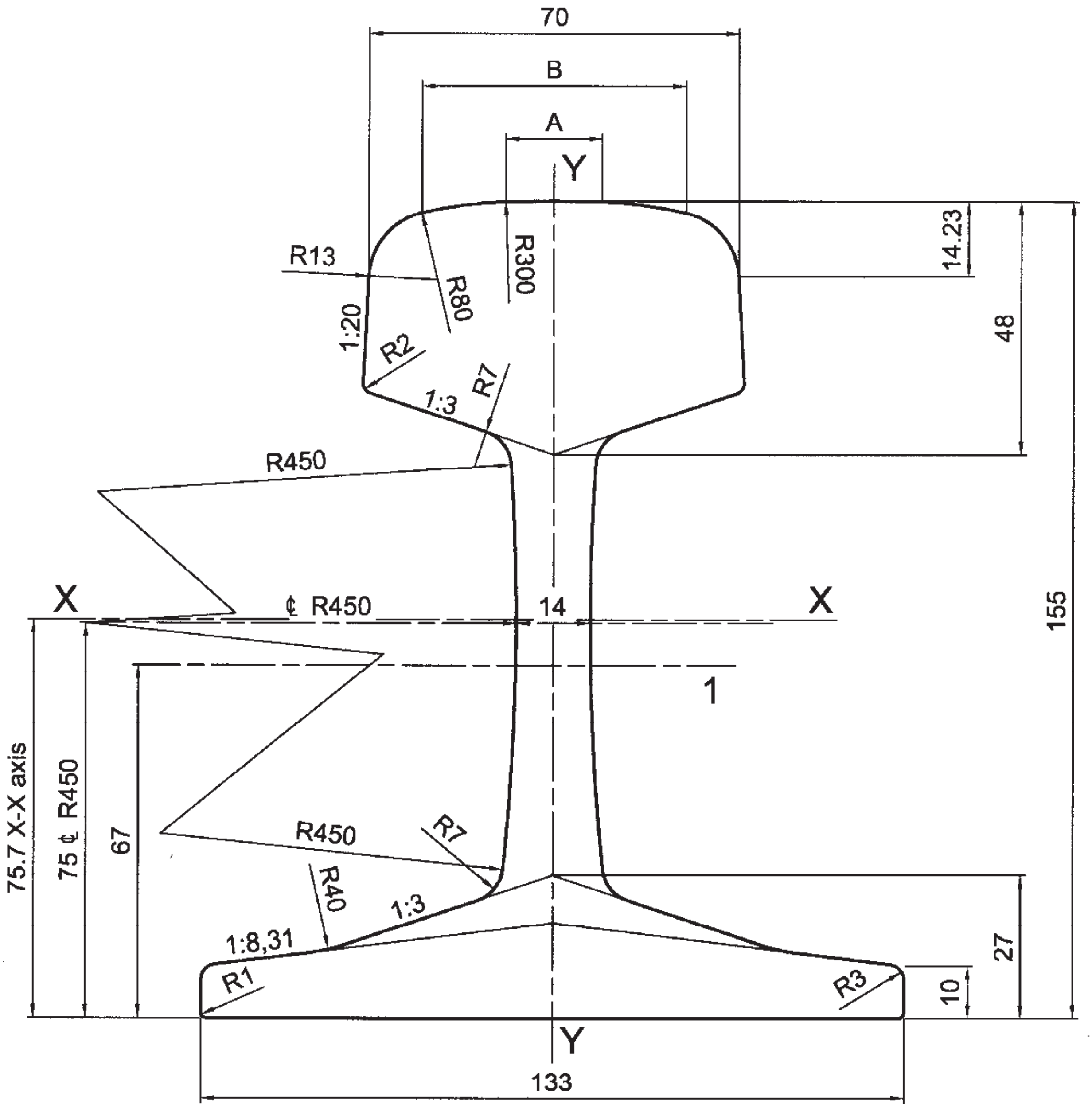
1 centre line of branding

cross-sectional area	:	63,65	cm^2
mass per metre	:	49,97	kg/m
moment of inertia x-x axis	:	1 988,8	cm^4
section modulus - Head	:	248,5	cm^3
section modulus - Base	:	280,3	cm^3
moment of inertia y-y axis	:	408,4	cm^4
section modulus y-y axis	:	58,3	cm^3

indicative dimensions: A = 20,456 mm
B = 52,053 mm

Figure A.9 — Rail profile 50E2

Dimensions in millimetres



Key

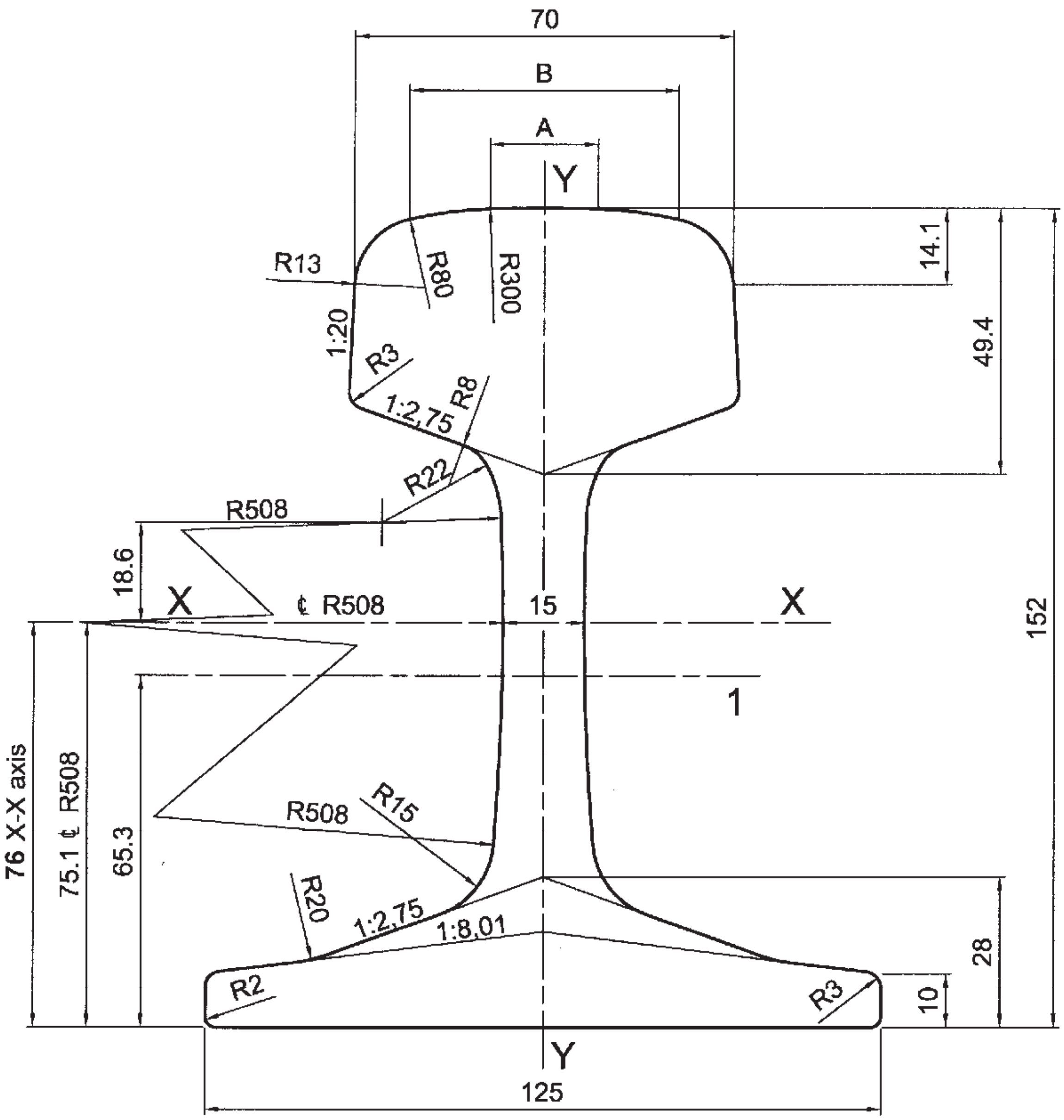
1 centre line of branding

cross-sectional area	:	63,71	cm^2
mass per metre	:	50,02	kg/m
moment of inertia x-x axis	:	2 057,8	cm^4
section modulus - Head	:	259,5	cm^3
section modulus - Base	:	271,8	cm^3
moment of inertia y-y axis	:	351,3	cm^4
section modulus y-y axis	:	52,8	cm^3

indicative dimensions: A = 18,233 mm
B = 49,982 mm

Figure A.10 — Rail profile 50E3

Dimensions in millimetres



Key

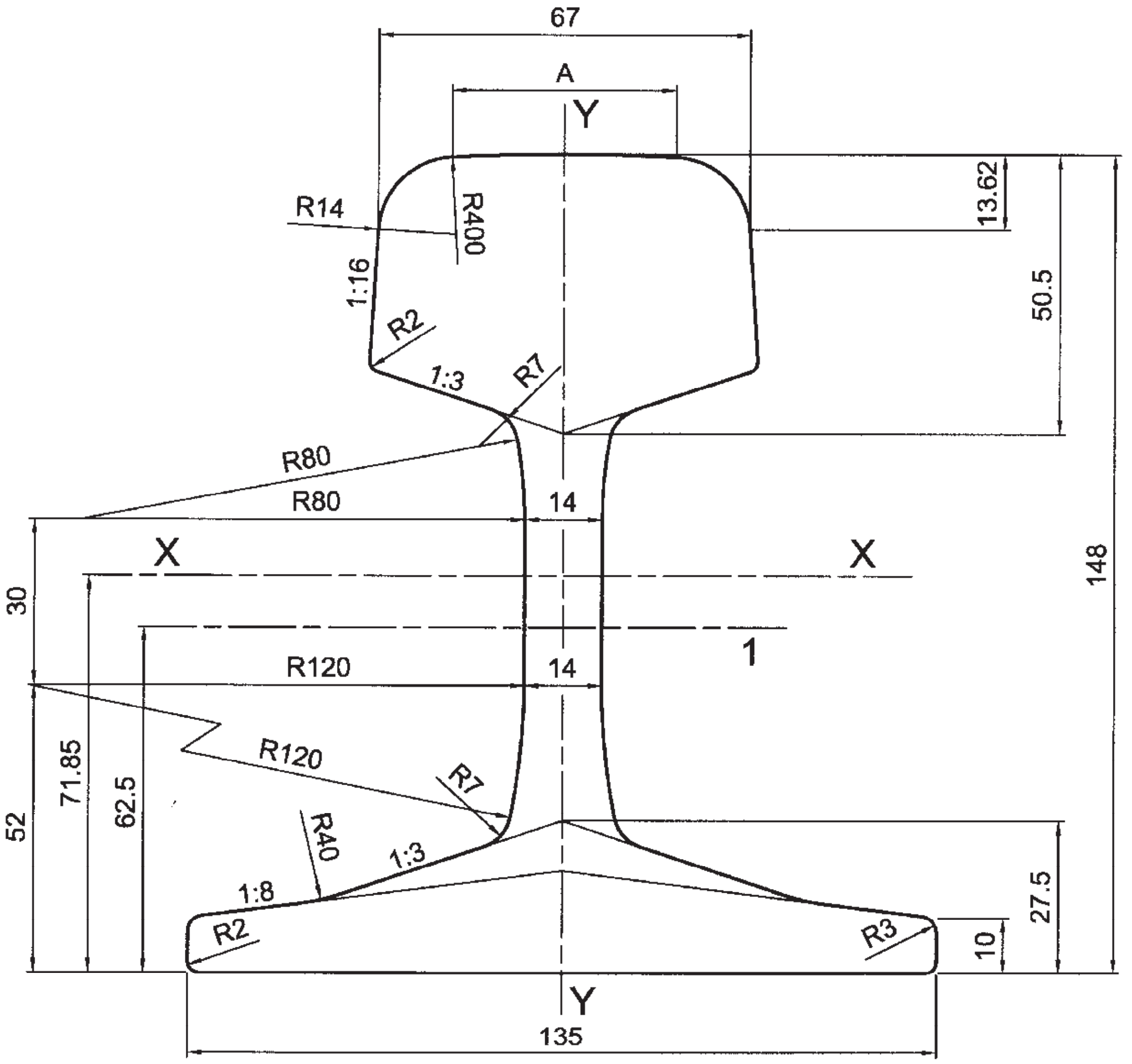
1 centre line of branding

cross-sectional area	:	63,91	cm^2
mass per metre	:	50,17	kg/m
moment of inertia x-x axis	:	1 931	cm^4
section modulus - Head	:	251,4	cm^3
section modulus - Base	:	256,8	cm^3
moment of inertia y-y axis	:	314,7	cm^4
section modulus y-y axis	:	50,4	cm^3

indicative dimensions: A = 20,025 mm
B = 49,727 mm

Figure A.11 — Rail profile 50E4

Dimensions in millimetres



Key

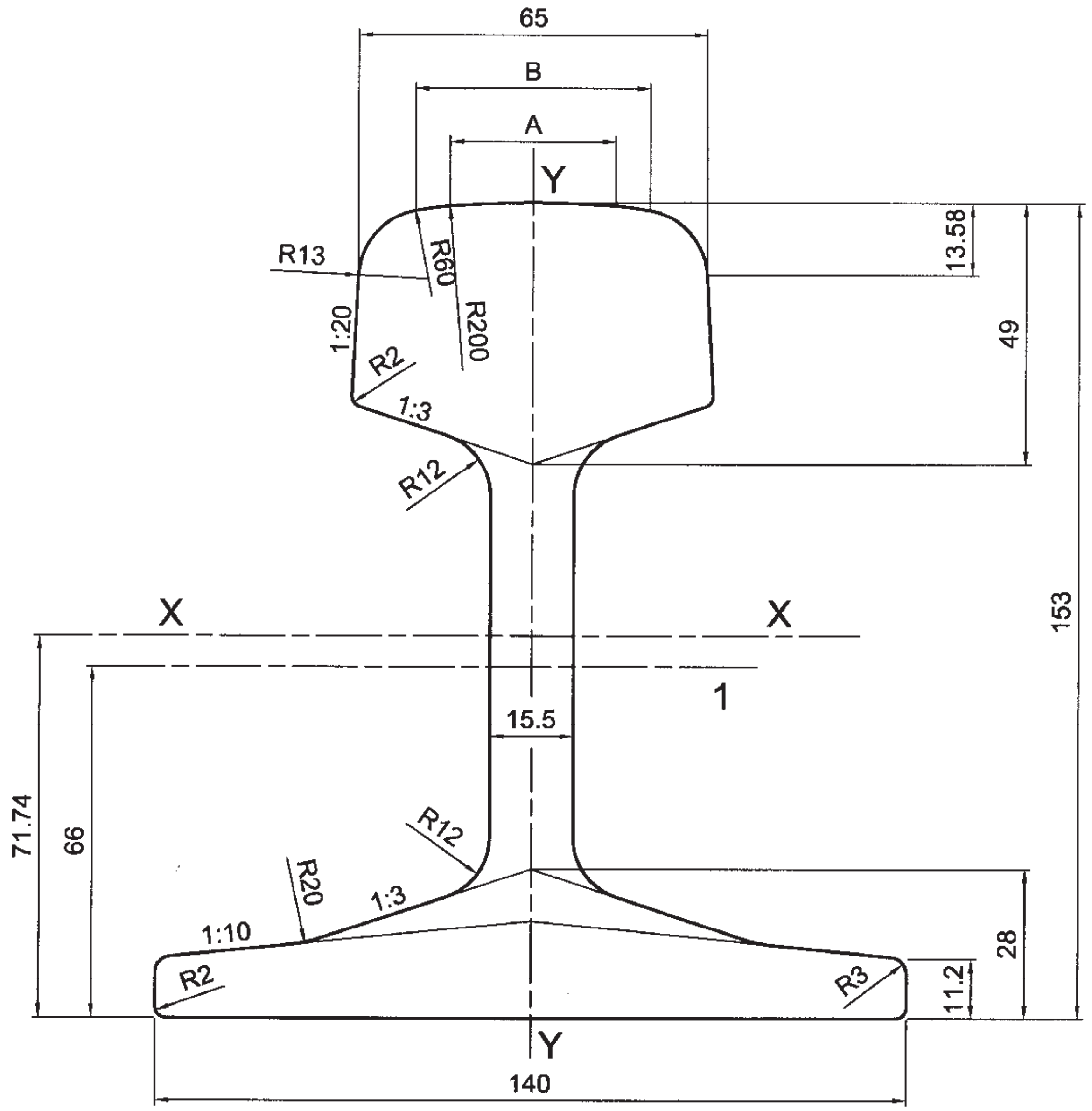
1 centre line of branding

cross-sectional area	:	63,62	cm^2
mass per metre	:	49,9	kg/m
moment of inertia x-x axis	:	1 844	cm^4
section modulus - Head	:	242,1	cm^3
section modulus - Base	:	256,6	cm^3
moment of inertia y-y axis	:	362,4	cm^4
section modulus y-y axis	:	53,7	cm^3

indicative dimensions: A = 40,471 mm

Figure A.12 — Rail profile 50E5

Dimensions in millimetres



Key

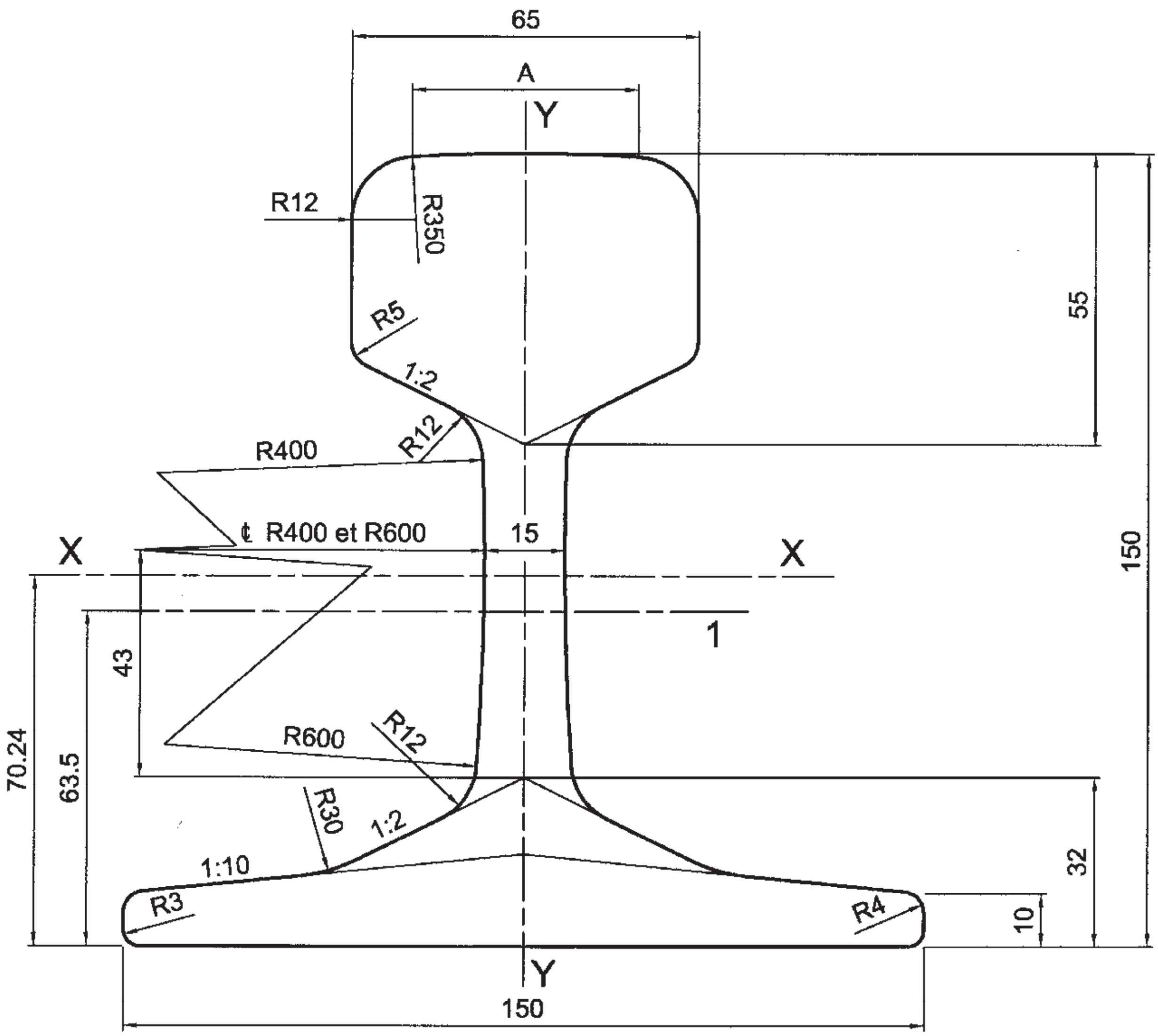
1 centre line of branding

cross-sectional area	:	64,84	cm^2
mass per metre	:	50,90	kg/m
moment of inertia x-x axis	:	2 017,8	cm^4
section modulus - Head	:	248,3	cm^3
section modulus - Base	:	281,3	cm^3
moment of inertia y-y axis	:	396,8	cm^4
section modulus y-y axis	:	56,7	cm^3

indicative dimensions: A = 30,942 mm
B = 43,838 mm

Figure A.13 — Rail profile 50E6

Dimensions in millimetres



Key

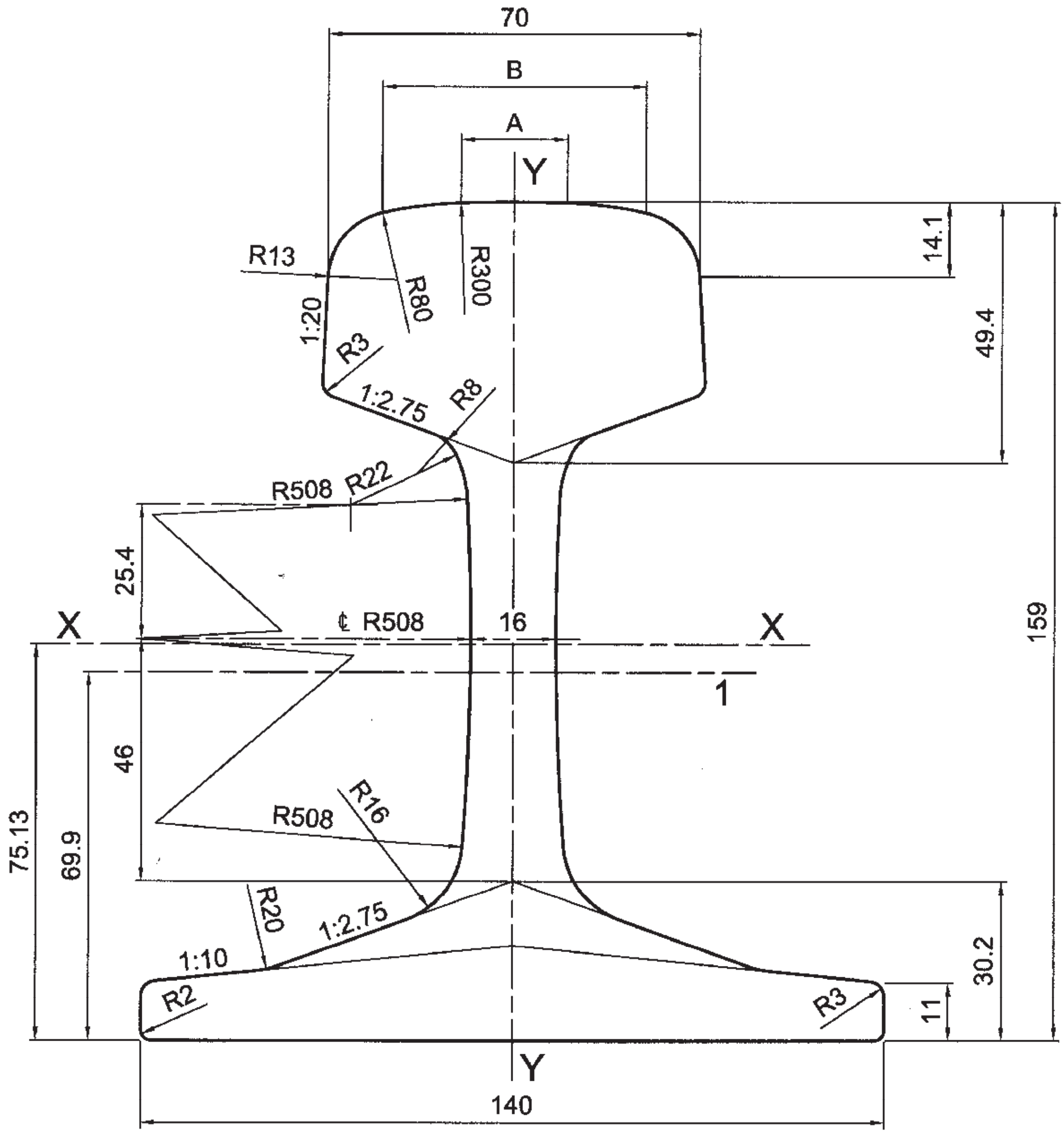
1 centre line of branding

cross-sectional area	:	66,43	cm^2
mass per metre	:	52,15	kg/m
moment of inertia x-x axis	:	1 970,9	cm^4
section modulus - Head	:	247,1	cm^3
section modulus - Base	:	280,6	cm^3
moment of inertia y-y axis	:	434,2	cm^4
section modulus y-y axis	:	57,9	cm^3

indicative dimensions: A = 42,456 mm

Figure A.14 — Rail profile 52E1

Dimensions in millimetres



Key

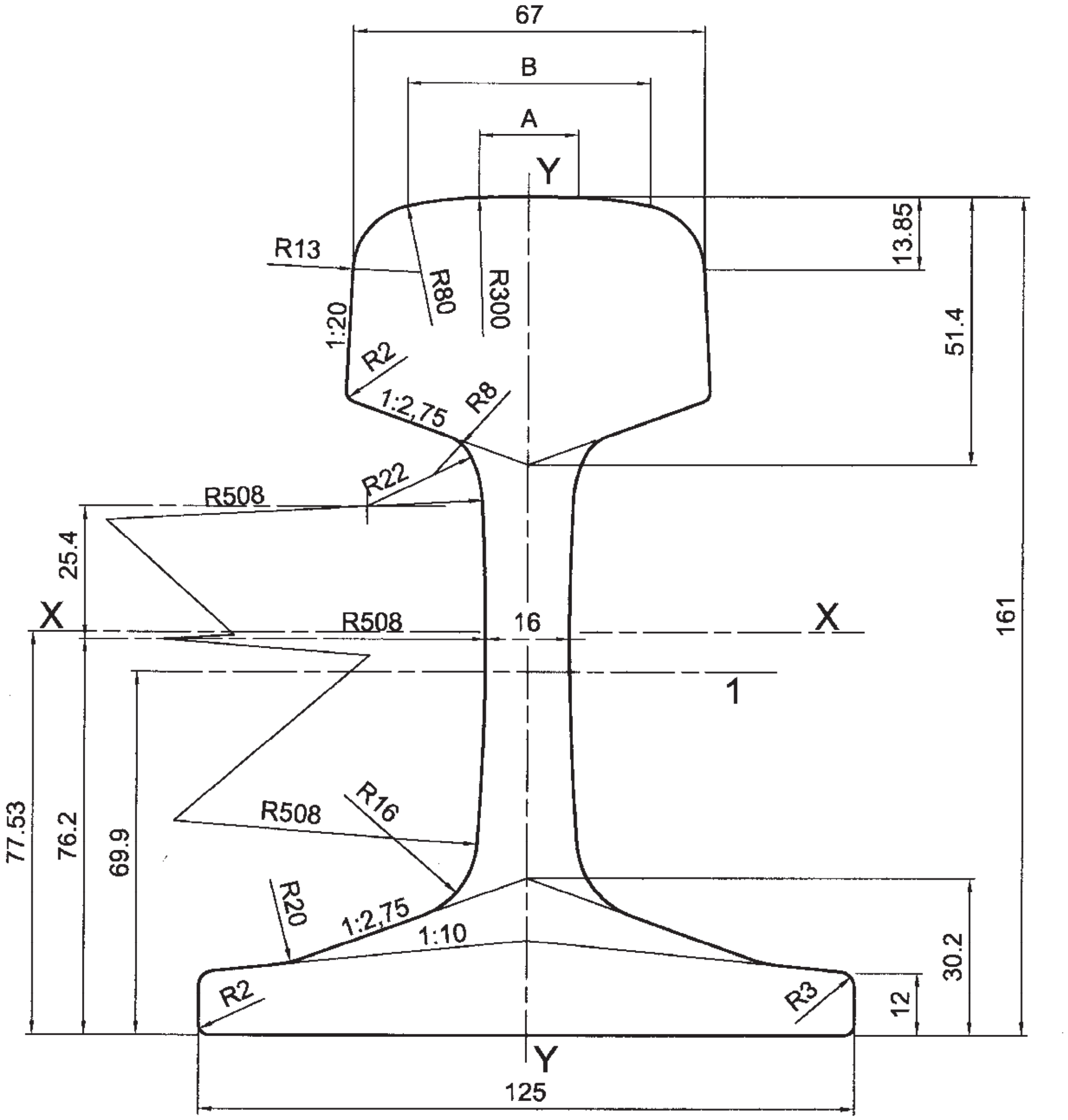
1 centre line of branding

cross-sectional area	:	69,77	cm^2
mass per metre	:	54,77	kg/m
moment of inertia x-x axis	:	2 337,9	cm^4
section modulus - Head	:	278,7	cm^3
section modulus - Base	:	311,2	cm^3
moment of inertia y-y axis	:	419,2	cm^4
section modulus y-y axis	:	59,9	cm^3

indicative dimensions: A = 20,024 mm
B = 49,727 mm

Figure A.15 — Rail profile 54E1

Dimensions in millimetres



Key

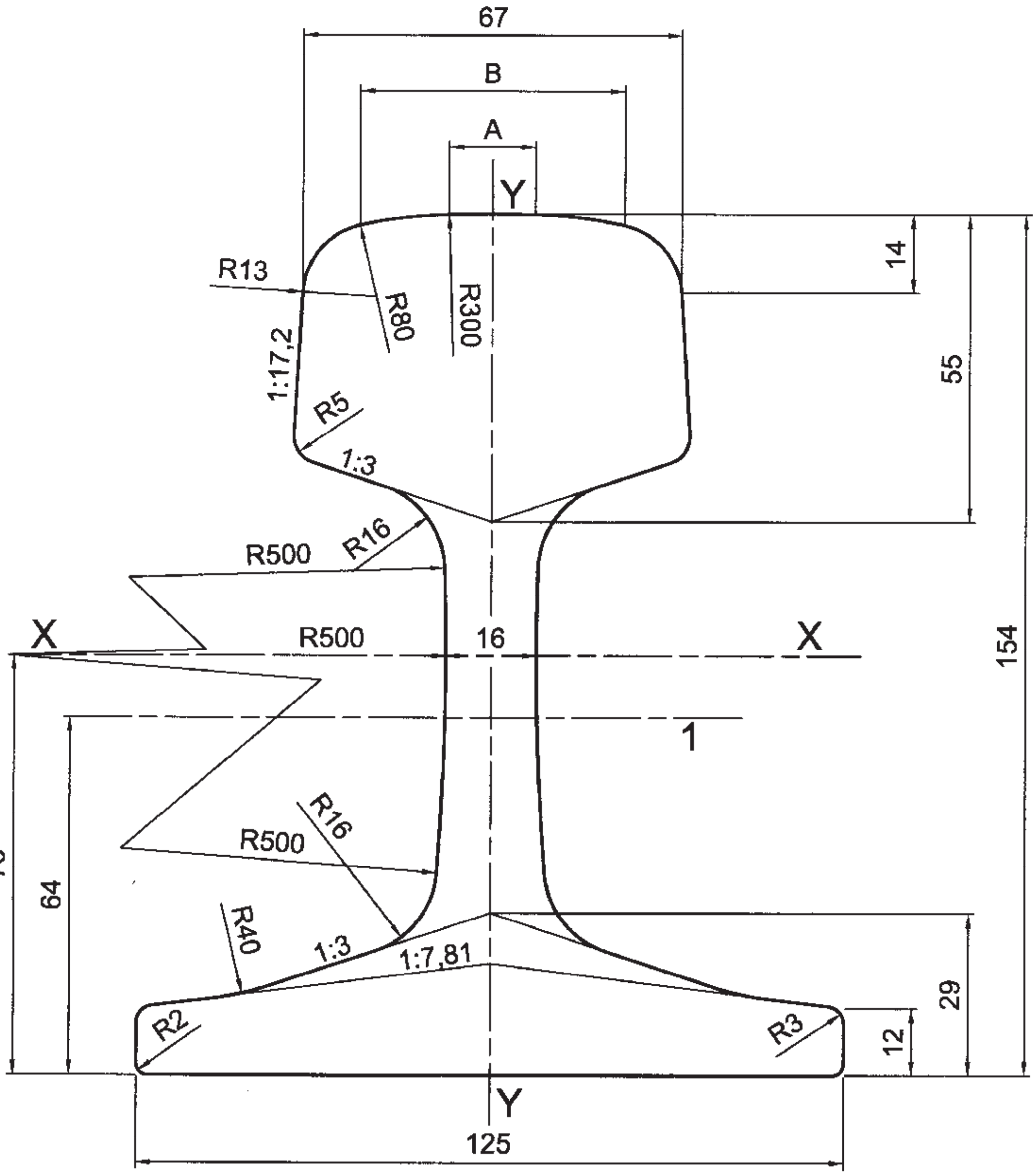
1 centre line of branding

cross-sectional area	:	68,56	cm^2
mass per metre	:	53,82	kg/m
moment of inertia x-x axis	:	2 307,4	cm^4
section modulus - Head	:	276,4	cm^3
section modulus - Base	:	297,6	cm^3
moment of inertia y-y axis	:	341,5	cm^4
section modulus y-y axis	:	54,6	cm^3

indicative dimensions: A = 18,946 mm
B = 46,310 mm

Figure A.16 — Rail profile 54E2

Dimensions in millimetres



Key

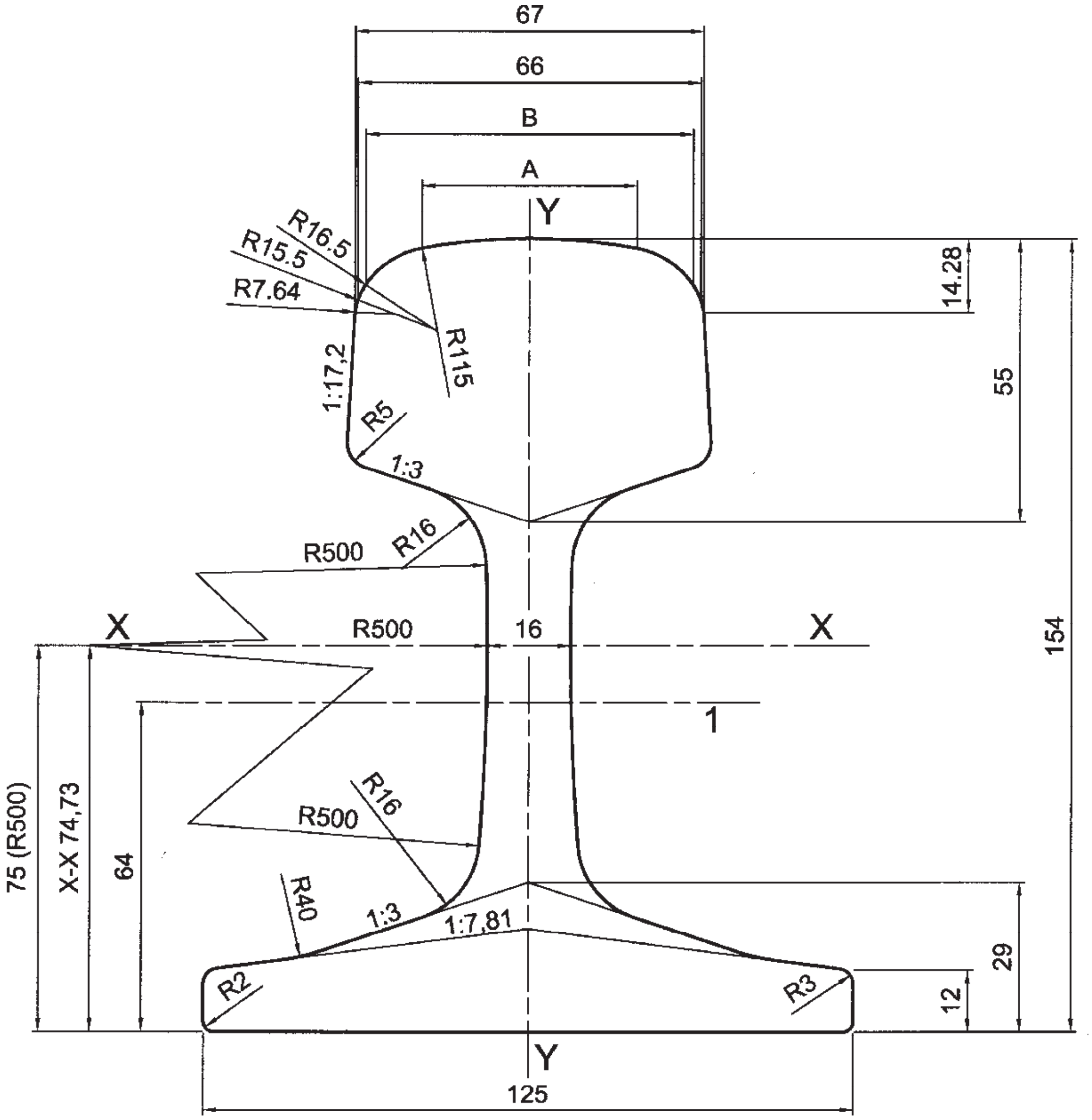
1 centre line of branding

cross-sectional area	:	69,52	cm^2
mass per metre	:	54,57	kg/m
moment of inertia x-x axis	:	2074	cm^4
section modulus - Head	:	262,8	cm^3
section modulus - Base	:	276,3	cm^3
moment of inertia y-y axis	:	354,8	cm^4
section modulus y-y axis	:	56,8	cm^3

indicative dimensions: A = 15,267 mm
B = 46,835 mm

Figure A.17 — Rail profile 54E3

Dimensions in millimetres



Key

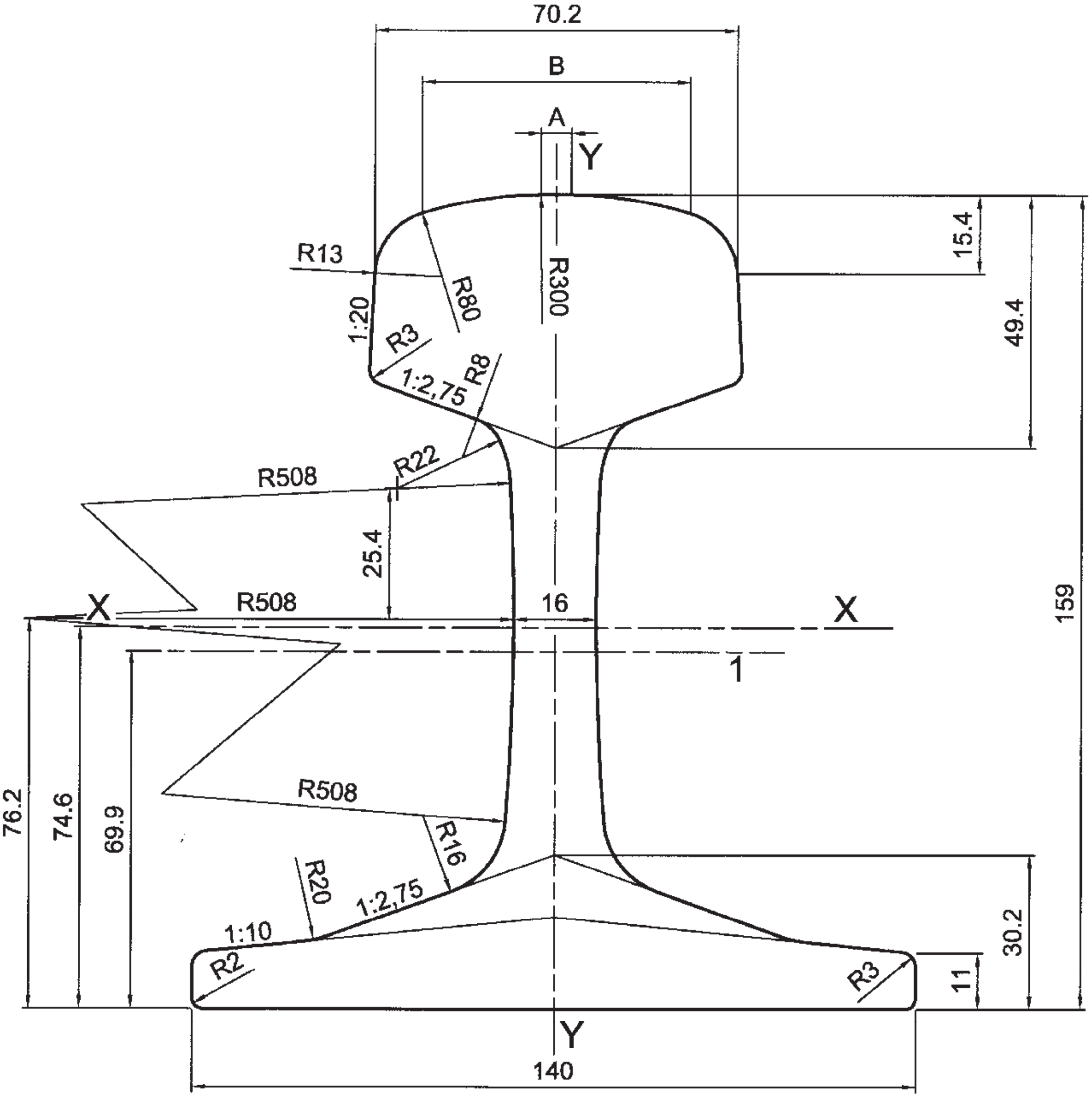
1 centre line of branding

cross-sectional area	:	69,19	cm^2
mass per metre	:	54,31	kg/m
moment of inertia x-x axis	:	2056,2	cm^4
section modulus - Head	:	259,4	cm^3
section modulus - Base	:	275,2	cm^3
moment of inertia y-y axis	:	352,7	cm^4
section modulus y-y axis	:	56,4	cm^3

indicative dimensions: A = 41,342 mm
B = 62,980 mm

Figure A.18 — Rail profile 54E4

Dimensions in millimetres



Key

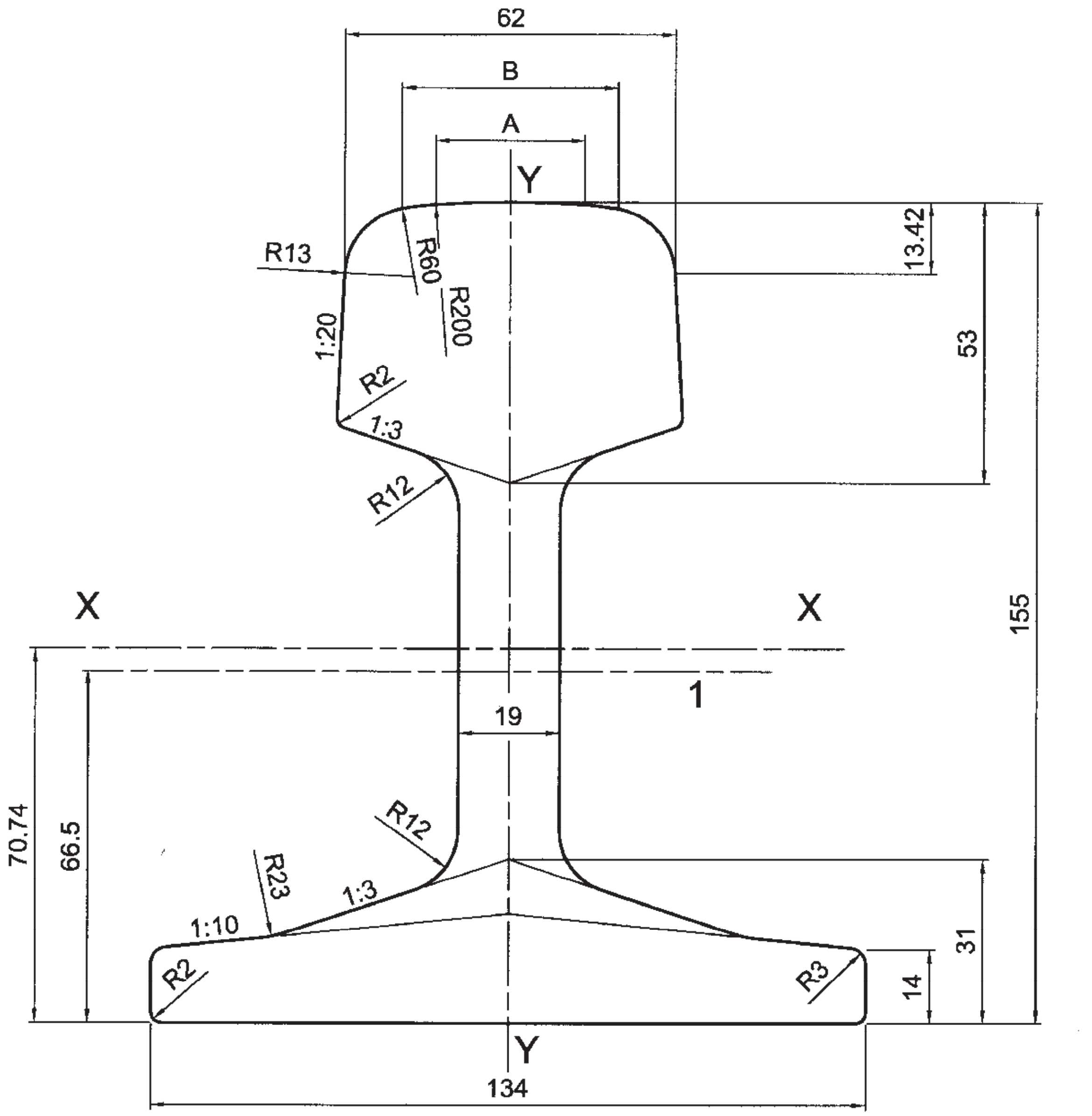
1 centre line of branding

cross-sectional area	:	69,32	cm^2
mass per metre	:	54,42	kg/m
moment of inertia x-x axis	:	2308,1	cm^4
section modulus - Head	:	273,5	cm^3
section modulus - Base	:	309,4	cm^3
moment of inertia y-y axis	:	416,3	cm^4
section modulus y-y axis	:	59,5	cm^3

indicative dimensions: A = 5,91 mm
B = 51,97 mm

Figure A.19 — Rail profile 54E5

Dimensions in millimetres



Key

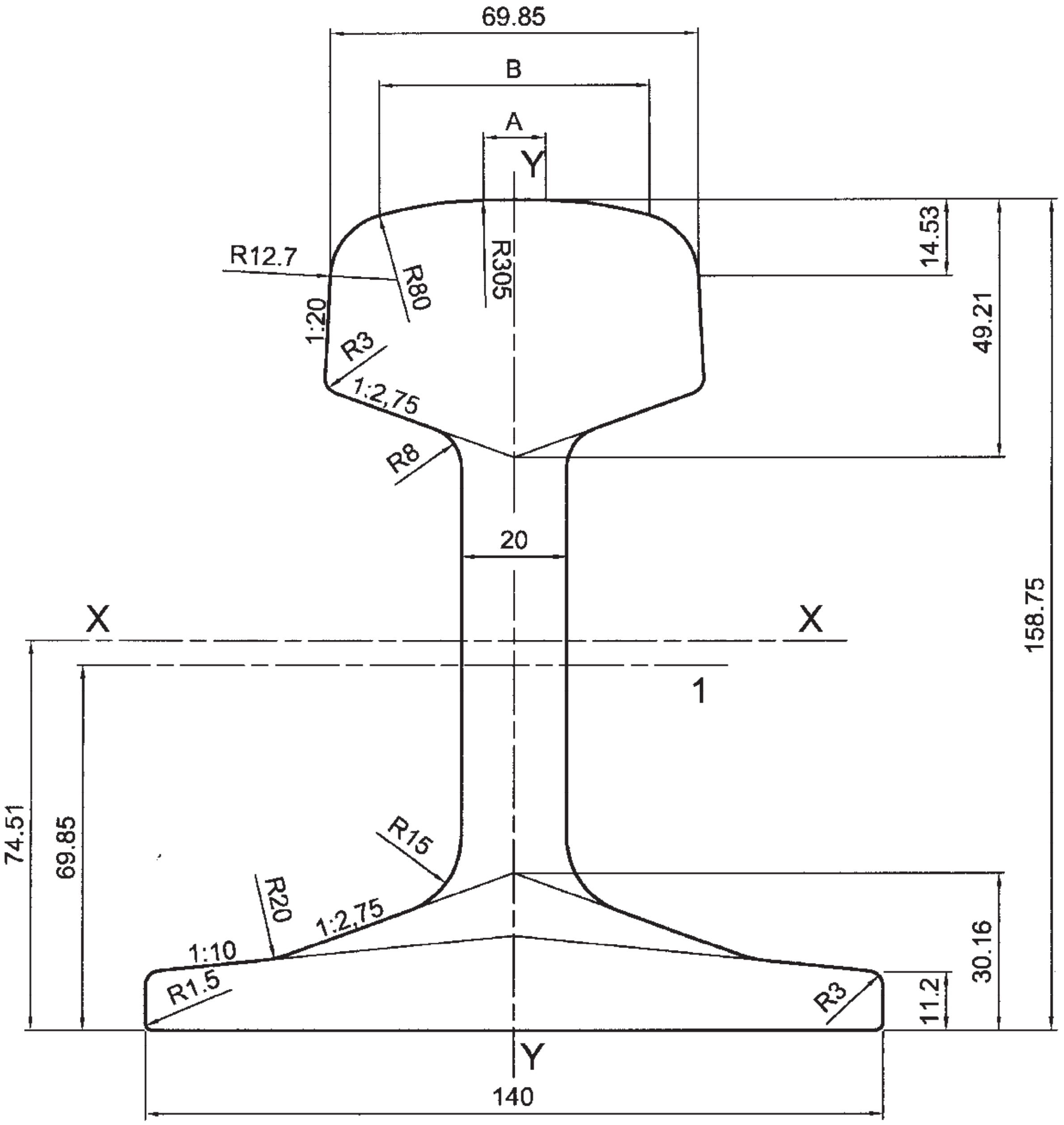
1 centre line of branding

cross-sectional area	:	71,37	cm^2
mass per metre	:	56,03	kg/m
moment of inertia x-x axis	:	2150,4	cm^4
section modulus - Head	:	255,2	cm^3
section modulus - Base	:	304	cm^3
moment of inertia y-y axis	:	418,4	cm^4
section modulus y-y axis	:	62,4	cm^3

indicative dimensions: A = 27,946 mm
B = 40,588 mm

Figure A.20 — Rail profile 55E1

Dimensions in millimetres



Key

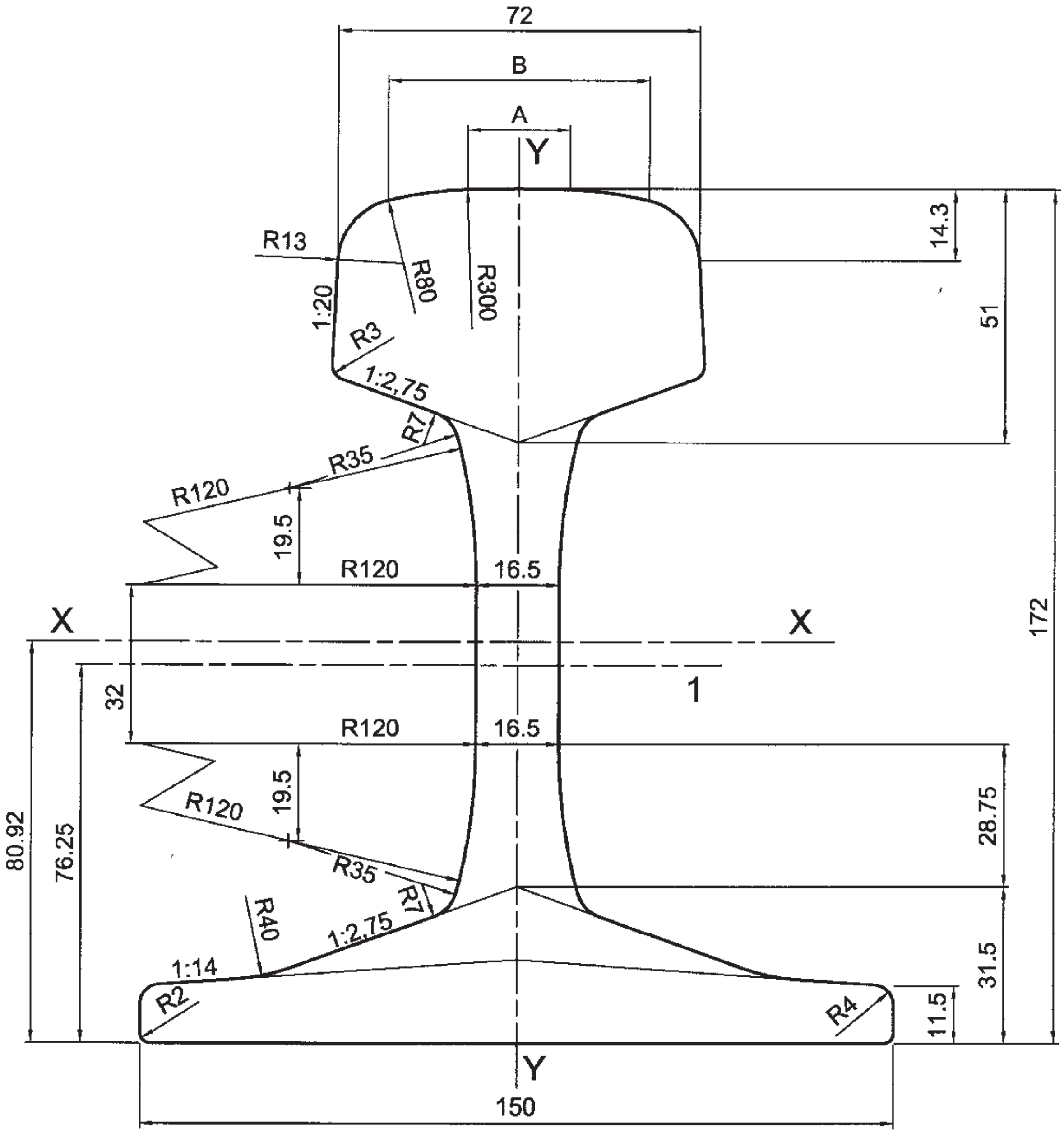
1 centre line of branding

cross-sectional area	:	71,69	cm^2
mass per metre	:	56,3	kg/m
moment of inertia x-x axis	:	2 321	cm^4
section modulus - Head	:	275,5	cm^3
section modulus - Base	:	311,5	cm^3
moment of inertia y-y axis	:	421,6	cm^4
section modulus y-y axis	:	60,2	cm^3

indicative dimensions: A = 11,787 mm
B = 51,235 mm

Figure A.21 — Rail profile 56E1

Dimensions in millimetres



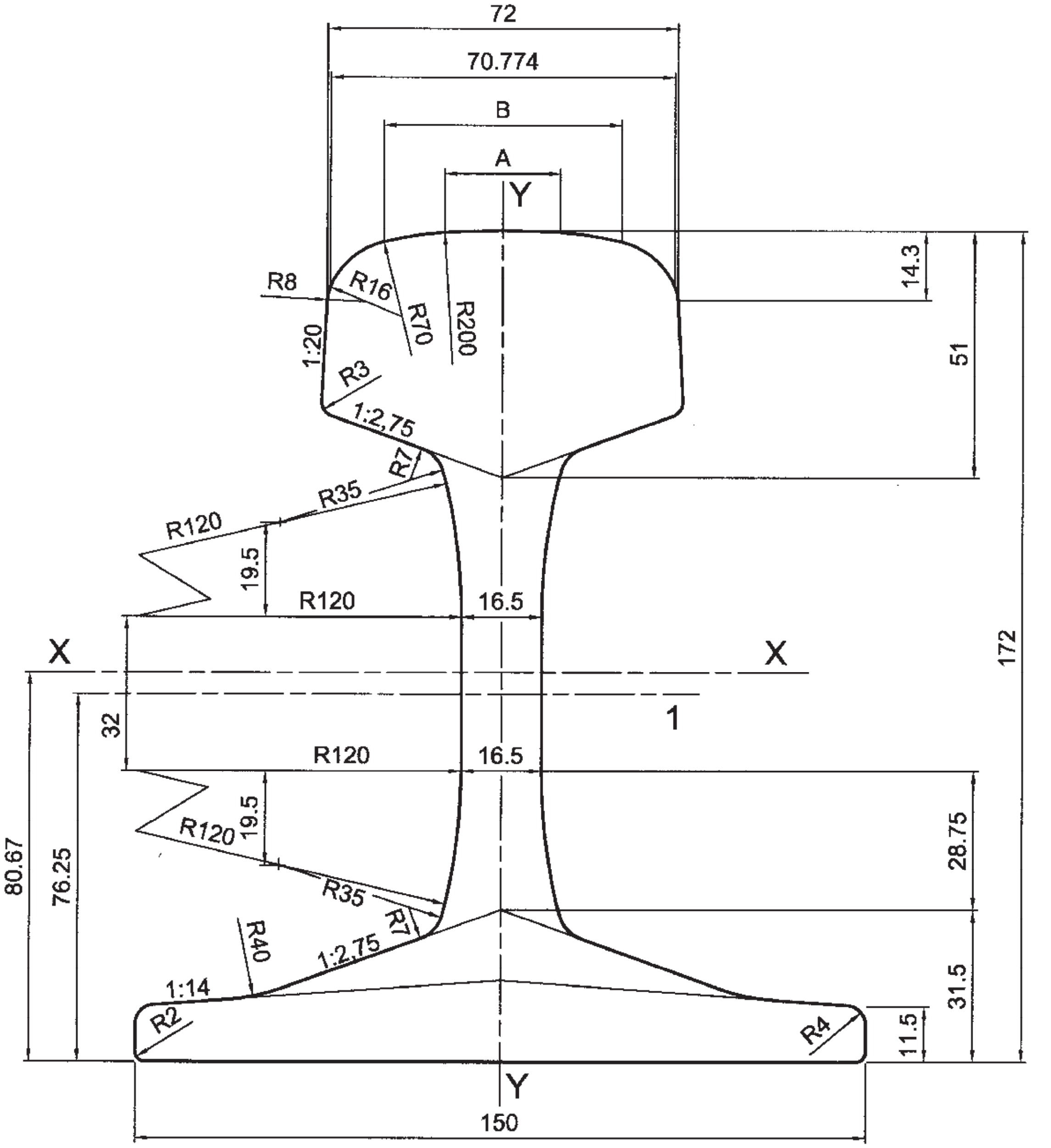
Key

1 centre line of branding

cross-sectional area	:	76,70	cm^2
mass per metre	:	60,21	kg/m
moment of inertia x-x axis	:	3 038,3	cm^4
section modulus - Head	:	333,6	cm^3
section modulus - Base	:	375,5	cm^3
moment of inertia y-y axis	:	512,3	cm^4
section modulus y-y axis	:	68,3	cm^3

indicative dimensions: A = 20,456 mm
B = 52,053 mm

Figure A.22 — Rail profile 60E1



Key

1 centre line of branding

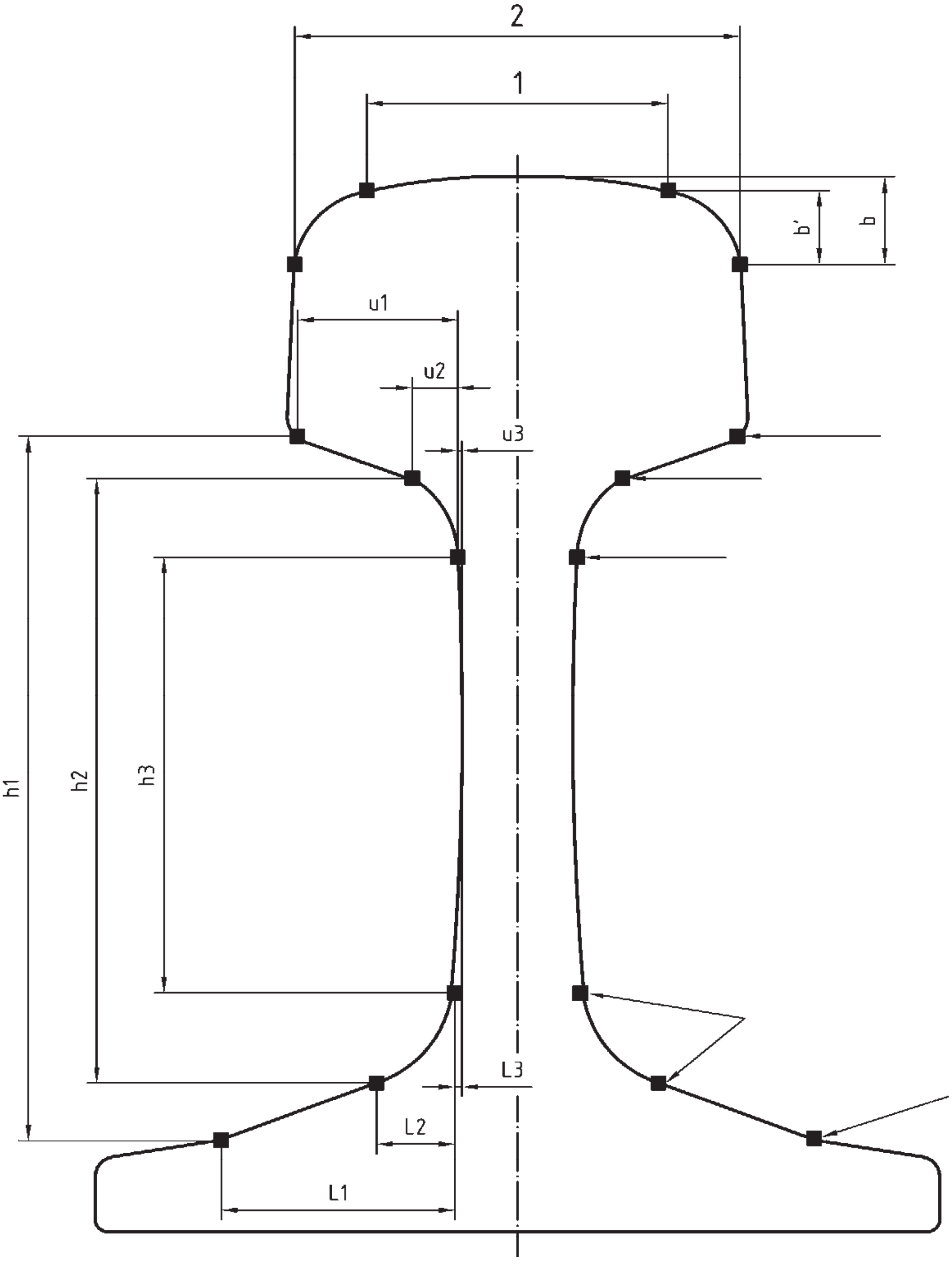
cross-sectional area	:	76,48	cm^2
mass per metre	:	60,03	kg/m
moment of inertia x-x axis	:	3 021,5	cm^4
section modulus - Head	:	330,8	cm^3
section modulus - Base	:	374,5	cm^3
moment of inertia y-y axis	:	510,5	cm^4
section modulus y-y axis	:	68,10	cm^3

indicative dimensions: A = 23,778 mm
B = 48,913 mm

Figure A.23 — Rail profile 60E2

Table A.2 — Rail transition references (see Figure A.24)

Rail profile	Dimension in mm												
	1	2	b	b´	h1	h2	h3	L1	L2	L3	u1	u2	u3
46E1	43,88	65,00	14,30	12,77	98,18	81,95	74,47	53,99	7,28	3,13	24,74	6,52	2,32
46E2	40,59	62,00	13,42	12,15	94,53	79,19	65,91	32,38	4,79	0	23,20	4,79	0
46E3	53,76	73,72	14,18	11,86	98,13	81,34	72,27	50,73	6,81	2,39	29,79	6,54	2,16
46E4	38,38	65,00	13,75	13,28	99,71	81,03	71,93	58,99	5,48	1,71	25,84	4,63	0,85
49E1	46,84	67,00	14,00	11,92	94,56	79,02	68,40	33,13	7,06	2,41	26,55	5,99	1,32
49E2	40,47	67,00	13,62	13,11	94,58	79,02	68,40	33,13	7,06	2,41	26,61	5,99	1,32
49E5	41,34	67,00	14,28	12,41	94,55	79,02	68,40	33,13	7,06	2,41	26,53	5,99	1,32
50E1	43,84	65,00	13,58	12,13	100,05	86,64	63,87	32,13	8,21	0	24,52	8,21	—
50E2	52,05	72,00	14,30	12,00	103,49	88,41	78,22	30,54	6,61	1,54	27,93	6,61	1,54
50E3	49,98	70,00	14,23	12,01	104,35	88,99	76,90	31,40	7,19	2,44	27,65	5,78	1,01
50E4	49,73	70,00	14,10	12,04	101,73	88,32	57,33	33,08	11,49	1,67	26,53	11,25	0,26
50E5	40,47	67,00	13,62	13,11	94,45	79,02	68,40	32,74	7,06	2,41	26,61	5,99	1,32
50E6	43,84	65,00	13,58	12,13	100,05	86,64	63,87	32,13	8,21	0	24,52	8,21	0
52E1	42,46	65,00	12,62	11,98	93,52	77,99	57,85	23,81	8,00	1,39	22,24	6,98	0,36
54E1	49,73	70,00	14,10	12,04	107,75	92,25	66,04	35,92	12,02	1,54	26,03	7,30	0,69
54E2	46,31	67,01	13,85	12,08	107,16	92,25	66,04	34,97	12,02	1,54	25,36	7,30	0,69
54E3	46,84	67,00	14,00	11,92	93,90	83,20	54,58	32,13	12,41	1,52	23,57	11,18	0,24
54E4	41,34	67,00	14,28	12,41	93,89	83,19	54,58	32,13	12,40	1,51	23,55	11,18	0,25
54E5	51,97	70,20	15,40	11,76	107,76	92,25	66,04	35,88	12,60	1,50	26,06	7,26	0,65
55E1	40,59	62,00	13,42	12,15	95,24	82,80	60,04	32,21	8,21	0	21,50	8,21	0
56E1	51,23	69,85	14,53	11,61	107,36	92,16	70,54	33,01	9,87	0	23,92	5,27	0
60E1	52,05	72,00	14,30	12,00	118,57	101,50	87,06	36,61	8,25	3,20	26,83	8,25	3,20
60E2	48,91	72,00	14,30	12,04	118,57	101,50	87,06	36,61	8,25	3,20	26,83	8,25	3,20



Key

■ transition point 0,01 mm

Figure A.24 — Principal rail transition references

Annex B
(normative)

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

B.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 part of EN 13674. The requirements specified in this part of the EN 13674 apply only to the determination of plane strain fracture toughness of railway rail steels covered by the definitions and requirements of this standard.

B.2 Test pieces

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

B.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.

B.3 Number of tests

A minimum of 5 tests from each sample shall be performed.

B.4 Test conditions[1)]

B.4.1 Fatigue pre-cracking shall be carried out in the temperature range + 15 °C to + 25 °C using a stress ratio in the range > 0 < + 0,1. Fatigue pre-cracking shall be carried out at a cyclic frequency in the range 15 Hz to 120 Hz. The final crack length to test piece width ratio shall be in the range 0,45 to 0,55 and during the last 1,25 mm of crack growth K_{max} shall be in the range of 18 MPa $m^{1/2}$ to 22 MPa $m^{1/2}$.

B.4.2 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).

B.4.3 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 B.2.

[1)] It is recommended that the chevron notch in ASTM E399 is used to avoid crack front curvature problems.

B.5 Analysis of test data

B.5.1 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 B.5.2 to B.5.6.

B.5.2 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.

B.5.3 The linearity of force-crack mouth opening curves Ia, Ib, IIa and III (see Figure B.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 0,8 P_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 $v_1 \leq 0{,}25\ v$.

B.5.4 The linearity of force-crack mouth opening curves IIb and IIc (see Figure B.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 0,8 P_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". Sum the values for "pop-ins" occurring below 0,8 P_Q and for those occurring between 0,8 P_Q and P_Q recording them as $\Sigma\ v_{1pi}$ and $\Sigma\ v_{pi}$ respectively.

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

B.5.5 The linearity criterion cannot be applied to force - crack mouth opening curve IV.

B.5.6 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 the 0,2 % proof stress at the fracture test temperature of –20 °C.

B.6 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:

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

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

3) 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 giving the following information.

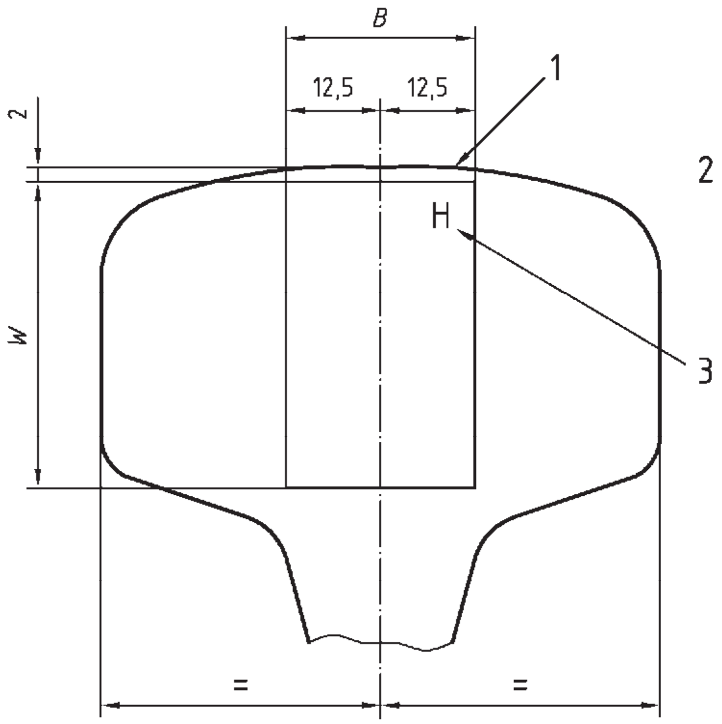
Steel Grade	0,2 % Proof strength at –20 °C MPa	Mean K_{IC} (MPa m$^{1/2}$)	Number of K_{IC} results	Sample standard deviation (MPa m$^{1/2}$)	Mean K_Q (MPa m$^{1/2}$)	Number of K_Q results	Sample standard deviation (MPa m$^{1/2}$)

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 ten.

All values of K_{IC} and K_Q^* shall be above the minimum value specified in Table 2.

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

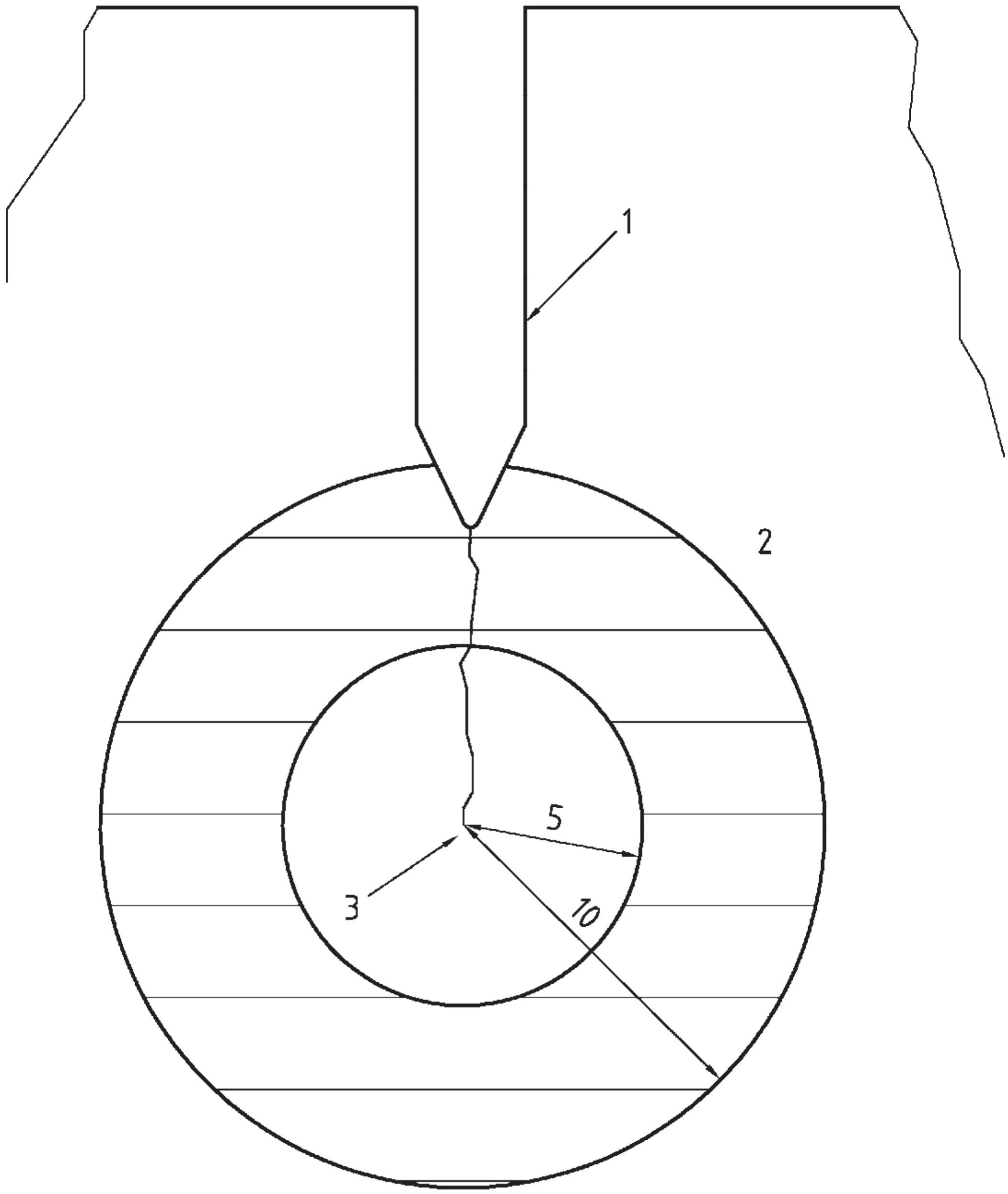
B = 25

W = see B.2.2

For all other test piece proportions, see ASTM E399.

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

Dimensions in millimetres



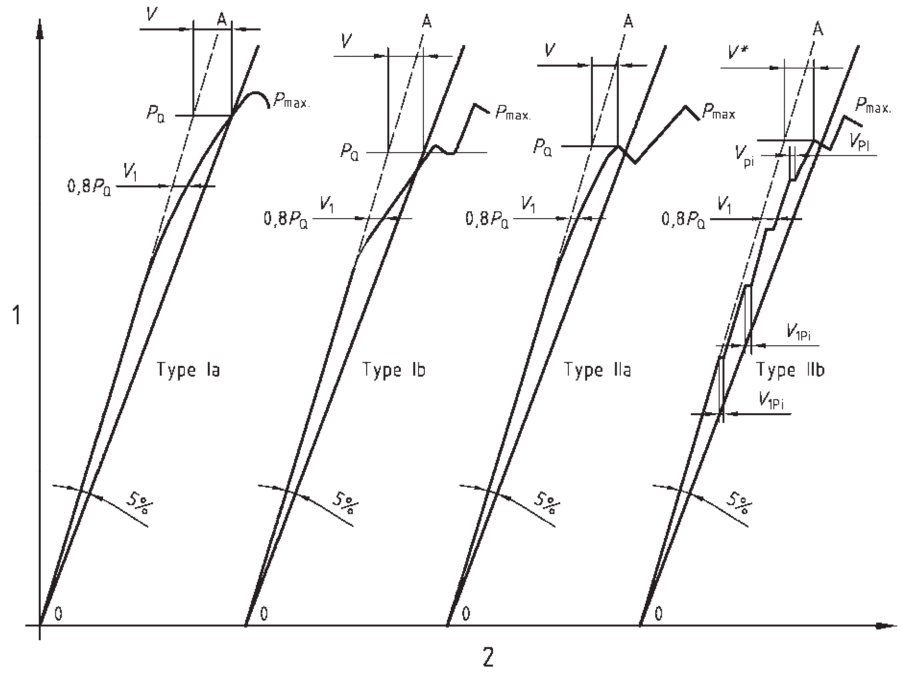
Key

1 notch

2 thermocouple to be placed in the shaded zone

3 fatigue crack tip

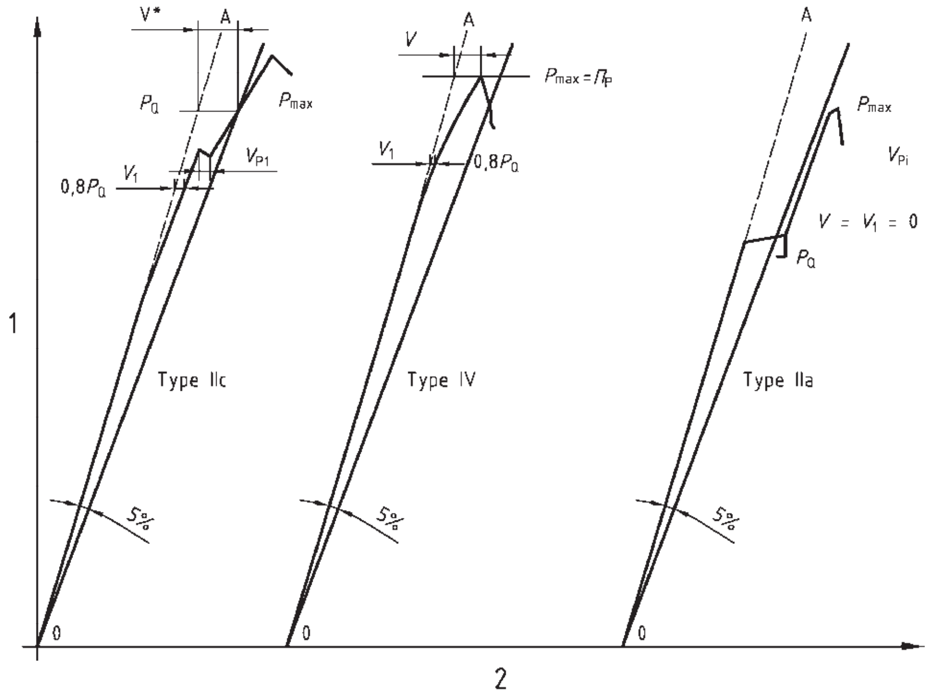
Figure B.2 — Location of thermocouple on fracture toughness specimens



Key

1 force, P

2 crack mouth opening displacement (v)



Key

1 force, P

2 crack mouth opening displacement (v)'

Figure B.3 — Force – Crack mouth opening curves

Annex C
(normative)

Method for the determination of rail foot surface longitudinal residual stresses

C.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 whilst the original residual stresses are taken to be those values but with a change of sign.

C.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 %.

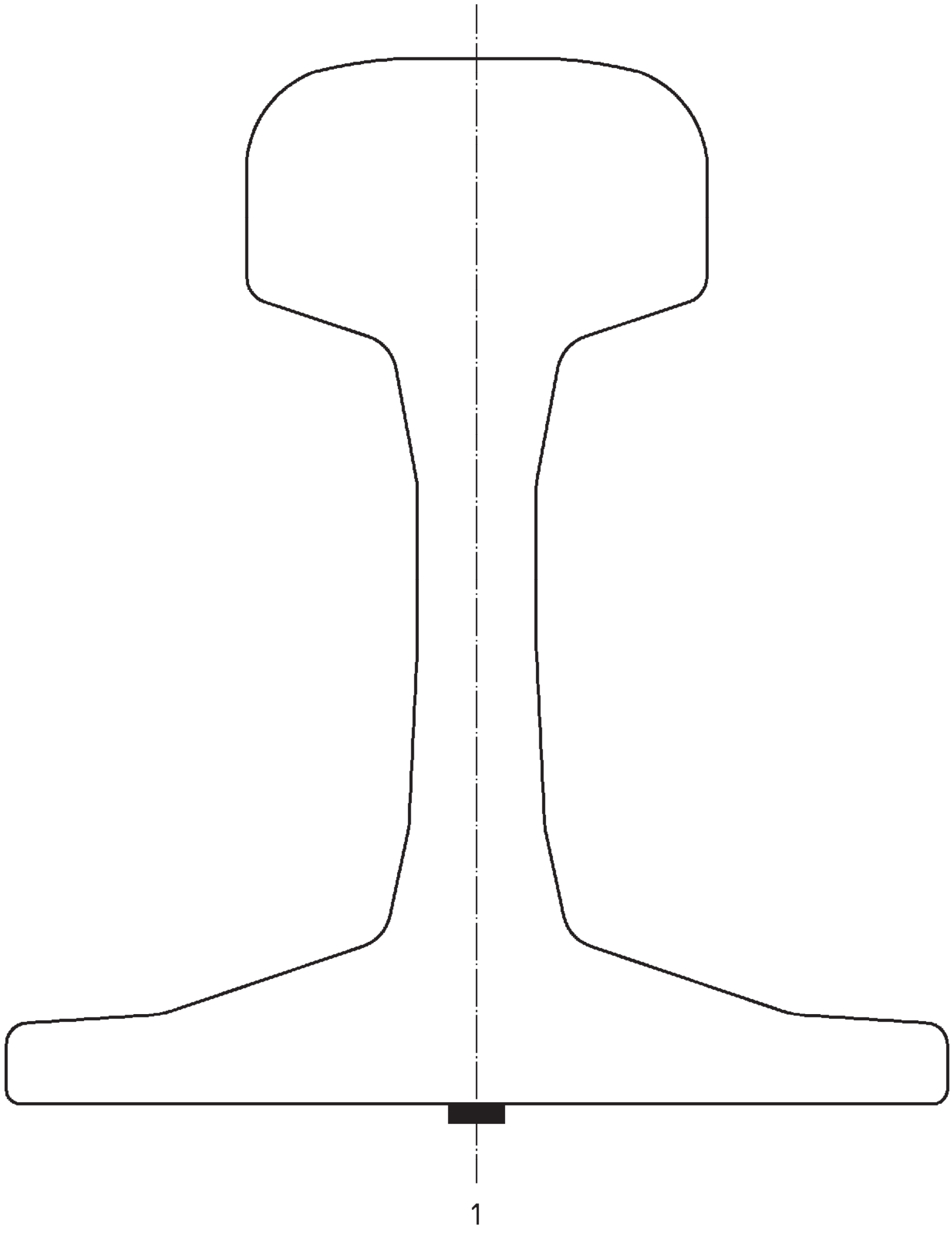
The strain gauge shall be attached to the surface of the rail foot in order to measure longitudinal strain at the positions as shown in Figure C.1. The surface of the rail foot shall be prepared and the strain gauge shall be attached, in accordance with the recommendations of the strain gauge manufacturer.

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

NOTE 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 C.2). A second set of measurements shall be taken.

The residual stresses shall be calculated from the differences between the first and second sets of measurements of relieved strains by multiplying by $2{,}07 \times 10^5$ MPa.

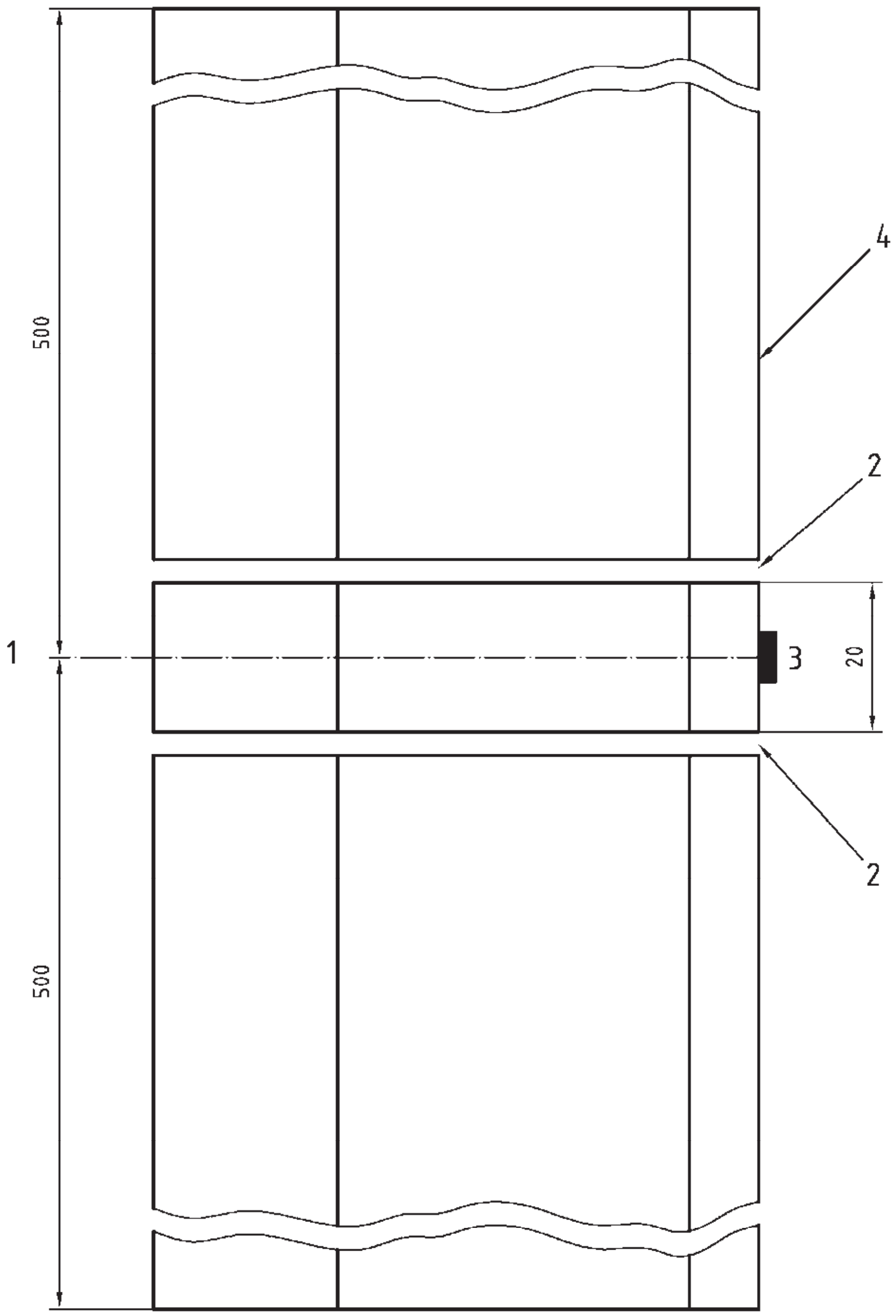


Key

1 strain gauge

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

Dimensions in millimetres



Key

1 centreline

2 saw cut

3 strain gauge

4 rail foot

Figure C.2 — Slice removed from the rail

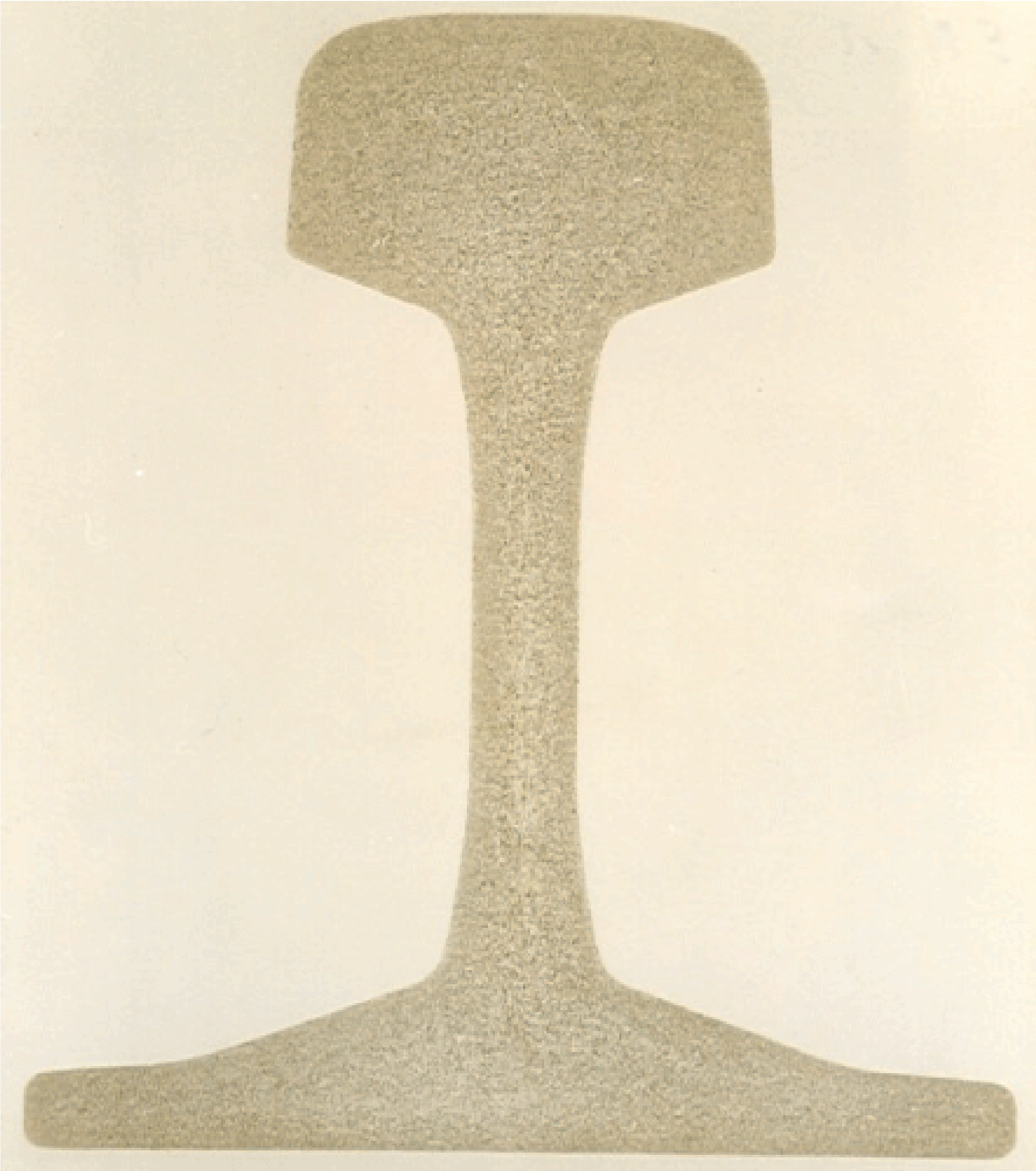
Annex D
(normative)

Limiting sulfur prints

The limiting sulfur prints presented in this annex are summarised in Table D.1.

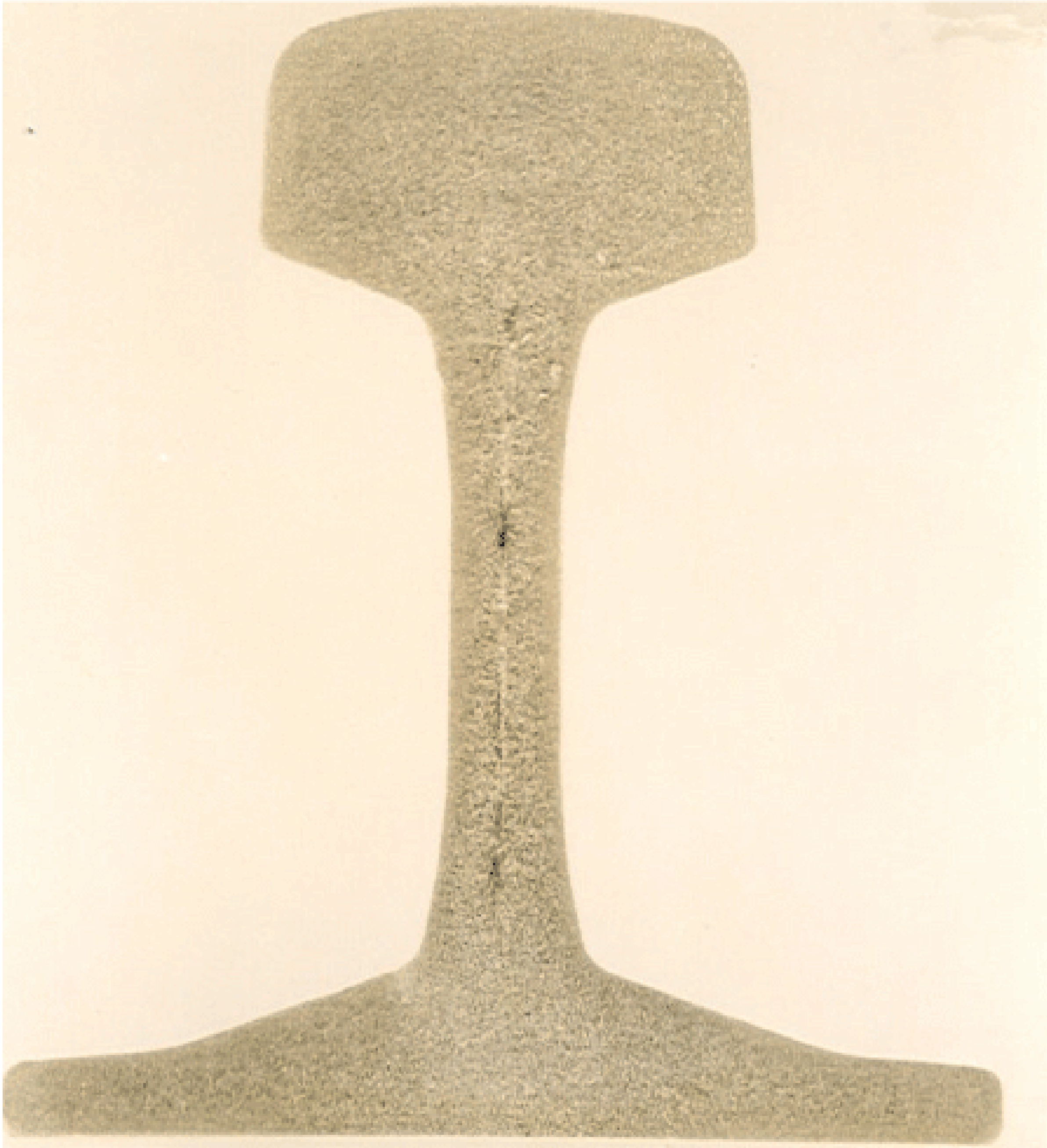
Table D.1 — Limiting sulfur prints

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



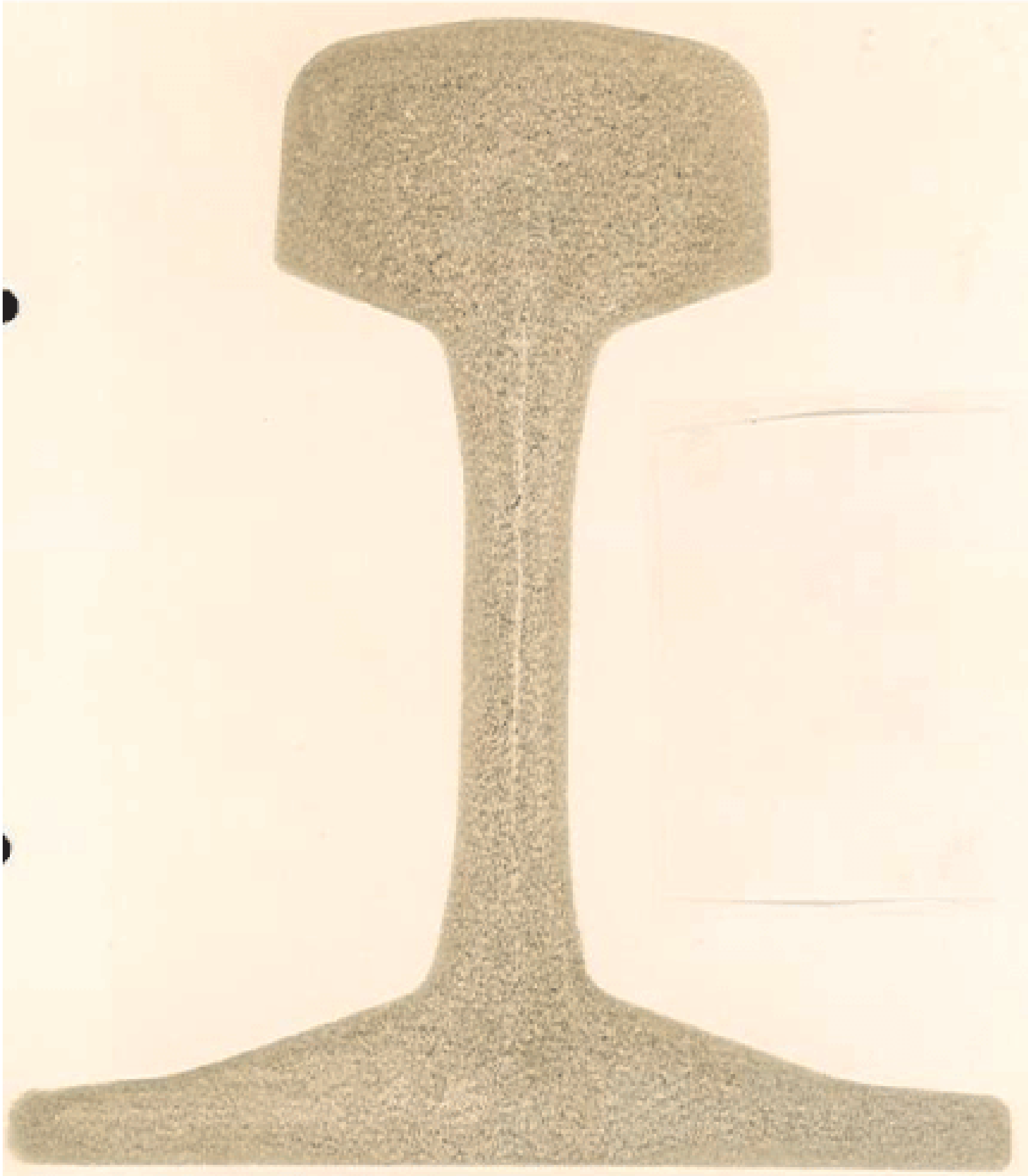
Classification: acceptable

Figure D.1 — Perfect sulfur print



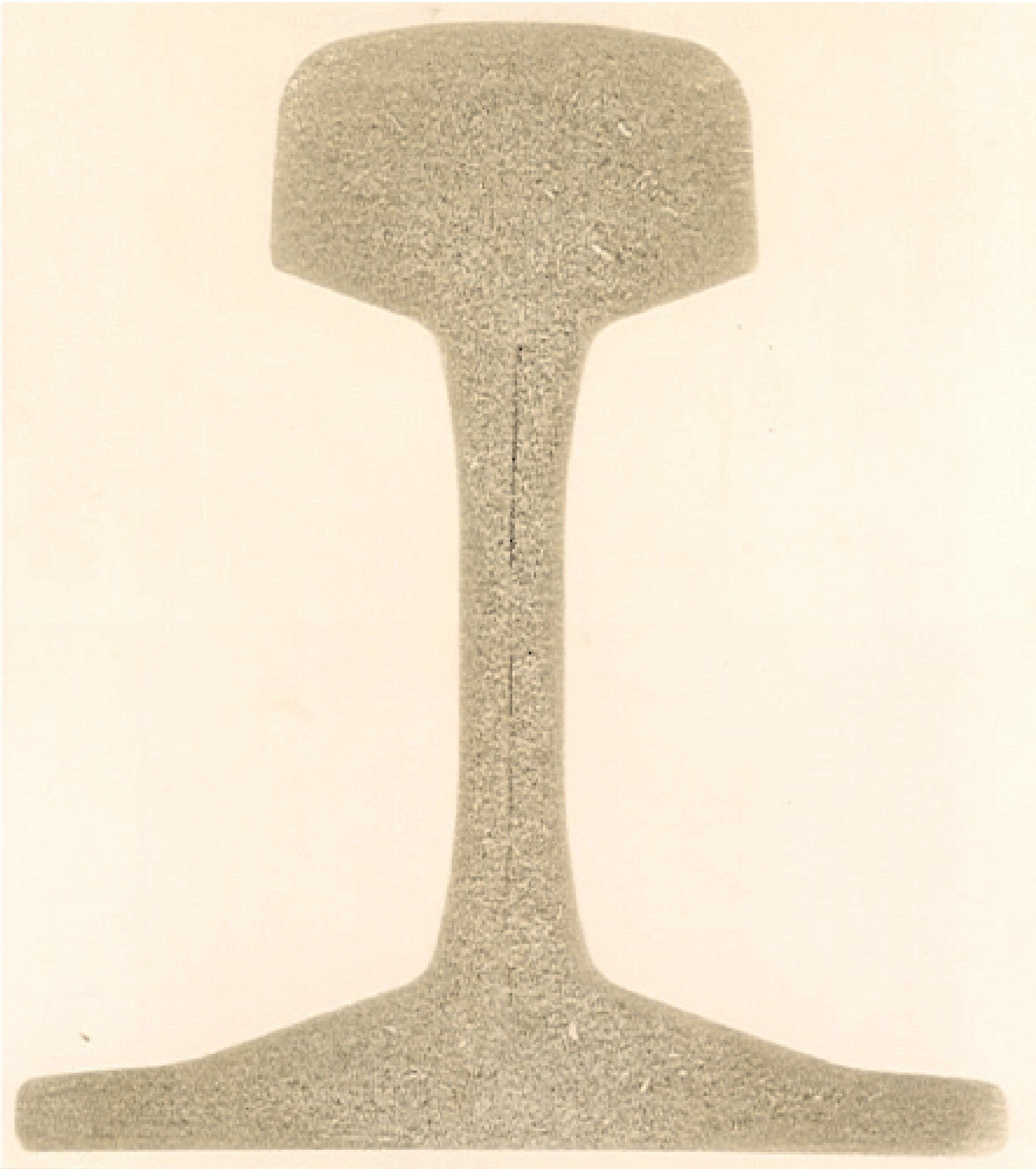
Classification: acceptable

Figure D.2 — Small negative and positive segregation



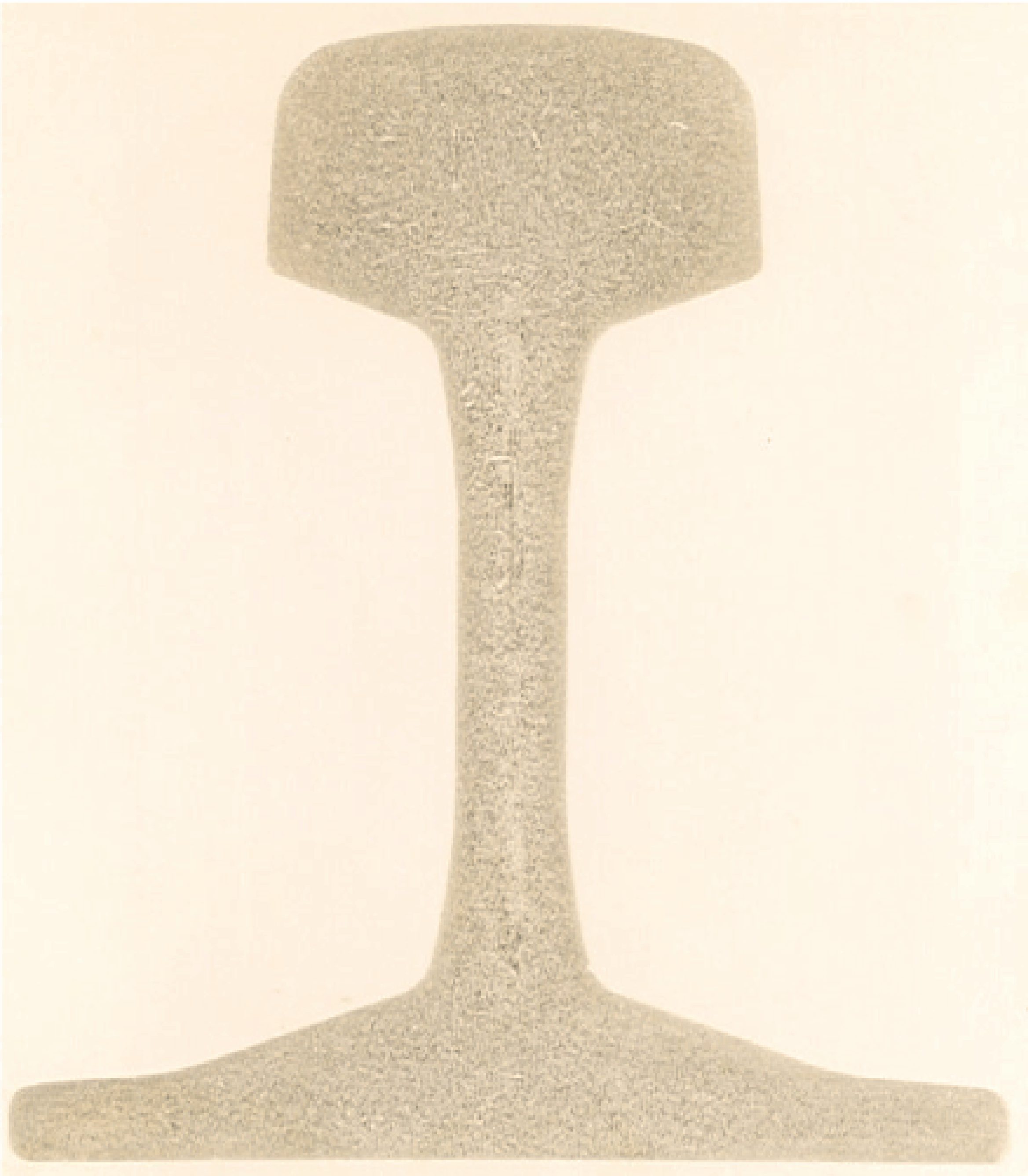
Classification: acceptable

Figure D.3 — Negative segregation in the web



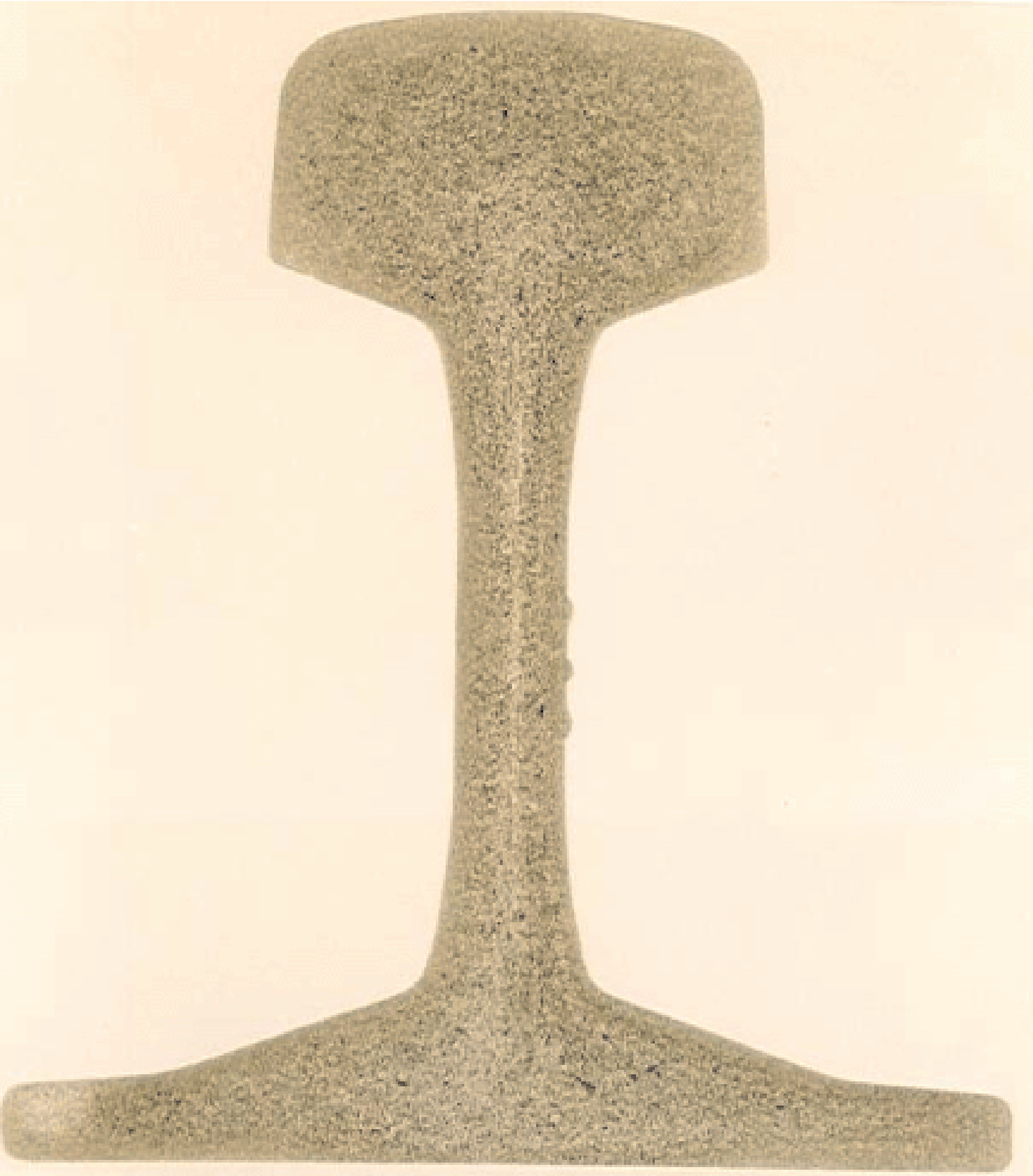
Classification: acceptable

Figure D.4 — Small positive segregation



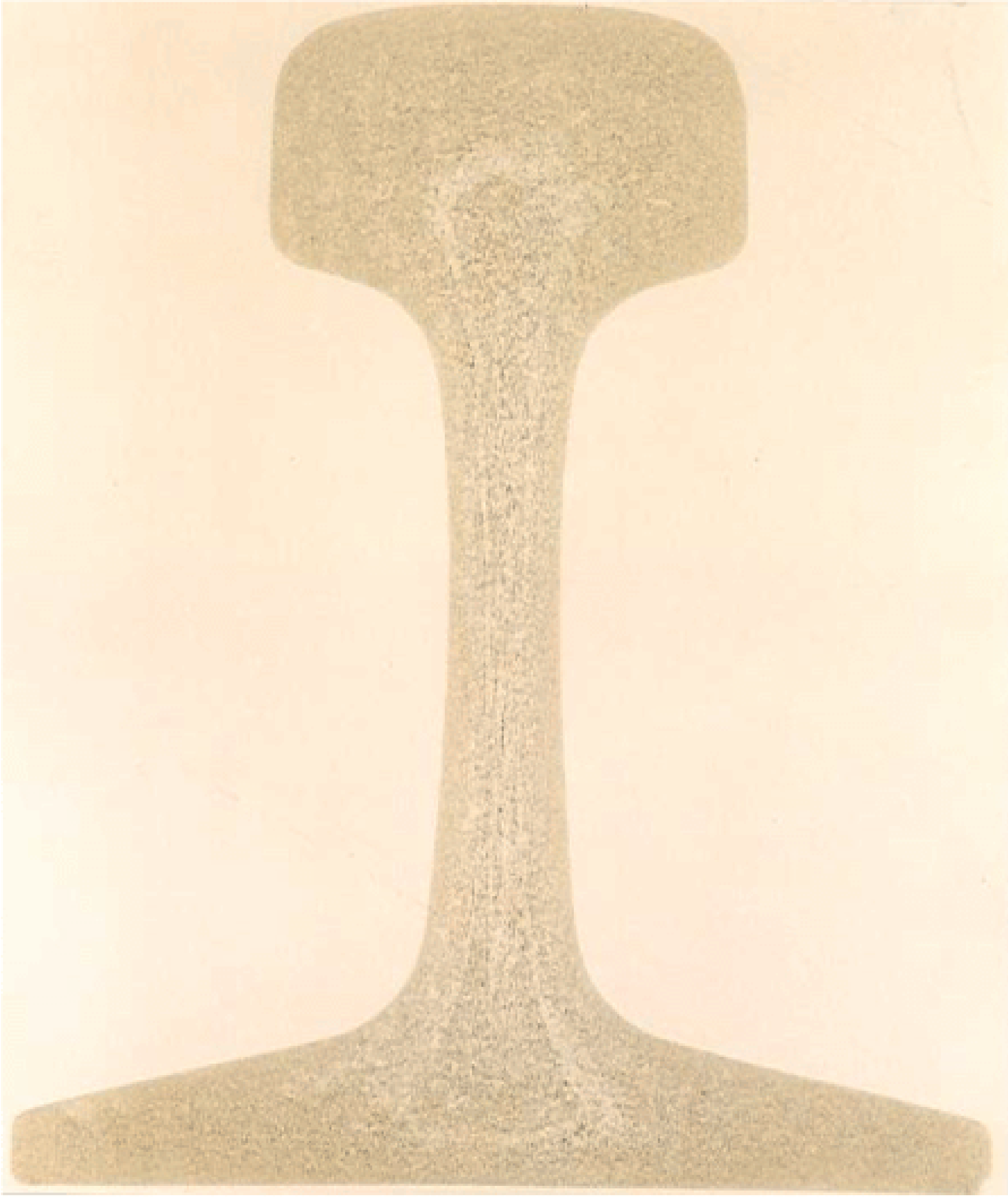
Classification: acceptable

Figure D.5 — Dendritic structure



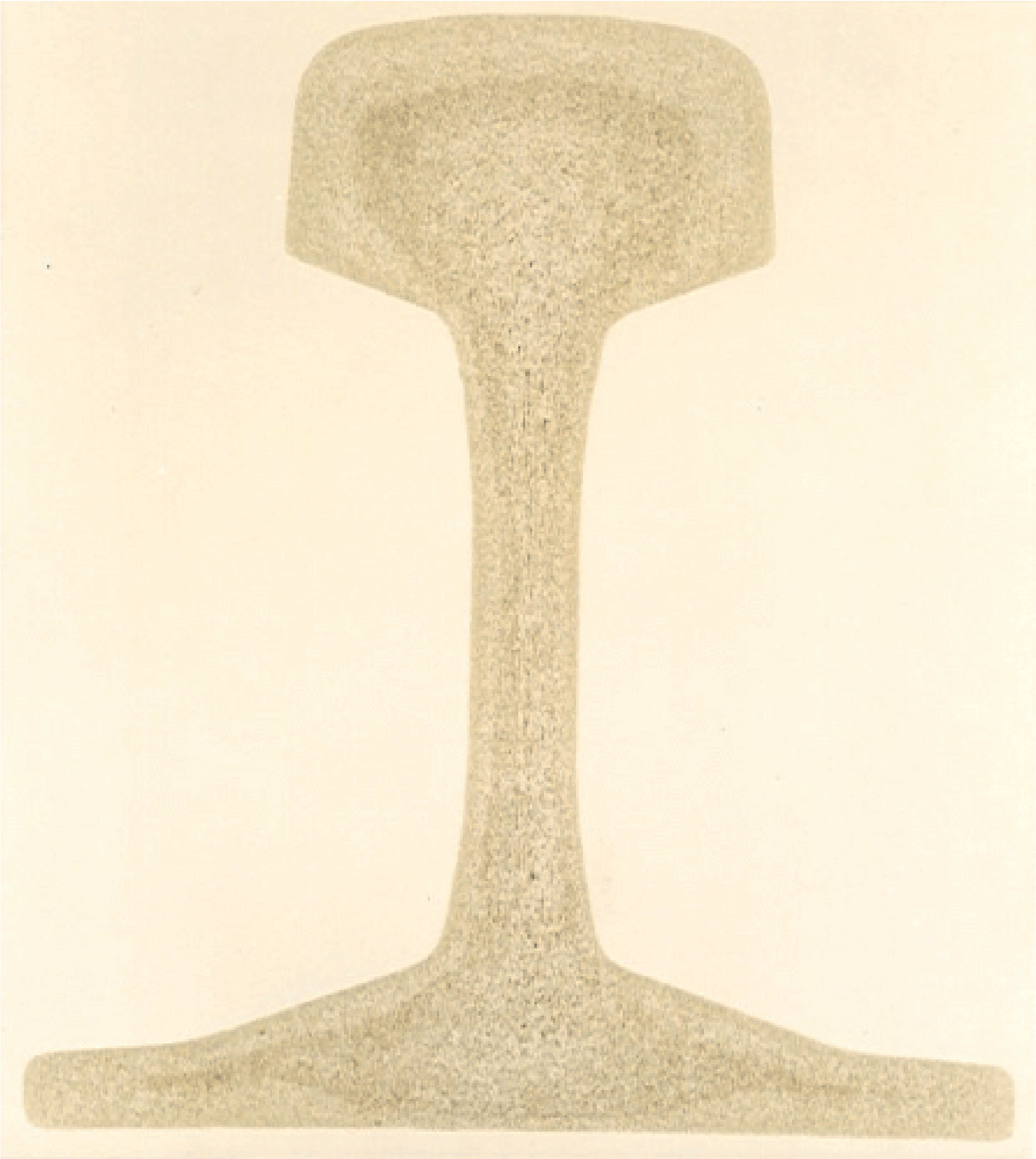
Classification: acceptable

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



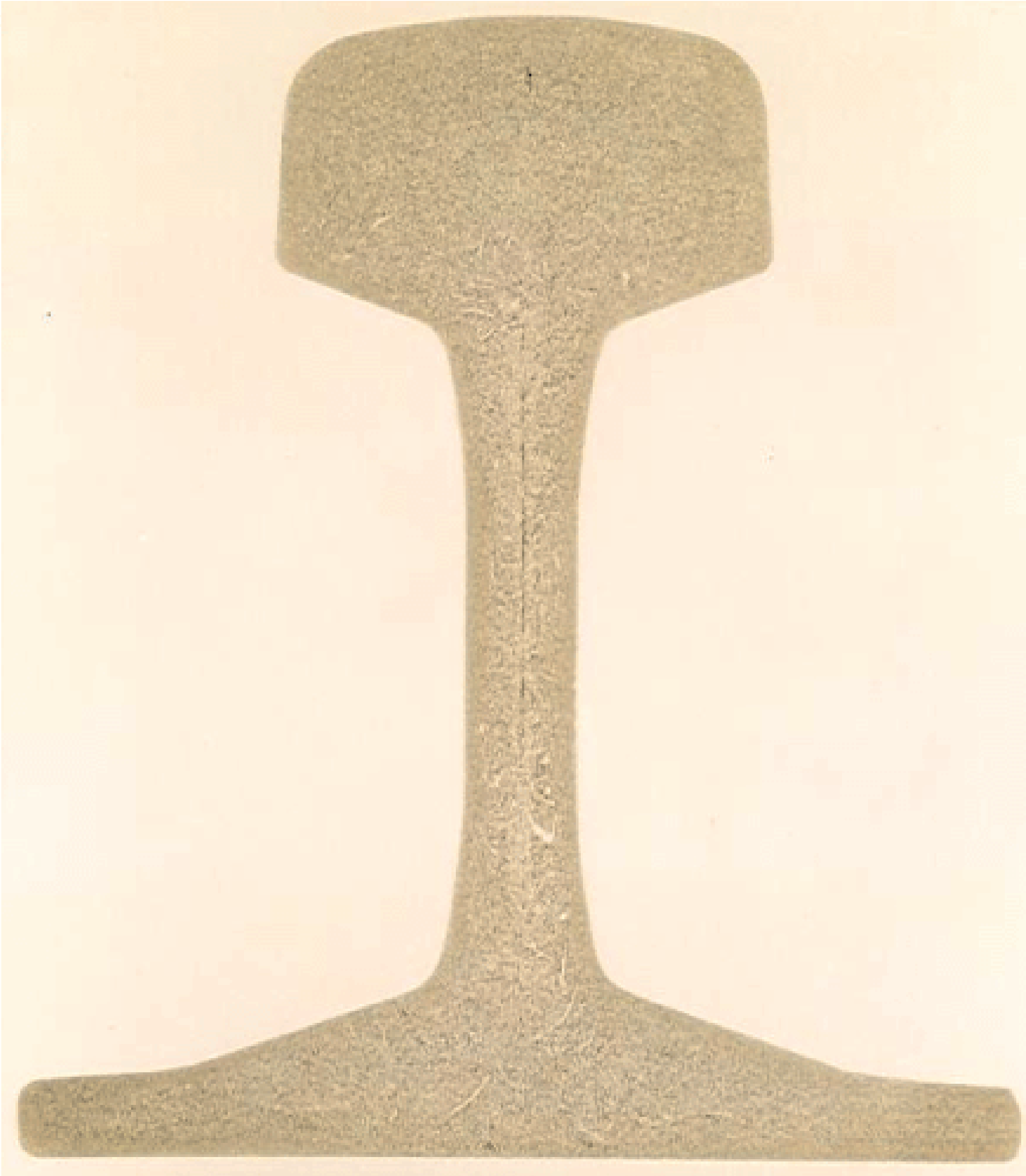
Classification: acceptable

Figure D.7 — Negative segregation – zone arising from electromagnetic stirring



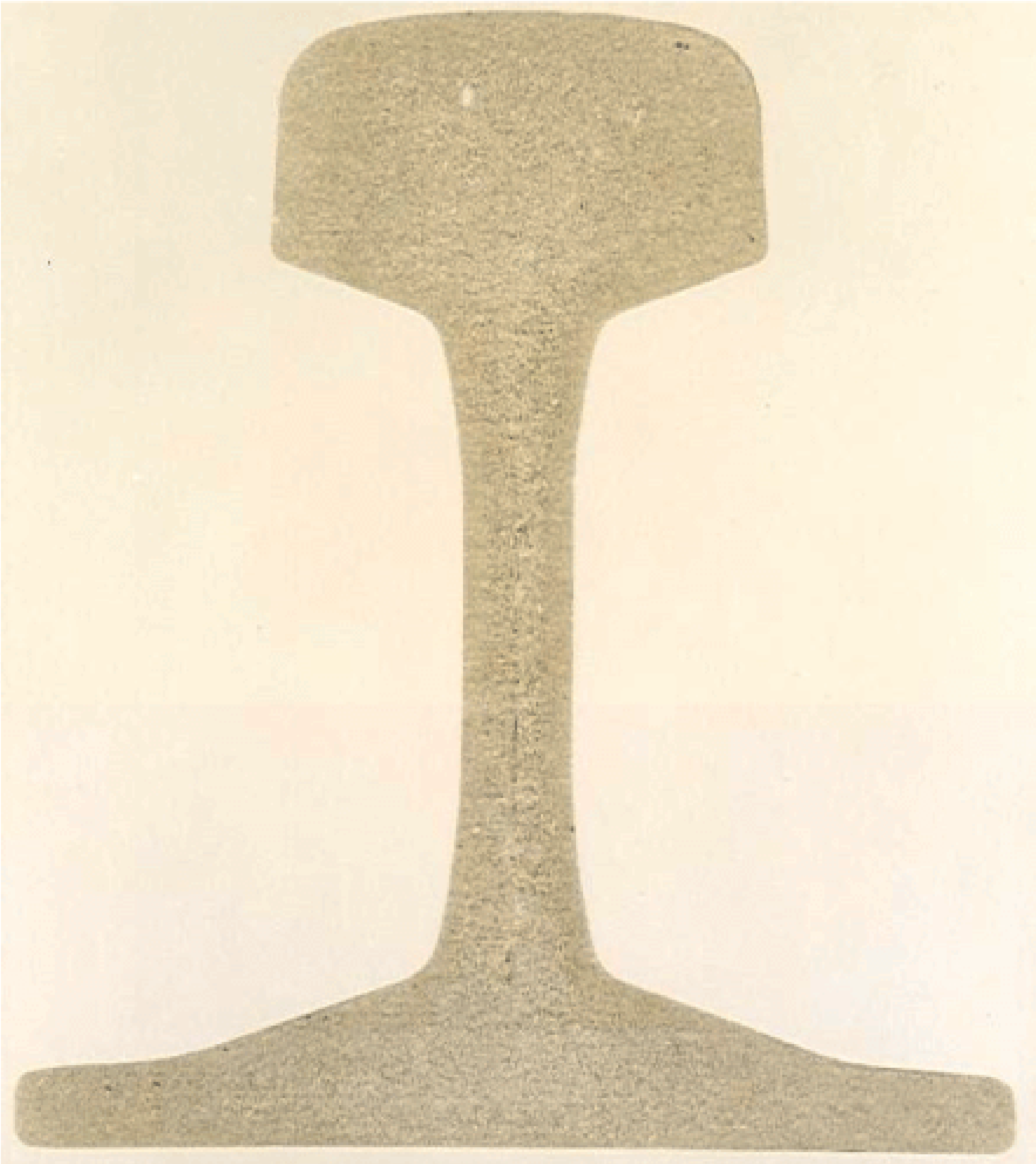
Classification: not acceptable

Figure D.8 — Negative rim



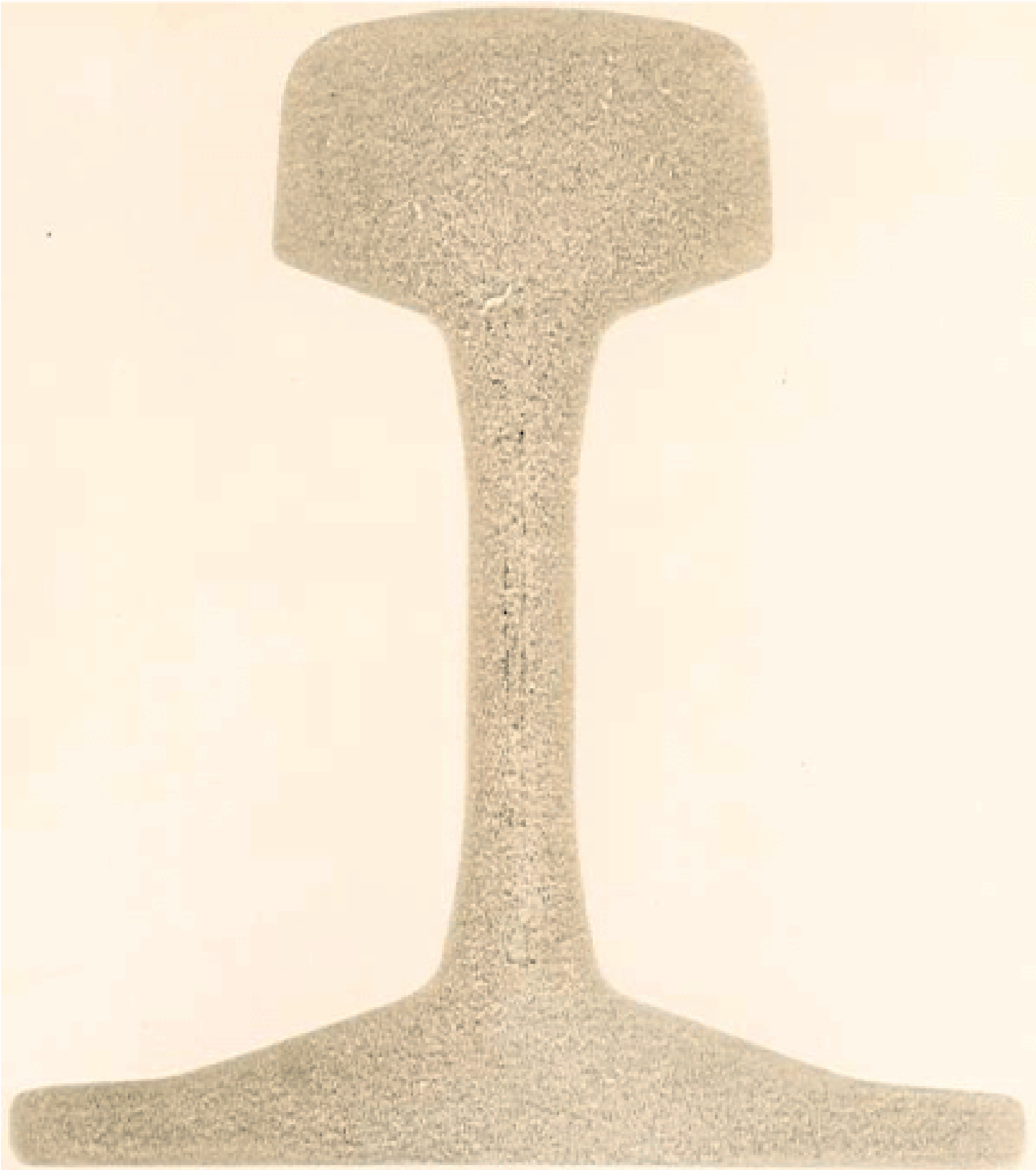
Classification: acceptable for crack length < 5 mm for not heat treated and < 3 mm for heat treated materials
acceptable for added length of single cracks < 10 mm

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



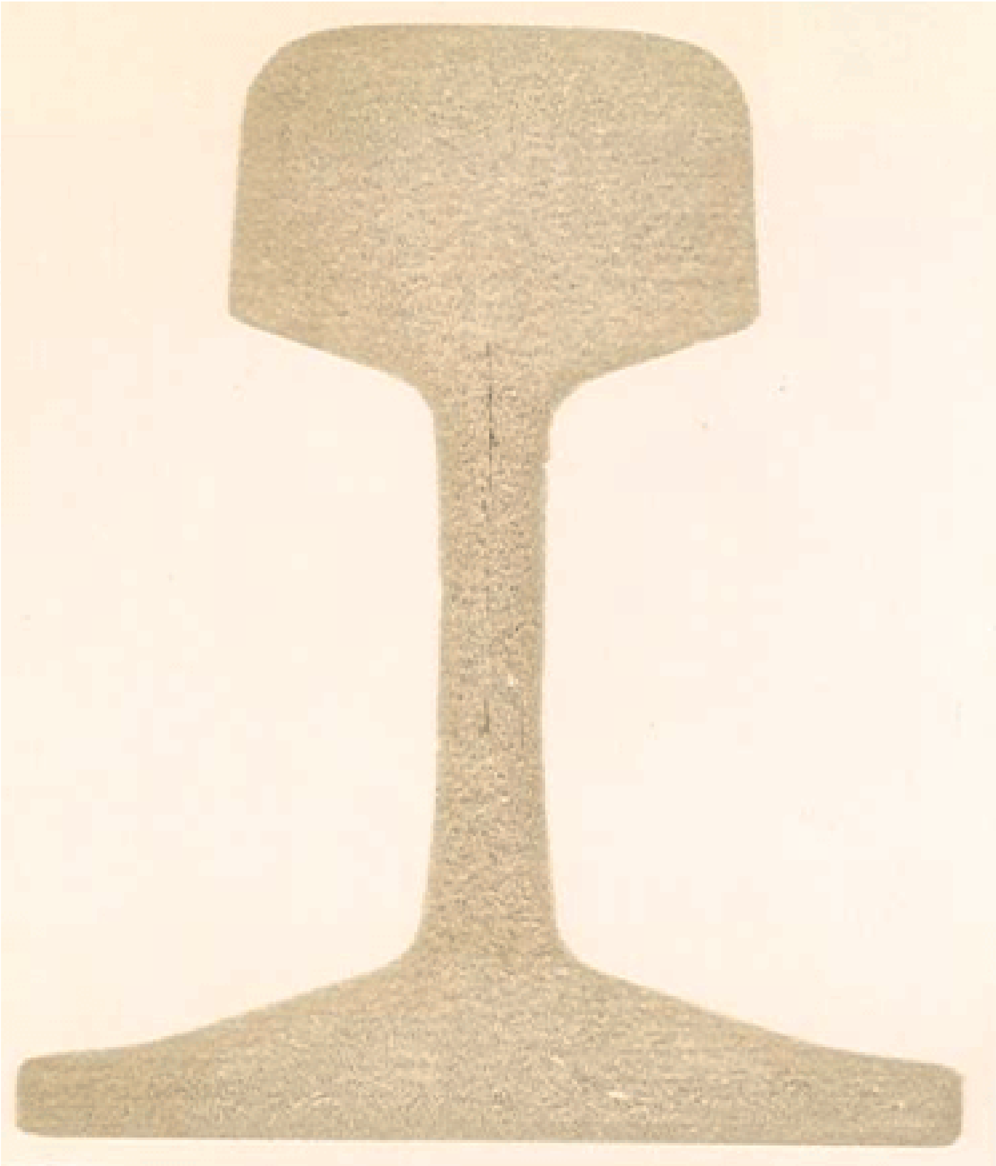
Classification: not acceptable

Figure D.10 — Subsurface pin holes



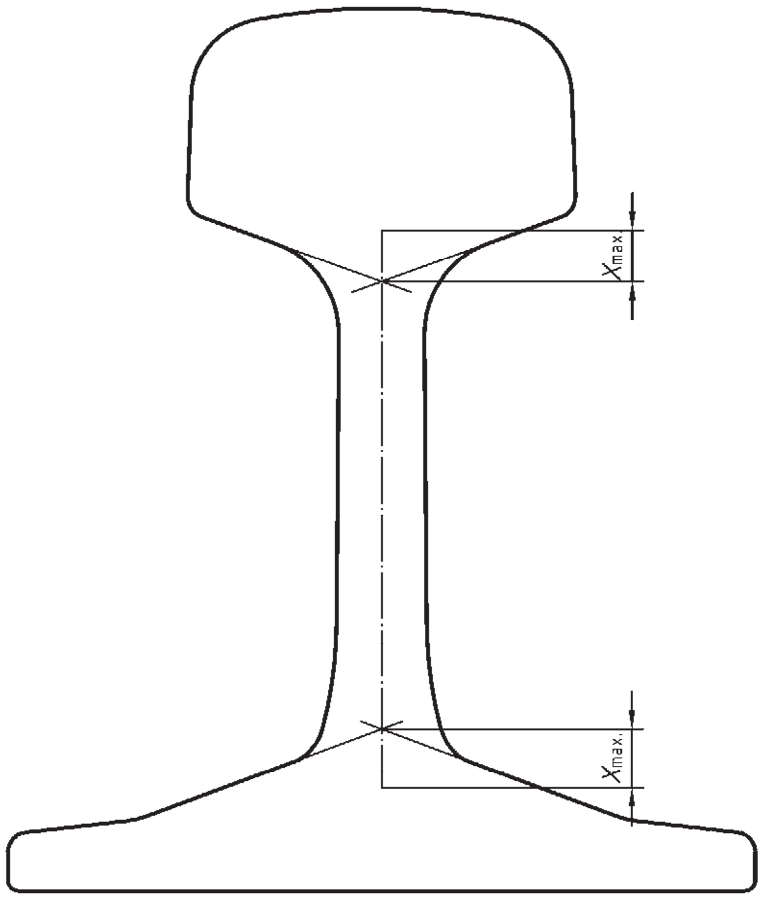
Classification: not acceptable

Figure D.11 — Double positive segregation in the web



Classification: not acceptable

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



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

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

Annex E
(normative)

Profile and drilling gauges

The gauges for manufacture as specified in 9.3 are shown in the figures which are summarised in Table E.1.

Table E.1 — Summary of figures

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

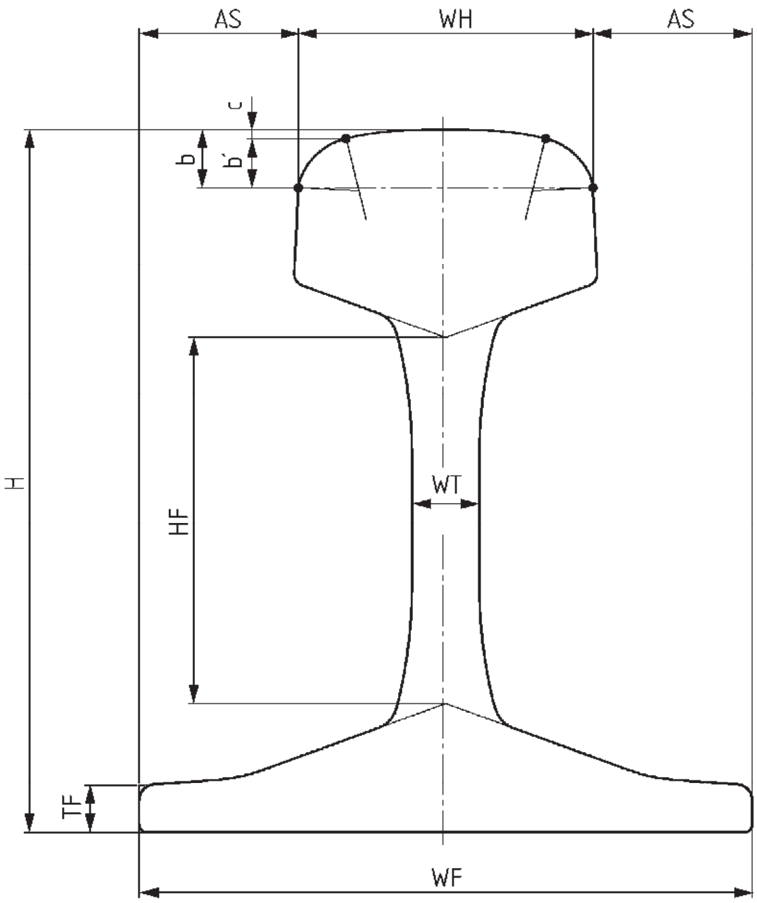
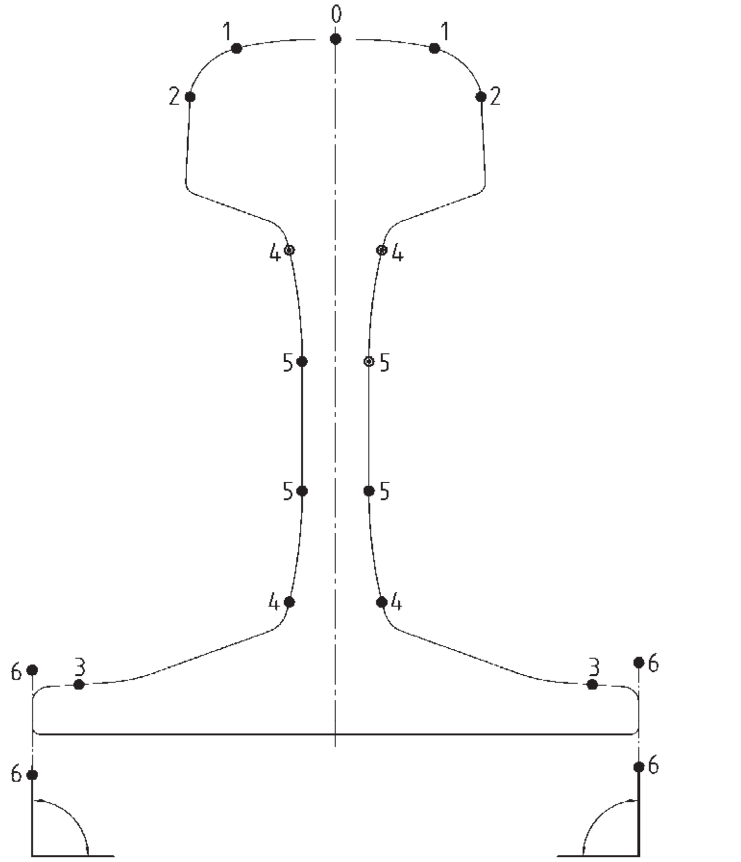


Figure E.1 — Datum references for tolerances (see Table 7 and Figure A.24)



Datum	Reference	Figure No.
0	- height - must not + must pass	E.3
0	- crown profile - must + must not pass the wedge	E.4
1	- width of rail head - must not + must touch	E.5
2	- rail asymmetry - must not + must touch	E.6, E.7
4, 5	- height of fishplating - must + must not touch	E.8
5	- web thickness - must not + must pass	E.9
3,6	- foot toe thickness	E.11
	must touch foot edge must be into the +/- range	E.11
6	- width of rail foot - must not + must pass	E.10

Figure E.2 — Datum references for decision

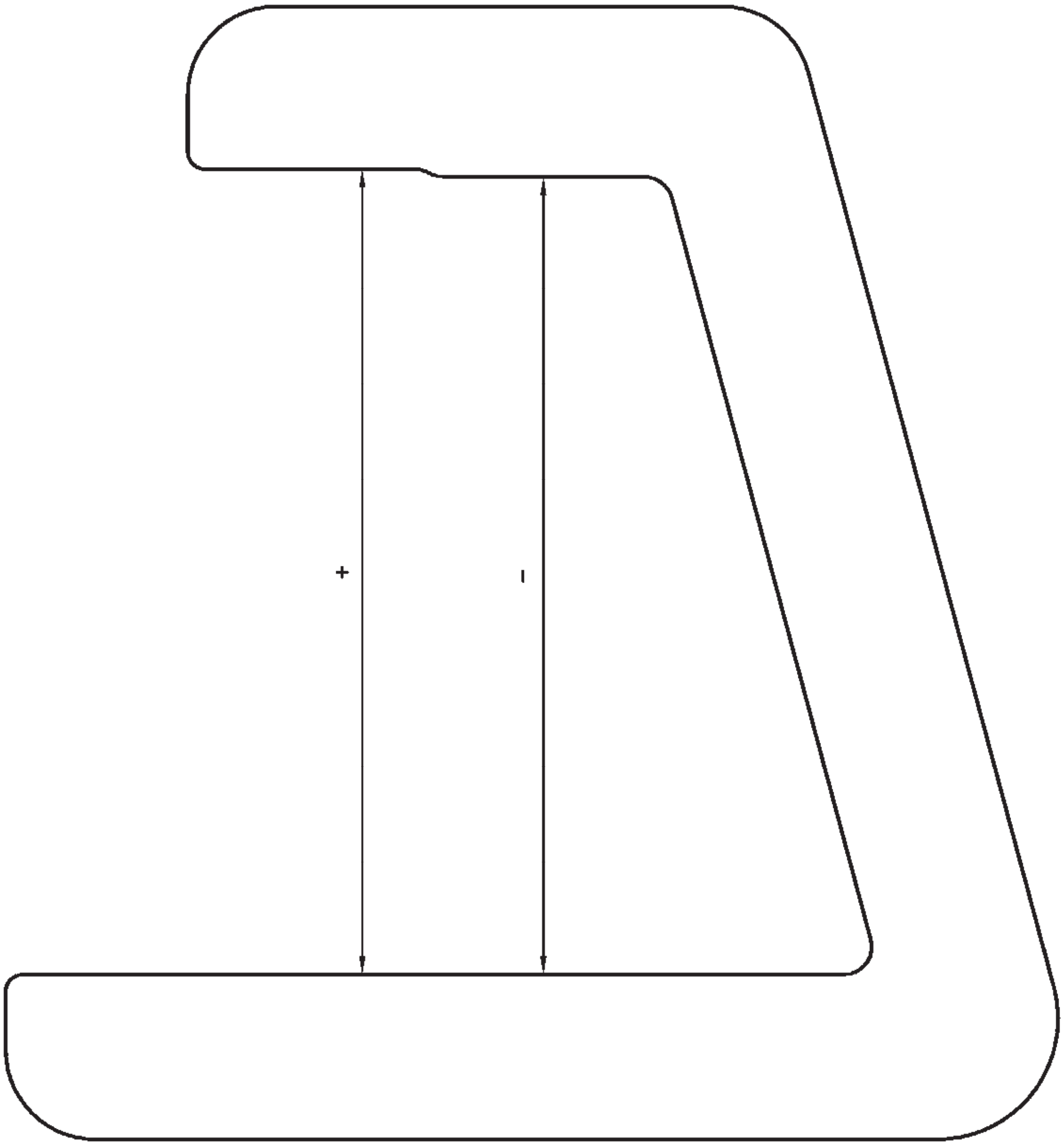
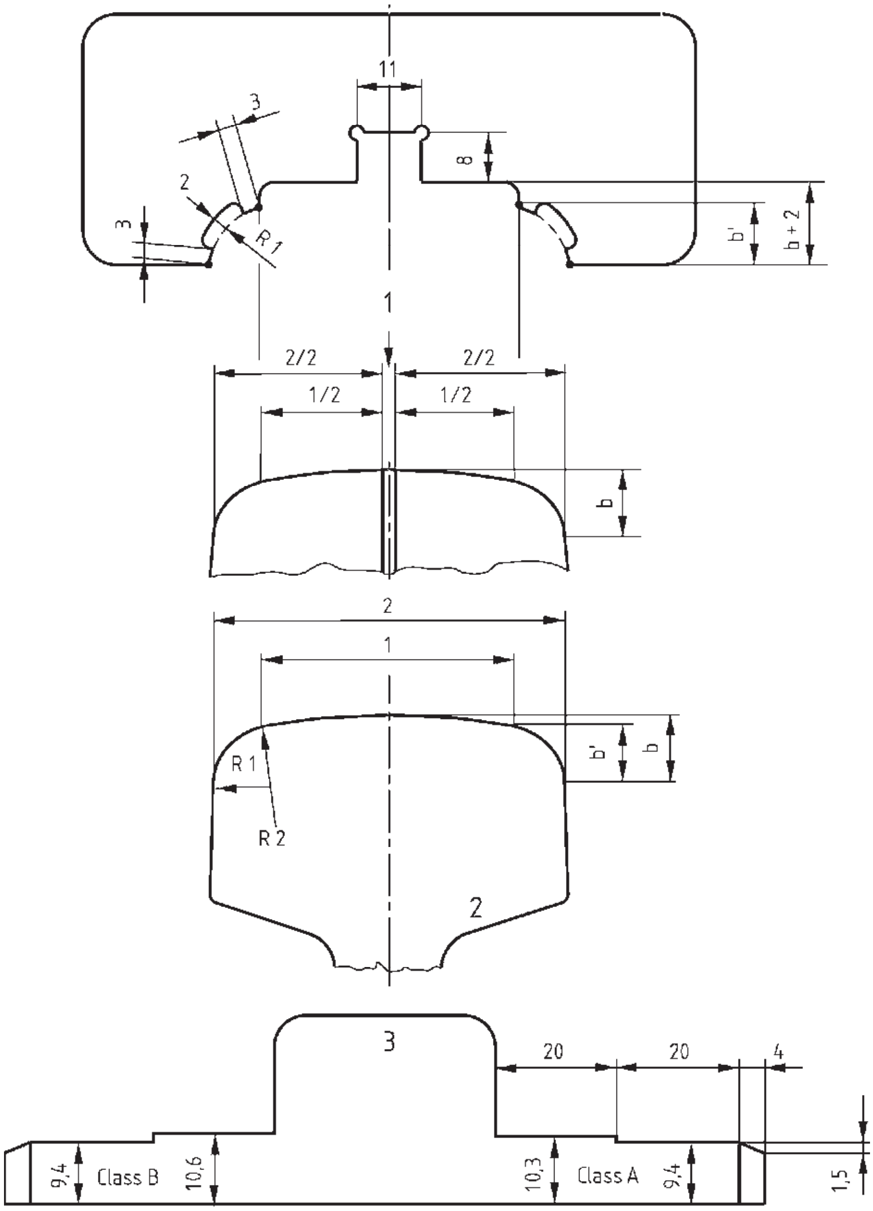


Figure E.3 – Height of rail



Key

1 maximum width of rail head tolerance

2 theoretical profile

3 step gauge to check the table shape, 10 mm thickness

Figure E.4 — Crown profile

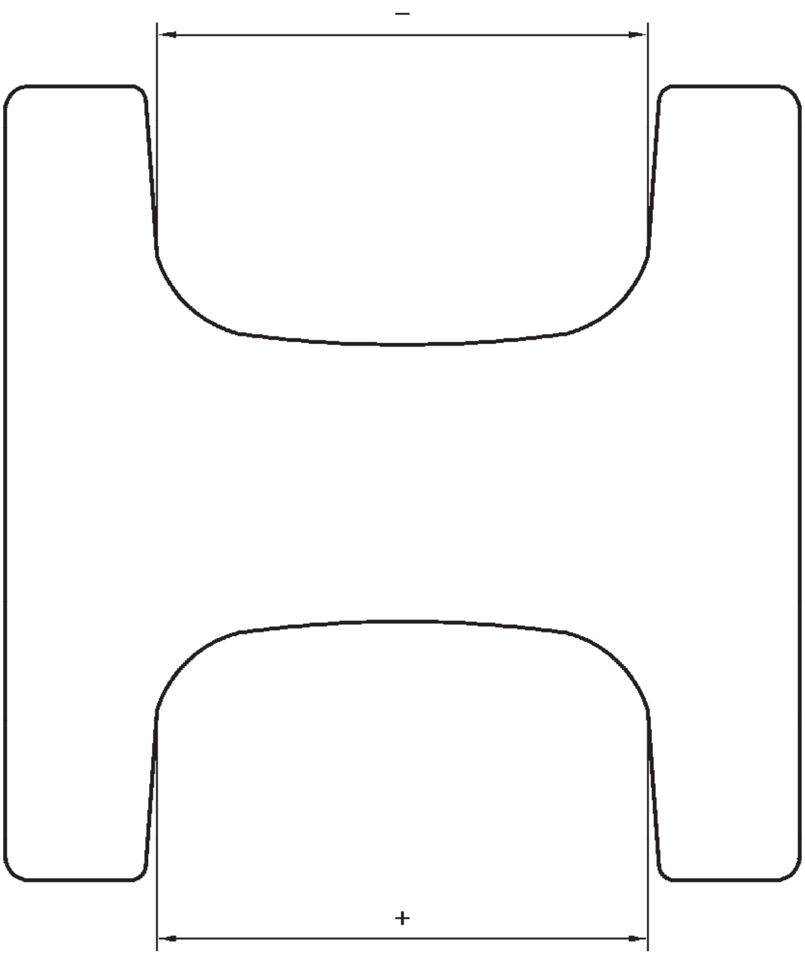


Figure E.5 — Width of rail head

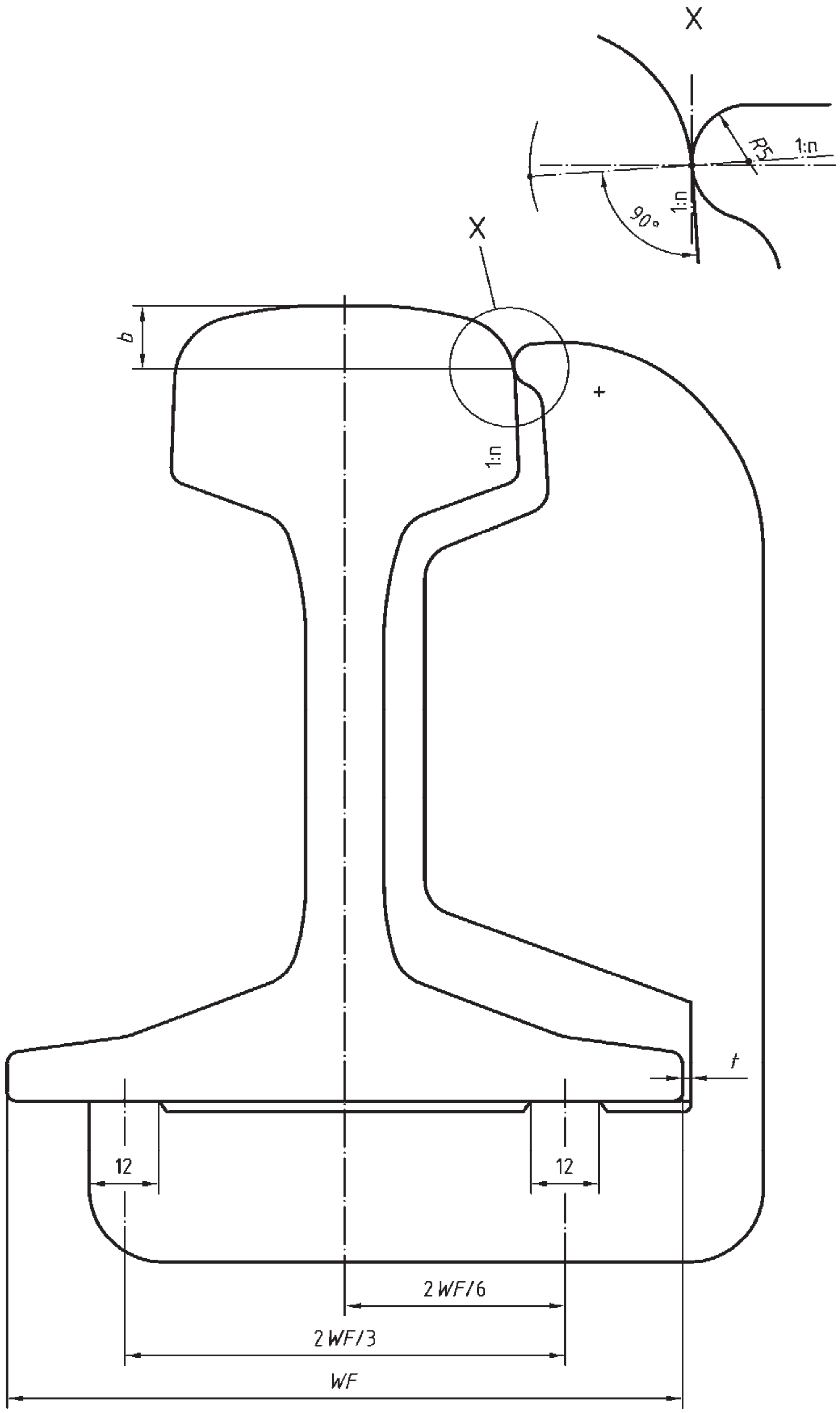


Figure E.6 — Rail asymmetry

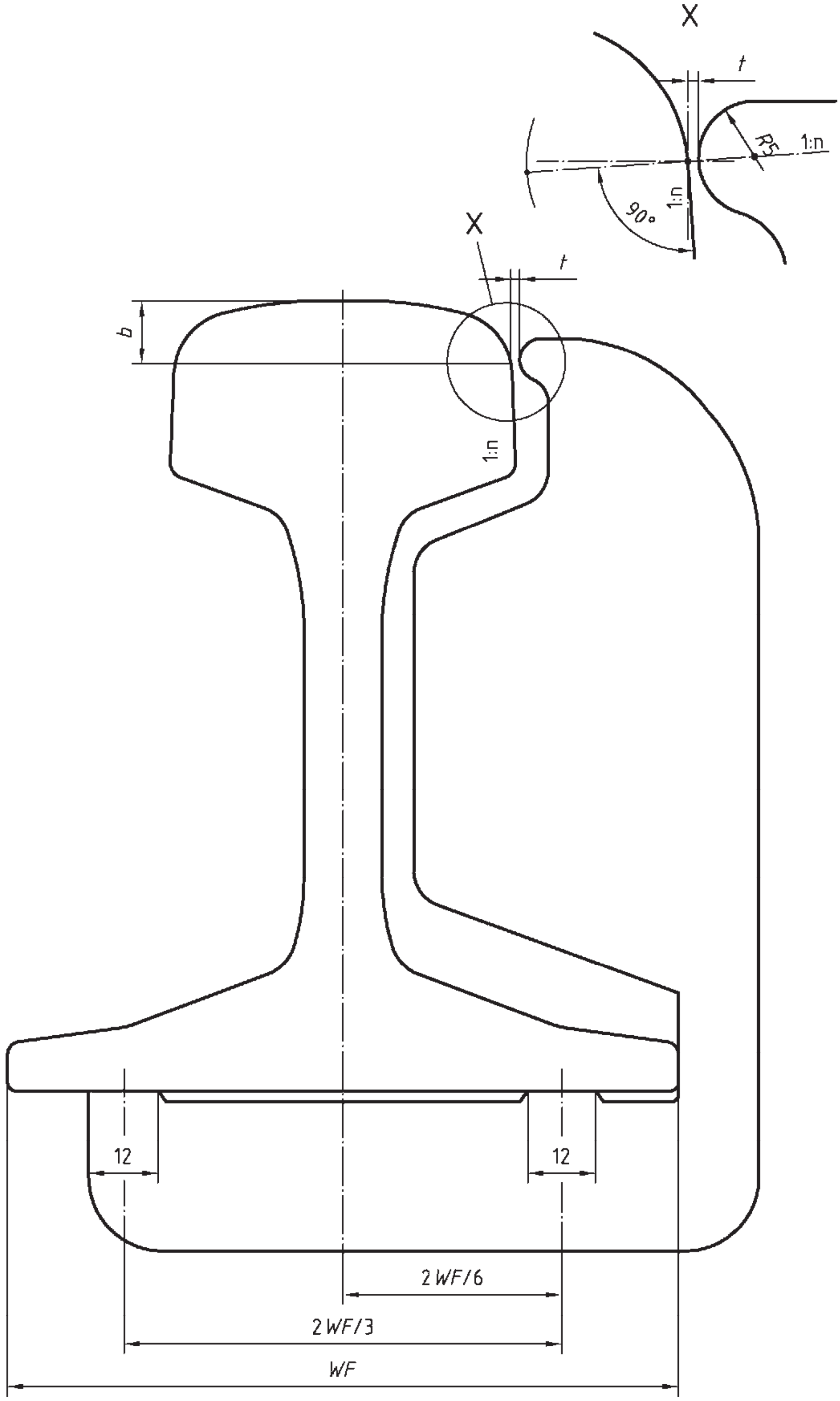
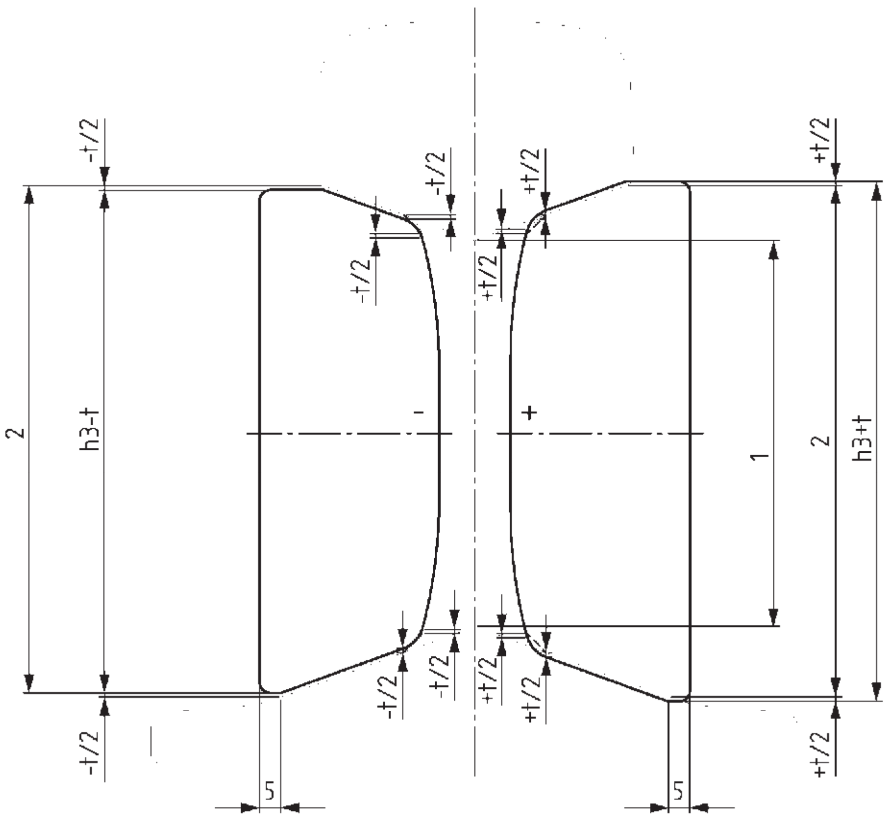


Figure E.7 — Rail asymmetry

Dimensions in millimetres



Key

1 and 2 marks engraved 14 mm apart to indicate measuring point
h3 = theoretical

Figure E.8 — Fishing height

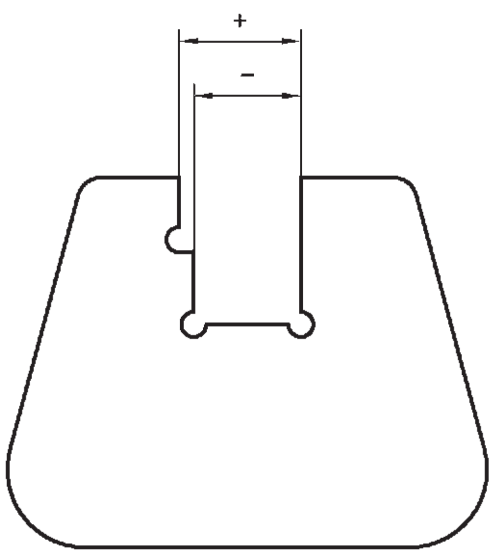


Figure E.9 — Web thickness

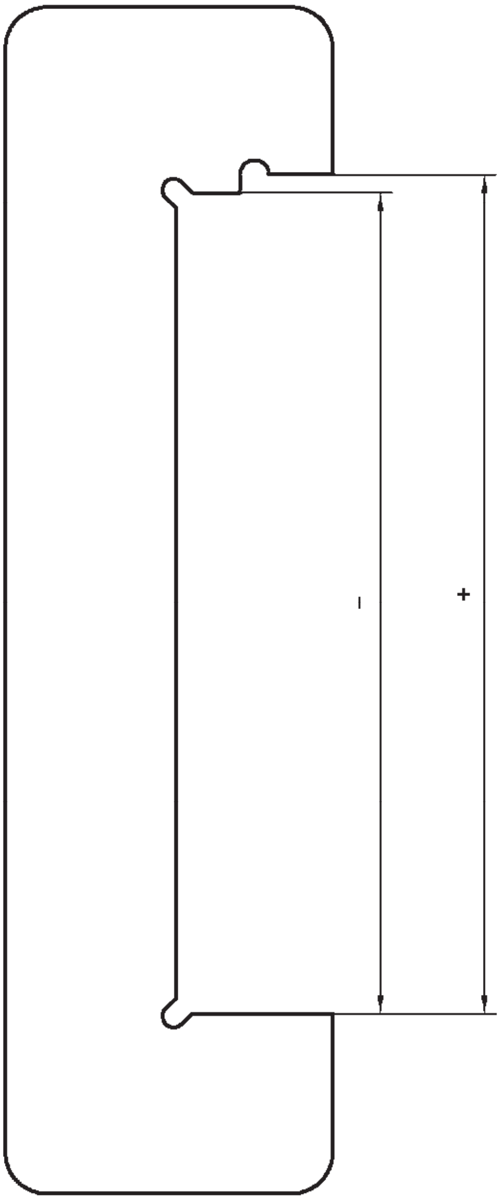
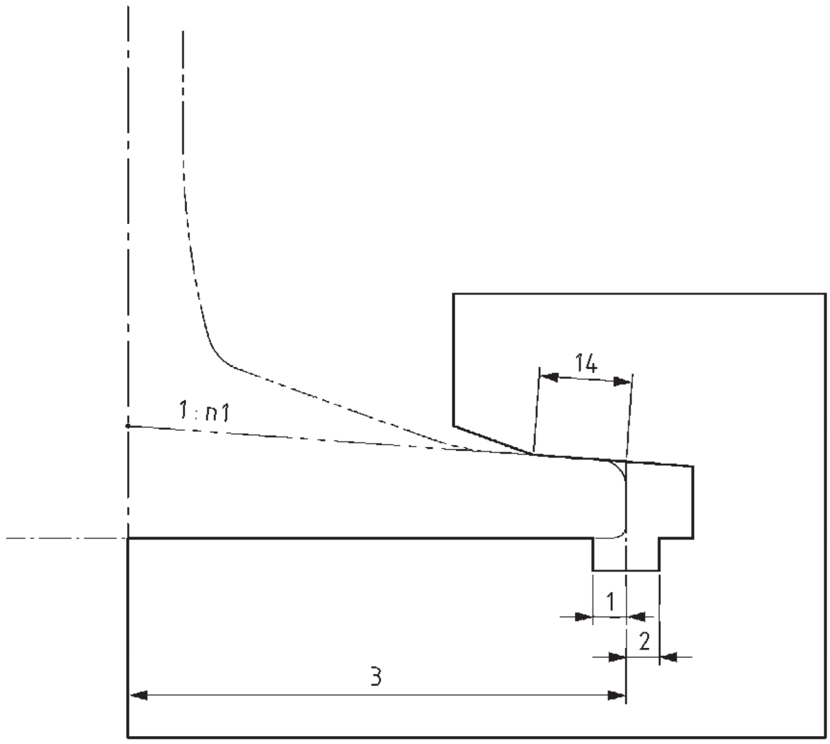


Figure E.10 — Width of rail foot



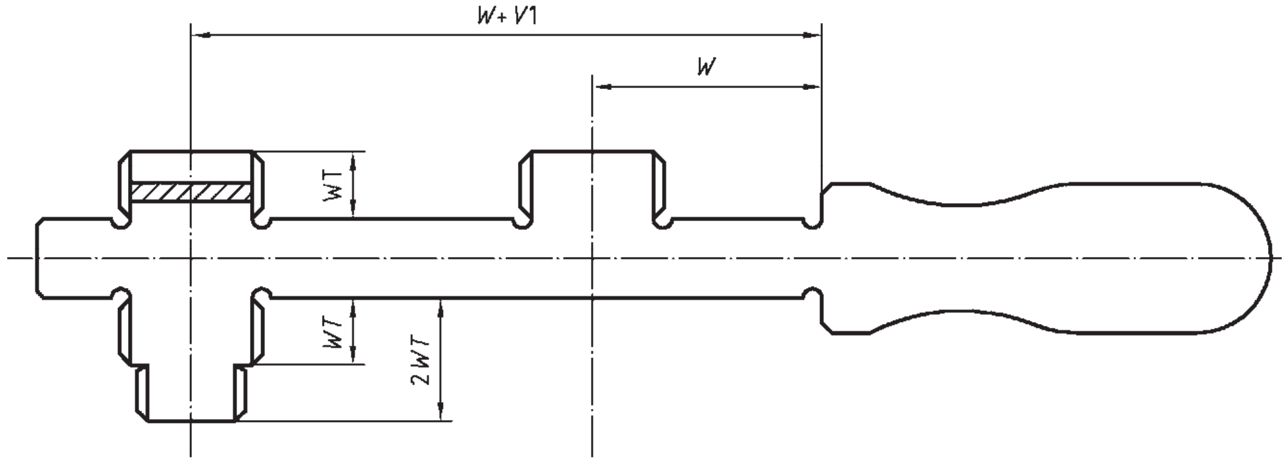
Key:

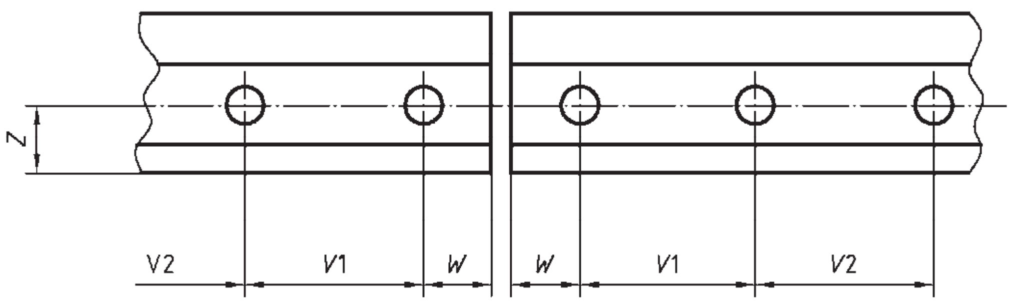
1 maximum = + Tolerance * n1 in mm

2 mimimum = - Tolerance * n1 in mm

3 width of foot / 2 or WF/2

Figure E.11 — Foot toe thickness

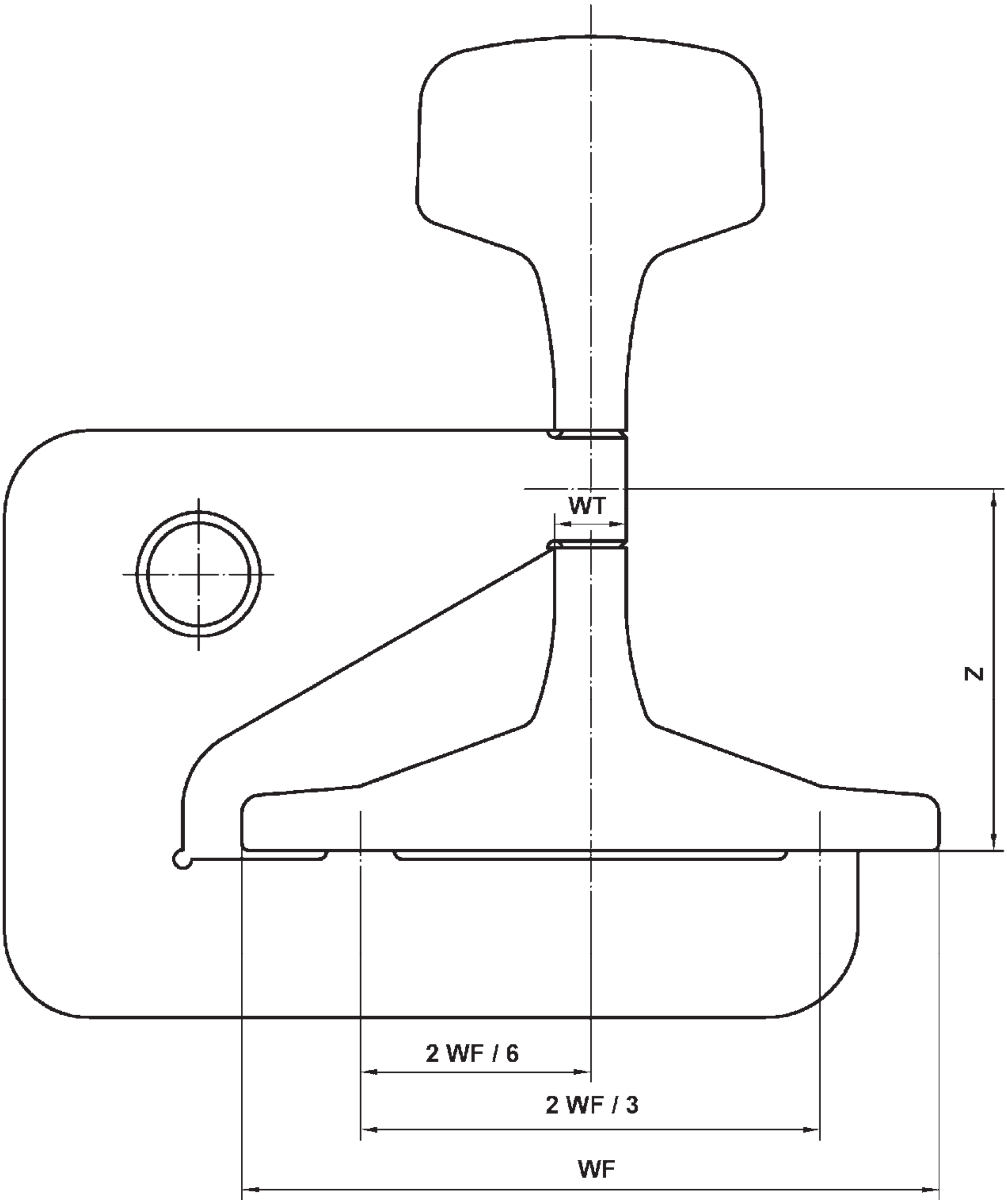




Key

WT web thickness

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

Annex F
(informative)

Significant technical changes between this European standard and the previous edition

Clause/Paragraph/Table/Figure	Change
1	2 more pearlitic steel grades specified. 2 new rail profiles added.
3.10	Term and definition of "rail running surface" added.
4, h)	Cold stamping on the cut face added to the list of information to be provided by the purchaser to the supplier at the time of tender or order.
5, Table 1	R370CrHT and R400HT steel grades added.
7.4.4	Modification of the requirement to read: "The purchaser shall specify their requirements for any colour coding or special marking instructions and their position on the rail at the time of enquiry or order."
8.1.2	"In addition the residual stress test shall be carried out on all available grades every 2 years" deleted.
8.2.2, Table 2	R370CrHT and R400HT steel grades added.
8.3.1	BS 6835-1 replaced by ISO 12108.
8.7.4	Modification of the requirement to read: "The updated equations shall be based on a minimum of the last 100 results."
9.1.2	New clause added.
9.1.3.1	New paragraph added.
9.1.3.2	4th and 5th paragraphs from previous edition deleted. Former Table 6 deleted. Text modified.
Tables 4, 5 a) and 5 b)	R370CrHT and R400HT steel grades added. Several modifications to the contents of the tables.
9.1.4.2	New clause added.
9.1.5	Text modified.
9.1.6	Text modified.
9.1.8	Text modified.
9.1.8, Table 6	Former Table 7 renamed Table 6 and contents modified.
9.1.9.1	Text modified.
9.1.9.2	Text modified.
9.2.1, Table 7	Former Table 8 renamed Table 7 and contents modified.

9.2.2.	Text modified.
9.2.2, Table 8	Former Table 9 renamed Table 8 and contents modified.
9.4.1.3	Text modified.
9.4.1.4	Text modified.
9.4.2.2	Text modified. New Table 10.
9.4.2.3	Text modified.
9.4.3	Text modified.
Annex A, Table A.1	Table modified.
-	Rail profile 49E4 deleted (former Figure A.8).
Figure A.7	Rail profile 49E5 and corresponding key modified.
Figure A.11	Rail profile 50E4 and corresponding key modified.
Figure A.18	Rail profile 54E4 added.
Figure A.19	Rail profile 54E5 added.
Figure A.24, Table A.2	Table modified.
-	Former Annex E deleted.
Annex ZA	Text modified.
NOTE The technical changes referred include the significant technical changes from the EN revised but is not an exhaustive list of all modifications from the previous version.	

Annex ZA
(informative)

Relationship between this European Standard and the Essential Requirements of EU Directive 2008/57/EC

This European Standard has been prepared under a mandate given to CEN/CENELEC/ETSI by the European Commission and the European Free Trade Association to provide a means of conforming to Essential Requirements of the Directive 2008/57/EC[2].

Once this standard is cited in the Official Journal of the European Union under that Directive and has been implemented as a national standard in at least one Member State, compliance with the clauses of this standard given in Table ZA 1 for HS Infrastructure and in Table ZA.2 for CR Infrastructure confers, within the limits of the scope of this standard, a presumption of conformity with the corresponding Essential Requirements of that Directive and associated EFTA regulations.

[2] This Directive 2008/57/EC adopted on 17th June 2008 is a recast of the previous Directives 96/48/EC ‘Interoperability of the trans-European high-speed rail system’ and 2001/16/EC ‘Interoperability of the trans-European conventional rail system’ and revisions thereof by 2004/50/EC ‘Corrigendum to Directive 2004/50/EC of the European Parliament and of the Council of 29 April 2004 amending Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system and Directive 2001/16/EC of the European Parliament and of the Council on the interoperability of the trans-European conventional rail system’.

Table ZA.1– Correspondence between this European Standard, the HS TSI INF, published in OJEU dated 19 March 2008, and Directive 2008/57/EC

Clause(s)/ sub-clause(s) of this European Standard	Chapter/ § of the TSI	Essential Requirements of Directive 2008/57/EC	Comments
Clause 5: Steel grades Clause 6: Profile drawings/properties/ mass Clause 8: Qualifying tests Clause 9: Acceptance tests Annex A: Rail profiles	3.3. Essential Requirements- Meeting the essential requirements by the specifications of the Infrastructure domain 3.3.1. Safety (2 first paragraphs) 3.4 Elements of the Infrastructure domain corresponding to essential requirements 5.3.1 Interoperability constituents – Constituents performances and specifications - The rail 5.3.1.1 a) Railhead profile - plain line. 5.3.1.2. Design linear mass 5.3.1.3. a). Steel grade – plane line Annex A – Table A.1 Interoperability constituents of the infrastructure domain – Assessment of interoperability constituents for the EC declaration of conformity 5.3.1.1 – Rail head profile 5.3.1.2 – Design linear mass 5.3.1.3 – Steel grade Annex F – Rail profile 60 E 2	Annex III - Essential Requirements – 1.General Requirements 1.1. Safety Sub-clauses 1.1.1 – 1.1.2 and 1.1.3 Sub-clause 1.5 - Technical compatibility.	Clauses of the standard made mandatory by being quoted in the TSI: - Selection of railhead profile from the range of Annex A of the standard or shall be profile 60 E 2 defined in Annex F - Design linear mass of the rail, specified in Annex A of the standard shall be more than 53 kg/m - The steel grade of the rail shall comply with clause 5 of the standard. § of the HS TSI INF which are not treated by the standard - Equivalent conicity (§ 4.2.9 and § 6.2.5.2 of the HS TSI INF)

Table ZA.2 – Correspondence between this European Standard, the draft CR TSI INF (IU-INF-090902-TSI 4.0 dated 18/09/2009) and Directive 2008/57/EC

Clause(s)/ sub-clause(s) of this European Standard	Chapter/ § of the TSI	Essential Requirements of Directive 2008/57/EC	Comments
Clause 5 Steel grades Clause 6 Profile drawings/properties/ mass Clause 8 Qualifying tests Clause 9 Acceptance tests Annex A Rail profiles	3. Essential Requirements – Table 1 – Basic parameters of the infrastructure subsystem corresponding to the essential requirements. 4.2.5.6 Description of the infrastructure subsystem - Functional and technical specifications of subsystem - Track parameters - Railhead profile for plain line 5.3.1 Interoperability constituents - Constituents performances and specifications - The rail 5.3.1.1 Railhead profile. 5.3.1.2 Moment of inertia of the rail cross section 5.3.1.3 Rail hardness 6.1.4.2 Assessment of conformity of interoperability constituents and EC verification of the subsystems – Interoperability constituents – EC Declaration of conformity for interoperability constituents – EC declaration of conformity for the rail Annex A – Table 20 Assessment of interoperability constituents for the EC declaration of conformity 5.3.1.1 Railhead profile. 5.3.1.2 Moment of inertia of the rail cross section. 5.3.1.3 Rail hardness	Annex III - Essential Requirements – 1.General Requirements 1.1. Safety Sub-clauses 1.1.1 – 1.1.2 and 1.1.3 Sub-clause1.5 - Technical compatibility.	The following parameters - Railhead profile - Moment of inertia of the rail cross section - Rail hardness are considered as relevant to satisfy the essential requirements of the Directive 2008/57/EC § of the draft CR TSI INF which are not treated by the standard - Equivalent conicity (§ 4.2.5.5 and § 6.2.4.4. of the draft CR TSI INF)

Warning – Other requirements and other EU Directives may be applicable to the product(s) falling within the scope of this standard.

Bibliography

[1] EN ISO 9001, *Quality management systems – Requirements (ISO 9001:2008)*

[2] EN 10027-1, *Designation systems for steel – Part 1: Steel names*

[3] EN 10027-2, *Designation systems for steel – Part 2: Numerical system*

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